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(Not) Knowing and (Not) Caring About Animal Research: An Analysis of Writing from the Mass Observation Project

Renelle McGlacken

School of Sociology and Social Policy, University of Nottingham, United Kingdom/
renelle.mcglacken@nottingham.ac.uk

Abstract

Animal research remains a practice marked by controversy and moral dilemma. However, UK science-society dialogues on the issue are increasingly managed via one-way transmissions of information which construct publics as passive and attribute their concerns to a lack of 'correct' knowledge. Challenging such assumptions, this paper questions how and why people actively manage their interactions with animal research through entangled practices of knowing and caring. Based on an analysis of writing from the UK Mass Observation Project, this paper explores difficulties and discomforts associated with animal research which can cause strategic withdrawals from engagements with the topic. In doing so, it extends existing concepts of 'uncomfortable knowledge' (Rayner) and 'strategic ignorance' (McGoey) to develop novel concepts of 'uncomfortable' and 'strategic' care. Finally, in examining desires to respond to animal research, I engage with Haraway's notion of 'response-ability' to introduce the concepts of 'responsive caring' and 'responsive knowing'.

Keywords: animal research, knowing, caring, ignorance, discomfort, Mass Observation Project

Introduction

Dominant modes of examining the views of publics on animal research have tended to concentrate on assessing '*what*' publics know about the issue, weighing this against the scientific '*facts*', and judging civic contributions as either scientifically congruent or not. Despite the thorough critique levelled at this 'deficit-model' approach to lay understandings of techno-scientific issues (Millar and Wynne, 1988), which, of course, often concern more than just the 'technoscientific', such an approach persists in UK science-society dialogues around animal research. Seeking to address this situation, this paper instead explores the practices of knowing and not-knowing and caring and not-caring about animal research, asking how knowledge of the topic is perceived and negotiated and what role care plays in interactions with it.

Through the recent emphasis on openness and transparency in animal research, a shift encapsulated in the UK via the 2014 launch of the *Concordat on Openness on Animal Research* (UAR, 2014), societal concerns around the issue are, in part, cast as the result of secrecy in the bioscience sector (McLeod and Hobson-West, 2015; Mills et al., 2018). Such explanations for the controversy that animal research continues to generate lend to assumptions that publics are ignorant and reinforce the authority of scientific experts in 'correcting' an absence of knowledge on the practice and regulation of biomedical science in the public domain. For instance, Martinez-Sanchez and Leech (2015) claim that a "lack of transparency and openness in many European research centres encourages misconceptions about animal research" (Martinez-Sanchez and Leech, 2015: 1). Hence, they determine that 'without reliable, authoritative communication from the biomedical sector, public understanding can be manipulated through "leaks" and "exposés" that do not accurately reflect either the rationale and need for the research or the ethical standards to which such research is held' (Martinez-Sanchez and Leech, 2015: 1). In seeking to regain control over societal opinion on animal research then, the Concordat encourages bioscience institutions to better communicate with 'the public' about how and why they use animals.

However, in considering not simply *what* individuals know (or do not know) about animal research but *why* this is so, this paper challenges assumptions that increased scientific or regulatory information will alleviate societal concerns around the practice (Festing and Wilkinson, 2007). Rather than judging levels of awareness or the 'correctness' of knowledge held, in analysing writing from the UK Mass Observation Project (MOP), I question how and why people actively manage their interactions with animal research through entangled practices of knowing and caring. In exploring this, I examine difficulties and discomforts associated with the topic, such as the emotional toll of knowing, conflicting care obligations, and civic (in)capacities to bring about change in this area, all of which may encourage or necessitate strategic withdrawals from engagements with animal research. To understand the interrelation of knowing and caring around this issue, the paper draws on concepts from the sociology of ignorance and care ethics. In doing so, it engages with and, in parts, develops conceptualisations of (not) knowing and (not) caring to focus on the themes of uncomfortable knowledge (Rayner, 2012) and uncomfortable care, strategic ignorance (McGoey, 2012) and strategic care, and finally, responsive knowing and responsive caring.

In contesting deficit-model fixations with public knowledge on animal research and emphasising the interwoven nature of knowing and caring, this paper thus also seeks to address the absence of care lenses in this area. Research on care practices related to animal research has tended to concentrate on the laboratory, with a favouring of ethnographic methods to explore how multispecies care relations emerge in such spaces (Svendsen and Koch, 2013; Giraud and Hollin, 2016; Greenhough and Roe, 2018; Friese and Latimer, 2019), which are often discussed as constitutive of a specific 'culture of care' (Davies et al., 2018). The achievement of a culture of care in bioscience facilities is encouraged by regulatory bodies. In the UK, this includes the government's Animals in Science Regulation Unit (ASRU), which defines a good culture of care as "an environment which is informed by societal expectations of respectful and humane attitudes towards animals used in research" (ASRU, 2015: 4). As notable in this definition, wider societal values around the appropriate treatment of animals are taken as informing care relationships in the laboratory. However, to date there has been little attention given to how publics and representations of publics feature in such care networks. With focus directed inside the physical space of the laboratory in which care is emphasised as the performative product of a situated intersubjectivity, a "common existential corporeal experience" (Svendsen and Koch, 2013: 124), how publics who rarely enter the laboratory space may care about and for those involved appears currently overlooked.

Indeed, concentrating on knowledge, UK animal research advocacy group Understanding Animal Research (UAR) claim that because "much opposition to animal research is based on misinformation" it is "necessary to be open and informative in our public messaging about how animal research is conducted with ethical oversight and regard for the 3Rs" (UAR, 2019: 2). However, in the first instance, such narratives of educating publics on animal research presume that publics actually *want* to know. Yet, as this paper aims to show, relating to the scientific use of animals is not only a matter of knowing but also of caring, meaning that how we manage our knowledge or ignorance of an issue is always also part of a practice of care. As van Dooren (2014) explains, the "obligation to 'know more' emerges as a demand for a kind of deep contextual and critical knowledge about the object of our care, a knowledge that simultaneously places us at stake in the world and demands that we be held accountable" (van Dooren, 2014: 293). In the case of animal research, this paper will argue that it is precisely the responsibility that knowing confers upon publics that poses moral discomfort and, for some, necessitates the act of turning away.

As I will demonstrate in this paper, what might look like detachment from the issue of animal research may instead reflect a negotiation of personal responsibility and (in)capacity for action. Such insights are important for those invested in fostering care for issues with widespread political and ethical ramifications, what some have termed 'wicked problems' (Rittel and Webber, 1973), those characterised by a plurality of definitions of what the inherent problem actually is. Given the tangled nature of wicked problems, the ways in which they are produced by and knotted with other problems, generating care towards their resolution can be fraught with feelings of powerlessness and futility. Recognising processes of knowing and caring as enmeshed in broader structures of power that prevent some from feeling *able* to engage in either practice thus unsettles the onus placed on individuals, instead directing attention to existing barriers to knowing and caring.

Method: The Mass Observation Project

Unlike the use of opinion polls which dominate the UK dialogue around animal research (Hobson-West, 2010), this paper draws on a novel resource for rich and reflexive writing, the Mass Observation Project (MOP). Described as a "national life writing project about everyday life in Britain" (Mass Observation, 2015), the MOP maintains a panel of voluntary correspondents from across the UK, referred to as 'Mass Observers', who are engaged with through 'Directives', a set of questions or prompts on a particular topic. Directives span a varied range of topics and have been used to investigate a variety of areas, from gardening (Bhatti, 2014) to genetic modification (Haran and O'Riordan, 2018), but can all be brought together under the heading of 'everyday life'.

In responding to Directives, the writing of Mass Observers can take myriad forms. As former Mass Observation Director (1990-2008) Dorothy Sheridan (1993) describes, written responses may include "letter-writing, answering questionnaires, being interviewed, keeping a diary, writing a life story" (Sheridan, 1993: 34). With no single genre of writing proving to be the most appropriate, Sheridan (1993: 34) characterises those involved in Mass Observation as engaged in "the process of forging a new genre: the 'Mass-Observation directive reply'". Although, of course, MOP writing is a relational product and, as Pollen (2014) indicates, "writing to MO is always solicited and consequently shaped by the nature of the questions asked and the contributors' conceptualisation of the larger project" (Pollen, 2014: 10).

Given the MOP's commitment to documenting the 'ordinary' and 'everyday', Mass Observers may view their role in the Project as one of local historian, documentarian, or citizen journalist (Bloome et al., 1993; Pollen, 2013), situating their views in local and broader contexts and often incorporating those of others. This reflexivity and attention to positionality means that Mass Observers often muse over not only what they know but also what they do *not* (Kramer, 2014). In this way, MOP writing illustrates the plurality of narrative and knowledge, disrupting the privileging of a singular, unified telling. Because of this, analysis of MOP writing calls for approaches which steer away from generalisations and quantifications (Pollen, 2013), instead demanding attention to the particularity of MOP writing and its emergence within the wider project.

Though the writings of Mass Observers will be discussed in this paper as part of wider societal feelings towards animal research, it is pertinent to state that Mass Observers are not intended here to act as a proxy for 'the public'. Indeed, this notion of the 'general public' is not neutral yet is often constructed in animal research dialogues in ways which falsely portray neutrality (Davies et al., 2020). Rather, in offering analysis of MOP writing, this paper aims to emphasise the necessary situation of Mass Observers in their particular, yet shared, 'everyday' worlds, demonstrating the rich insights that attention to the micro in the macro can generate for studies of how publics relate to science.

This paper is based on an analysis of responses to the 2016 MOP Directive on 'Using animals in research' commissioned by the University of Nottingham, which received a total of 159 responses (72 postal and 87 electronic). All accounts were initially read in their original state (as word-processed responses and hand-written responses which were photographed at the archive and converted into PDFs) and uploaded onto NVivo 12 to provide word search functionality and an easier handling of the large dataset. In analysing the accounts, this study takes a constructionist thematic analytical approach, which, as Braun and Clarke (2006) describe, "examines the ways in which events, realities, meanings, experiences and so on are the effects of a range of discourses operating within society" (Braun and Clarke, 2006: 81). In employing this approach, I followed Braun and Clarke's (2006: 87) six steps of: 1) familiarising yourself with your data; 2) generating initial codes; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) producing the report. This allowed me to remain at a meta-analytical level, looking at themes across the MOP responses collectively and focusing on relational processes which structure interactions with animal research, such as knowing and caring.

In exploring the three dualisms which structure this paper, those of uncomfortable knowledge and uncomfortable care; strategic care and strategic ignorance; and responsive caring and responsive knowing, each section will discuss excerpts from the writings of different Mass Observers. Mass Observers will be referred to by the identification numbers they are given by the Project and, in the aim of preserving their style of writing and formatting, when reproducing their writing here I have tried to include grammatical errors, typos, and paragraphing. Only spelling and grammatical errors that might seriously obscure the coherence of the extracts have been amended.

In the first section of this paper, I discuss the ways in which animal research is bound up with caring for the self, other humans, and other animals. To make sense of these dynamics, touching on the tensions that can emerge between them in deciding whose care should come first, I expand on Rayner's notion of 'uncomfortable knowledge' to account for its entanglement with 'uncomfortable care'. In the second section, I build on McGoey's concept of 'strategic ignorance' to introduce the concept of 'strategic care' as a way of exploring how Mass Observers convey ideas of not wanting to know and not wanting to care. In expressing a need to withdraw from knowing or caring about animal research and the uncomfortable knowledge that it presents, I suggest that some Mass Observers appear to employ practices of caring and knowing *strategically*, prioritising some care relations over others or deliberately turning away from the issue. Finally, in the third section, I discuss MOP extracts which demonstrate ways in which the issue of animal research requires some kind of response. This is made sense of via new concepts of 'responsive caring' and 'responsive knowing', as a way of highlighting possible alternatives to the withdrawal of knowing and caring. In doing so, I emphasise the centrality of acknowledging one's responsibility *to* care and know and draw attention to the need to cultivate the ability to *respond* in such ways.

The problems of attending to animal research

Rayner (2012) describes 'uncomfortable knowledge' as 'disruptive knowledge' (Rayner, 2012: 113), that is, knowledge which is in tension with our simplified ways of understanding the world. Knowing about animal research can be disruptive in that recognition of one's complicity in and benefiting from the practice (i.e. as a patient or medical consumer), whilst knowing of the confinement and killing of animals involved, threatens to disturb self-perceptions built upon care for and about non-human animals. In thinking with Rayner's concept around the topic of animal research, I will introduce the notion of 'uncomfortable care', not as a counterpart to the former, but, rather, as an integral component at the core of uncomfortable knowledge. Indeed, because knowing and caring are entwined, so too are uncomfortable knowledge and uncomfortable care. It is due to our *caring* about others, both human and non-human, that *knowing* about animal research may be uncomfortable and, as will be discussed in the second section, for some, identified as an area to be avoided.

In acknowledging the role of care in motivating (dis)engagements with animal research, this section will outline three ways in which knowing about the issue may be experienced as uncomfortable. These involve the disturbing impact that knowing about animal research can have on existing care obligations we have for the self, the humans we love, and the other animals we love. In discussing how each of these care relations can make knowing about animal research uncomfortable, the messy entanglement of each in the animal research domain will be illustrated, complicating assumptions about the mobilisation of species boundaries in constructing moral communities and obligations of near and far care.

Caring for the self

In articulating discomfort towards the topic of animal research, some Mass Observers describe their own state of health as preventing them from knowing or caring about the issue. For such Observers, feeling *too close* to animal research, due to dependence on medical treatments produced through the use of animals, acts as an obstacle to caring about the issue. Feeling somewhat dependent on the scientific use of animals in this way meant that the Directive was a challenging topic for some, as the following Observer discusses –

> This is such a difficult topic for me! I know that as a cancer patient for the last 11 years my treatments will probably, highly probably, been tested on animals and I love animals and believe that as creatures of the world they have a right to a good and free life.
>
> […]
>
> My views have changed, perhaps because of my condition and perhaps because my husband wants me to live longer. I try not to think too much about this when I have my chemotherapy. (Mass Observer A4820)

As this Observer (A4820) suggests, animal research may prove a particularly difficult topic to engage with when writing from the position of a current (or future) patient. In sensing a tension between their values towards the treatment of animals and their reliance on medical interventions as a cancer patient, this Observer's quandary highlights how multiple subjects are implicated in caring about animal research. In this case, such care relations involve oneself as a patient, animals involved in medicine production, and loved ones whose welfare and wishes are here entwined with the patient's own. In feeling invested or complicit in animal research through a reliance on medical interventions, knowing and caring about animal research can be distressing and raise tensions between one's care priorities, unsettling hierarchies of whose care should come first.

Another Mass Observer (H1470) expressed a similar sentiment in writing about their dependence on insulin and the experimentation with dogs involved in its development –

> Unfortunately, I am having to take commercial medicines daily to stay alive. I need insulin twice a day besides other medications. I do know the story of how insulin came about. It breaks my heart having to take this medication as I often think as to how many dogs were sacrificed and in severe pain , in order that this medicine be created. (Mass Observer H1470)

Similar to the previous correspondent (A4820), this Observer (H1470) expresses a sense of regret towards their continual use of a treatment developed through the use of animals. Importantly, this Observer's feelings towards their insulin use suggests that the emotional distress caused by the use of animals in developing medicines is not necessarily lessened if said animal use was in the 'past'. Such insights complicate the assumption that transparency around the role of animals in medicine development will boost public support, as has been suggested in the proposal to disclose the use of animals in medicine labelling (Collins, 2011). Rather, past or ongoing use of animals in the research and development of a treatment that one is now reliant on can still be meaningful and morally problematic to those who care about research animals, with certain species, such as dogs in this case, arguably having particular significance.

Moreover, being reliant on medications at the time of writing might make thinking about animal research not only uncomfortable, but further, unreasonable. In periods of acute or longstanding illness it may be difficult for individuals to consider their relation to the practice beyond an individual need for effective medical treatment. As can be inferred from the following Mass Observer (M5113), in times of ill health, broader thinking around medical consumption and animal research may be impeded –

> It is not fair that some diseases get more research funding than others. It is not fair when medicines and treatments exist but people cannot afford to have them because companies want to make a profit as well as support research and development. But it is not a perfect world. All I want when I buy medicine is to feel better. If you want me to think more widely, ask me when I'm not ill! (Mass Observer M5113)

As captured here, broader concerns than simply the need for medical treatment when ill are raised by this Mass Observer (M5113), as they touch on the (un)fairness of funding priorities in biomedical research and access to healthcare. However, such concerns are drawn back to the Observer's principal interest in the role of medicines to make one feel better when unwell. Significant here is the suggested difficulty to care *about* others when one needs to be cared *for* themselves, echoing Smith's (1998) characterisation of disadvantaged groups who might be "too preoccupied with feeling the need for care, or with the difficulty of providing it, to think of much else" (Smith, 1998: 16). Such analysis reveals that investments in one's self-care, represented here in current or future medicine use, can pose an obstacle to caring about the process by which medical treatments are produced.

Caring for the humans we love

As well as representing a way to care for oneself in current or future illness, biomedicine can also signify a way to care for the health of loved ones, with such care obligations, again, making knowing about animal research uncomfortable. In conceding the need for animal research and the role it is said to play in producing and advancing healthcare treatments, some Mass Observers articulate a sense of being torn between their values towards the treatment of animals and their stake in (current or future) medical interventions. As the following Mass Observer (D2585) suggests –

> Just seeing written, or heard said, the term 'Laboratory Animal Research' makes me feel very sad. Of course I realise over many years cures and treatment for many illnesses, some of which were terminal some years ago, medicines now widely used safely would not have been 'found' without long years of research and experimentation, and probably members of my family, friends and acquaintances have benefited from this research, but the poor animals that have been kept sometimes in poor conditions who cannot speak but have been used to find some of the cures, make me very emotionally upset. (Mass Observer D2585)

This Observer (D2585) opens their response to the Directive by expressing their sadness upon encountering the words 'laboratory animal research'. They go on to acknowledge animal research as a facilitator of medical advances, which have personal significance, yet return to the mistreatment of vulnerable animals ("who cannot speak") and the emotional impact of this. The tension felt here between wanting the expected benefits of animal research, i.e. effective medical treatments, whilst also not wanting animals to be used in such a way means that they find thinking about the practice particularly difficult.

As suggested earlier, caring for one's own and loved ones' health *through* the use of animals in biomedical research is often tied to future imaginaries which may hold illness. In discussing the need for animal research to produce medical interventions which may safeguard against future illnesses, relations involving those whose care is legally obliged, such as children, were significant amongst Mass Observer accounts. As suggested in the following excerpt, the construction of animal research as a way to channel care to others, in current or future illness, can generate moral conflict –

> Not an area I have thought about, it is difficult if a loved one or I became very ill and no drug was available or a new on may be being developed then testing would certainly be considered however should animals be tested on, no oh what a dilemma. Feel I am not being useful in this topic. (Mass Observer C4988)

As suggested by this Mass Observer (C4988), ethical relating to animal research can be bound up with hypothetical and future-oriented modes of caring, in which lives are pitted against one another. In caring not only for one's own health and wellbeing but also that of loved ones, it may be that using animals for biomedical research offers a sense of health security for potential futures and thus any resistance to this constitutes a failure to fulfil one's caring responsibilities. In this way, the ethical problem posed by the (mis) treatment of animals in biomedical research is juxtaposed with the (mis)treatment of loved ones by depriving them of potential medical treatments. Using animals in research thus becomes a way to protect oneself and loved ones against the threat of illness.

Therefore, whilst such interpretations of whose care comes first might initially suggest the pre-eminence of human needs over those of non-human animals, this analysis stresses the importance of familial bonds. This suggests that the ways in which we relate to animal research are not merely situated in Ryder's (1989) concept of 'speciesism', i.e. the prioritisation of human interests above those of other species; rather, they are enmeshed within relationships which are interpersonal rather than simply genetic. The assumed partiality to family members before unknown, distant, or indeed, *different* others, features often in the rhetoric of animal research advocacy organisations. In pitting the lives of family members, particularly children, against the lives of research animals, such groups often construct the choice that publics have to make on the matter as one of either/or and life/death. This is captured succinctly in a billboard campaign by US-based biomedical research advocacy organisation The Foundation for Biomedical Research (FBR) which juxtaposed an image of a white rat, symbolic of the laboratory, with that of a young girl and asked its viewers "Who would you rat/her see live?" (see Harrison, 2011). However, as illustrated, the use of animals for primarily human gain does not necessarily sit easy. Furthermore, as the following subsection will examine, the making of family and kin often transcends species boundaries and interspecies relations may hold a special importance.

Caring for the animals we love

With a long history of keeping animals as pets in Britain (Ritvo, 1987), such human-animal relations are often marked by intimate, interpersonal bonds (see Thomas, 1983 [1933]). There is much research documenting the intimacy and legitimacy of relations between humans and their companion species (see Cudworth, 2011; Fudge, 2008), and, as Charles (2014; 2016; 2017) claims, writings from the MOP also confirm the importance of interspecies relationships. The strength and significance of such interspecies relationships suggests that practices of care towards those who are tied up with animal research, from the breeding of animals, the experimental process, to the expected outcome for patients and publics, are not strictly determined by species barriers.

An example of the way in which companion animal relationships may shape how Mass Observers relate to animal research is illustrated in this correspondent's (R4365) deliberation over conversations with friends or family on the topic of animal research. As they write –

> For me the subject has never come up. I think this is because we all have animals and to think of them being harmed is too much to think about. I am aware that this is a very ignorant view. (Mass Observer R4365)

For this Observer (R4365), animal research presents a conflict between their views on the treatment of companion animals (the animals that *we care for*) and that of research animals (the animals that *care for us*) making this a challenging issue to contemplate. Implied here is that discussing animal research leads them to imagine their 'own' animals in the position of those used in the biomedical industry, a line of thought which takes an emotional toll, and indeed, is "too much to think about". Empathising with research animals through imagining one's companion animals in their place thus illustrates the role of care in relating to animal research, with the interpersonal connections shared with those animals we love serving as a way to understand the ways animals are treated in biomedical research.

Yet, attached to this, identifying as an animal 'owner' or 'lover' also means that confronting one's complicity in animal research, despite how problematic and constrained such complicity might be, is uncomfortable and can threaten self-identity. As Engdahl and Lidskog (2012) observe, ″citizens evaluate the social meanings of an issue and the extent to which it threatens or supports their social identities" (Engdahl and Lidskog, 2012: 707). Drawing back to ways of mitigating such discomfort, perhaps it is not surprising, then, that Rayner identifies four 'tacit information management strategies' to mediate one's exposure to uncomfortable knowledge all of which revolve around different forms of not-knowing: "denial, dismissal, diversion (or decoy) and displacement" (Rayner, 2012: 113).

In this case, writing from the MOP reveals that some would rather turn away from information on animal research which may unsettle existing care obligations we have for the self, the humans we love, and the other animals we love. The use of animals to produce new biomedical knowledge, a goal often treated as a universal good (Harris, 2005; and, for critique, see Callahan, 2003), is therefore disruptive in Rayner's sense in that it troubles such simplified understandings of ourselves. That is, how can we love animals whilst also causing them to suffer? In perceiving a lack of options to resolve the discomfort generated by the topic of animal research, as will be discussed in the following section, strategic ignorance of the issue becomes understandable and perhaps required.

Strategic care and strategic ignorance

In responding to the uncomfortable knowledge that animal research presents, some Mass Observers appear to employ practices of caring and knowing strategically, erecting care boundaries in which animal research is excluded or turning away from the issue. In exploring how caring and knowing are practiced around animal research, it is crucial to also attend to the ways in which they are *not*. In doing so, this section will begin with what I will call *strategic care*, that is, practices of caring that are based in strategically drawn boundaries, allowing one to justify channelling care in some directions over others. This concept is my response to McGoey's (2012) notion of 'strategic ignorance', which is described as being used to preserve one's internal harmony through "practices of obfuscation and deliberate insulation from unsettling information" (McGoey, 2012:555) and which will be explored in the second subsection through Mass Observer practices of not-knowing. Given the entanglement of knowing and caring, strategic care is used here to illustrate how practices of ignorance and denial are bound up with caring. Indeed, it is *because* we care that we may feel the need to turn away in situations where we feel powerless to act. Viewing McGoey's concept through the lens of care and analysing this through relations with animal research therefore reveals how caring practices can also be practiced strategically, being employed in ways which promote some care relations over others.

Strategic care

Before examining how Mass Observers negotiate their 'care-full' (van Dooren, 2014) engagement with the topic of animal research, it is first important to note that, for some, animal research was considered a low priority issue. In acknowledging disinterest or indifference towards the problem of animal research, its situation amongst many other socio-political issues that demand consideration becomes evident and, alongside which, some Mass Observers deem it as of lesser importance. Such practices may reflect a *strategic care*, through which boundaries are drawn to preserve some care relations over others. This boundary formation around which issues warrant care is articulated by the following Mass Observers –

> I am afraid that on the scale of issues, this is a low priority one for me. I am involved in so many issues to do with justice and human rights for people that I feel to be too preoccupied with this would be a kind of luxury when human tragedy is all around [sic] us. Having said that, however, I do believe

> that a society which is civilised in its treatment of animals is also more likely to be civilised in its treatment of people, so I am aware that these things are not separate entirely. (Mass Observer S4743)
>
> ~
>
> At the end of the day I do feel for any animals that suffer in the service of humanity, but there are a lot of issues in the world that I think are more pressing. And let's face it, we didn't get to be top dog on this planet by being nice to other species (or our own) – nor are animals, as a rule, nice to each other. I just hope our scientific understanding and control over the natural world can advance to a point where survival does not demand that we make moral compromises. (Mass Observer T5672)

For both Mass Observers, caring about animal research is situated amongst other issues that demand care, and for the first Observer (S4743), animal research is 'a low priority' compared to what are deemed as exclusively "human tragedies" [sic]. When located within such a landscape, in which one's care is needed in a plethora of directions, this Observer (S4743) regards attention spent on animal research as "a kind of luxury". Yet, this separation between humans and other animals is then unsettled in the connection made between the way a society treats both. For the second Observer (T5672), the exceptionality of humans is regarded as having been achieved through the struggle for survival that all animals engage in, with the biomedical use of animals reflective of a natural, evolutionary fight for dominance. When taken as representative of this species struggle for survival, animal research is therefore implicated as a low priority matter, with "a lot of issues in the world" considered "more pressing". However, as suggested in the hope that scientific endeavours for human survival do not entail "moral compromise" [sic], there are ethical limits to species survival.

That for these Mass Observers species presents a boundary to care demonstrates that caring is not neutral or unproblematic. Rather, care is a limited resource and one cannot care about everything. To direct one's care-full attention in a particular direction must mean there are sites and subjects left unattended to as a consequence. As Puig de la Bellacasa (2012) puts it, "where there is relation there has to be care, but our cares also perform disconnection" (Puig de la Bellacasa, 2012: 204). This means that care is strategically enacted to support certain relationships at the expense of others. Given the necessary confines of care, using species boundaries to guide normative decisions about who and what we should care about reflects wider sociocultural values around who *deserves* our care. In the case of caring about animal research, then, anthropocentric discourses which shape many areas of our social worlds and, indeed, are foundational to the biomedical use of animals, may make one's caring attention towards laboratory animals questionable when such effort could instead be directed towards humans.

In this way, although animal research involves and impacts bodies across species boundaries, caring about issues which are often defined as chiefly 'animal' within anthropocentric contexts may be subject to particular scrutiny. Furthermore, that grief over animal suffering and death is still often felt as taboo, being historically 'disenfranchised' (Stewart et al., 1989) and remaining acutely so in relation to particular animals (e.g. 'livestock') (Pallotta, 2016), may also contribute to the de-prioritisation of the issue. As to care about animal research in the face of human suffering may be to affectively disturb the cultural hegemony of anthropocentrism. Although a lack of interest or care towards animal research was expressed only by a minority of Mass Observers, such disconnections with the issue are important to acknowledge as they reveal how the practice is culturally situated amongst other socio-political issues which call for attention.

Strategic ignorance

As was more common in the Directive responses, if those implicated in the practice are recognised as deserving of care, pressure to learn more about the situation may be felt in order to better attend to it. However, knowledge of animal research practices might be uncomfortable and, with a lack of routes to act on such knowledge (Hobson-West, 2010; Pound and Blaug, 2016), perceived as ultimately futile. In these situations, ignorance may appear beneficial through the shelter it offers from disturbing information. McGoey (2012) defines this type of not-knowing as 'strategic ignorance', which is "distinguishable from deception or the suppression of data by virtue of the fact that unsettling knowledge is thwarted from emerging in the first place" (McGoey, 2012: 559). Using the language of denial rather than ignorance, Cohen (2001) also discusses how we manage unsettling information. For Cohen, there are multiple types of denial however most useful to consider here is his concept of 'implicatory denial' – denial of the *implications* of knowledge. As Cohen states, "unlike literal or interpretive denial, knowledge itself is not at issue, but doing the 'right' thing with this knowledge" (Cohen, 2001: 9). In this case, Cohen writes that "we turn away from our insights and hide their implications. We half-know, but don't want to discover the other half" (Cohen, 2001: 34).

As both ways of conceptualising practices of not-knowing suggest, individuals are not entirely absent of knowledge about issues they strategically ignore or deny. Rather, what one knows about a subject may fuel a desire to not know any more about it. This half-knowing and half-not-wanting-to-know is demonstrated in the following Mass Observer's (B3227) writing on the proposal of increased openness around animal research, in which they consider –

> If we were asked flat out, Do you approve of secrecy? Are you in favour of greater openness?, we would say no and yes, but the truth is that some of us, and some part of all of us, are essentially happy to be kept in the dark about unpleasant things. (Mass Observer B3227)

This Mass Observer (B3227) acknowledges a cultural valorisation of openness and consequent disapproval of secrecy, yet, in an almost confessional tone, claims that such support for openness exists alongside a willingness to remain unaware of "unpleasant" knowledge. In these circumstances, openness is presented as harmful and secrecy becomes an act of public protection. Such theorising reframes ignorance and denial as ordinary, everyday practices, which, rather than being inherently negative, can be personally and culturally beneficial. Challenging the notion that ignorance is something to be eradicated through the gaining of knowledge, an epistemology underpinning the classical enlightenment spirit of science (Bogner, 2015), such understandings of ignorance highlight both its social and psychological utility. When confronted with an opportunity in which one may come to know something about animal research and the topic is already associated with uncomfortable knowledge, the refusal to know more or engage with the implications of any knowledge acquired can thus be seen as a coping mechanism. Hence supporting Cohen's claim that "what looks like denial is an accommodation to cognitive threat. The attack on your life assumptions is blunted, and threatening information is cut down to tolerable doses" (Cohen, 2001: 49).

A key component in Mass Observer withdrawals from learning about or discussing animal research is a reported sense of being unable to alter their relation to the practice, and, more specifically, their perceived complicity in it as a patient or medical consumer. Not only are there limited opportunities to act upon knowledge gained if it is found to be troubling, given the proclaimed necessity of animal models to biomedical progress (Barré-Sinoussi and Montagutelli, 2015) 'care-full' relating with laboratory animals can be emotionally immobilising. Such fundamental discomfort around the prospect of benefiting from harming animals therefore troubles assumptions that awareness of regulation or the value of animal models will alleviate societal concerns. Hence, rather than encouraging an appreciation of animal research, as bioscience communications which aim to draw public attention to the use of animals in medicine development intend (UAR, 2016), this conflicting investment in the promises of animal research may make it all the more crucial to turn away.

As touched on in the introduction, there remains a strong leaning towards deficit-model approaches to publics in the animal research domain. Indeed, previous arguments made on the subject of openness around animal research have claimed that publics wish to remain wilfully ignorant and thus providing more information on the practice has at times been discouraged (Aziz et al., 2011:459). However, such characterisation of an 'ignorance is bliss' attitude of publics simplifies the ambivalence felt towards animal research. As this analysis of MOP writing shows, due to their caring about those implicated in the practice, some individuals feel guilt and shame over knowing and thinking about animal research and also *not* knowing or thinking about it. This is demonstrated in the MOP excerpt below –

> As regards buying and taking medicines, I don't think I have ever given the scientific research involving millions of animals a second thought which I suppose is rather shameful. It's just something I block out I suppose – back to my feeling of not being able to do anything about it (Mass Observer F890)

The sense of shame or hypocrisy expressed by this Mass Observer (F890) reflects how avoiding information on animal research might help to minimise any discomfort the issue causes, yet knowledge of the practice itself cannot be entirely eroded. Therefore, at times, one is aware of turning away and sheltering from unsettling information, a practice which may raise further feelings of guilt or shame. That such feelings accompany the avoidance of information on animal research illustrate that partial ignorance does not provide absolute shelter from moral trouble. Indeed, shame is intimately tied to our sense of morality, acting, in Scheff's (2003) words, as "our moral gyroscope" (Scheff, 2003: 254).

However, implicit to such practices of ignorance is the power, or lack of, that one possesses to act upon what they come to know. In order to combat silence and denial around animal suffering, Wicks (2011) suggests that "cultural channels should visibly be in place [sic] to validate the sense that something *can* be done, inform you *what* this something is and enable you to do it" (Wicks, 2011: 196, emphasis in original). However, with a lack of routes to affect change in the animal research domain, ignorance around animal research appears to offer protection from the uncomfortable knowledge the topic poses. Without autonomy in this area, individuals may feel that ignoring the issue is in their best interests.

Nevertheless, as the MOP excerpt above shows, self-protection from such information is not unproblematic. Rather, feelings of guilt or shame may accompany the acknowledgment of an active ignorance towards animal research and the suffering associated with the practice. Such guilt induced by turning away from animal research may also be attached to a perceived civic duty to engage with issues of social justice. Given the mounting attention placed on individuals to take responsibility for global challenges such as climate change (see Whitmarsh et al., 2011), for some Mass Observers, animal research may reflect yet another political or ethical issue that citizens feel obligated to engage with, yet also disempowered by.

Therefore, as this analysis of MOP writings on animal research suggests, practices of not-knowing do not necessarily indicate not caring. Indeed, active ignorance towards unsettling topics may be explicitly driven by care. Rather, turning away from the issue of animal research is here shown to be functional, protecting oneself from the negative emotional impact that knowing about animal research is expected to generate, particularly when individuals feel unable to act upon such information.

Responsive knowing and responsive caring

Although, as indicated by the previous section, knowing and caring about those implicated in animal research can be internally and interpersonally disturbing, some Mass Observers suggested that knowledge about the practice can be a useful resource for themselves and 'the public' at large. As well as being supportive of openness on animal research, some correspondents described ethical futures which were dependent on individual accountability for those involved and discussed current acts of beneficence which acknowledge and attempt to remedy the non-human vulnerabilities that human action can generate. In interpreting such writing, I introduce the concepts 'responsive knowing' and 'responsive caring'. In describing these practices as 'responsive', I draw explicitly on Haraway's (2016) notion of 'response-ability', describing an ethical awareness which primes us to be continually open to responding to and with others, "a praxis of care and response—response-ability—in ongoing multispecies worlding on a wounded terra" (Haraway, 2016: 105).

In doing so, I hope to emphasise how such forms of caring and knowing are practiced through an acknowledgment of one's responsibility *to* care and know and also draw attention to the need to cultivate the ability to *respond* in such ways. To be response-able, knowing and caring *responsively*, is therefore more than a personal ethical stance or sensitivity, it requires attention to power structures which empower and disempower us in varying ways. As Martin et al. (2015) put it, 'the capacity to respond is itself unevenly distributed and enmeshed within complex configurations and logics of power', a fact which means that 'an ethic of response-ability, and thus an ethic of care, cannot be institutionalized or standardized' (Martin et al., 2015: 635). Therefore, in the animal research domain, it is my contention that in order for individuals to responsively *care*, opportunities to responsively *know* must be available, and so it is with the latter that this section begins.

Responsive knowing

In responding to the Directive, not all Mass Observers expressed an aversion to knowing more about animal research. Indeed, some expressed support for proposals of increased openness on the issue. Key to many of the accounts in which Observers were enthusiastic about more openness around animal research was the capacity for openness to bring about action. As the following Mass Observers indicate –

> I have heard animal rights protesters say there are other ways of testing medicines + doing research. This is perhaps a taboo subject that should be brought into the open more. What are the other alternatives? Would they be as effective? The case was well made against animal testing for cosmetics so the debate should be moved onto health research more. (Mass Observer W3730)
>
> ~
>
> I feel that it would be useful for the general public to know more animal research to help them decide what is acceptable. (Mass Observer H5741)
>
> ~
>
> I think their ought to be more openness about animal research. At least not just to say who does it but to be able to legitimately justify it. If the same trials & tests can be done without animals but it costs more then I think so be it. Profit should not come before animal welfare. (Mass Observer G4296)

For these Observers, proposals to increase openness around animal research should enable publics to act in some way. This can be seen in how the first Observer (W3730) links openness around alternatives to fostering debate on the topic, the second (H5741) calls for information which will enable publics to make informed decisions on which kinds of research are "acceptable", and the third Observer (G4296) emphasises the importance of openness strategies which *justify* the scientific use of animals. In each of these excerpts the availability of such information in and of itself is not the key focus, rather, significance is placed on what agency such information could bestow upon publics in this domain. Information that enables publics to draw boundaries between necessary and unnecessary, humane or inhumane, and acceptable or unacceptable biomedical uses of animals is important in that it permits publics to be active co-constructors, rather than passive consumers, of scientific knowledge. In this way, such knowing becomes *responsive* in that it allows one to actively *respond to* the issue and be *responsible for* what one comes to know. Consequently, in providing routes for publics to intervene in animal research, such forms of knowing can be seen as facilitating ways to care *for* laboratory animals. In other words, responsive knowing enables responsive caring.

Yet, making certain data available as a way of appeasing a public characterisation of the sector as secretive without also providing ways for publics to act upon such information falls short of this. As Moore (2017) summarises in another context, "for governance to be 'adequately justified', the state must take an active role in explaining, evidencing and defending decisions and actions" (Moore, 2017: 425). Although there is value for science communication in making scientific and regulatory information on animal research publicly accessible, relying predominantly on this approach and treating one-way enactments of openness as ends in themselves potentially undermines the Concordat's aim to "build open dialogue with the public on the reality of the use of animals in research" (Williams and Hobson, 2019: 8).

A key element of enacting meaningful openness around animal research then appears to be that such strategies work towards fostering reciprocal science-society dialogues around the practice. In doing so, openness becomes a mechanism which can enable publics to engage with the issue in productive ways, rather than as an end-in-itself. As the following Mass Observer (T1843) reflects, openness is not only about transparency from the sector which can then be witnessed by public spectators, openness also signifies that an issue is open to public *involvement* –

> I think there should be total openness about the issue, just as there should be around abattoirs in fact. We should not flinch from knowing how we get from a to b: we become too protected from the truth about how we conduct ourselves in society in order to have what we supposedly want. As it's an ethical issue, everyone should be involved in it, particularly when it comes to medical research. (Mass Observer T1843)

This Mass Observer's (T1843) conception of openness seems imbedded in a sense of societal duty, with awareness of the steps in our consumption chains (i.e. 'abattoirs') being constructed as almost a civic responsibility. Similar to the writings on not wanting to know discussed in the previous section, this Observer regards ignorance around animal research as a form of protection – being "protected from the truth". However, in characterising animal research as an ethical issue, they determine that everyone has an obligation to know about and act within it. This links back to the feelings of guilt and shame discussed earlier, with some Observers' self-confessed practices of ignorance towards animal research perhaps felt as a shirking of the obligation to get involved that the above Observer highlights. Yet, as this section reinforces, in implementing beneficial openness strategies around animal research, such ways of knowing must be considered for how they might empower or disempower.

Responsive caring

In considering how responsive knowing is entangled with responsive caring, we will now turn to examples where Mass Observers articulated ways of caring about animals used in research. Although the Observers mentioned in this section may describe a current withdrawal from knowing about animal research, they can also be read as expressing a desire to respond to the issue through new, potentially subversive, modes of care. Though perhaps based in idealised visions of the future, such care relations centre on a transformation of human relations with laboratory animals and non-human animals more broadly, promoting an ethics of care obligated not only by the individual, but by humans as a species.

An example of this type of responsive caring is demonstrated in the focus of some Observers on a vulnerability that all sentient beings share (in different forms), that of the ability to suffer. In discussing the relations between laboratory animals and humans, Haraway (2008) writes of 'shared suffering', not attempting to mimic or subsume the suffering of others, what she calls a 'heroic masochistic fantasy', but doing "the work of paying attention and making sure that the suffering is minimal, necessary, and consequential" (Haraway, 2008: 82). Such considerations require us to continually critically assess what comes from the suffering of laboratory animals, to prevent such suffering from becoming taken-for-granted. Relevant here is one Mass Observer's (J5734) contemplation of a utopian future which is marked by its lack of suffering –

> […] if we're imagining a future world, we're imagining it without suffering, and so we stop the suffering we are causing. And if I am working towards a world in which there is no suffering, I need to stop allowing things to suffer on my behalf, and give up the pills. (Mass Observer J5734)

In envisioning a future "without suffering", this Observer (J5734) identifies their consumption of medicines as an area in which they can take individual responsibility for the suffering caused through animal research. Such reflection on how the management of one's vulnerabilities are entangled with the vulnerabilities of other species can be seen as leading this Observer to consider the responsibilities that we, as individuals and as a species, might bear towards other animals. Considering their accountability for the suffering of other animals in pursuit of human health advancements, the Observer concludes that they "need to stop allowing things to suffer on my behalf, and give up the pills", an act that requires not only recognition but also acceptance of one's own vulnerability.

Whether put into practice or not, such visions of the future reflect Puig de la Bellacasa's (2011) contention that "the commitment to care can be a speculative effort to think how things could be different" (Puig de la Bellacasa, 2011: 100). The ethical importance placed on individual responsibility here is central to Tronto's (2012) notion of 'relational responsibility', "where the fact of being alive and the nature of human vulnerability places one in relationships […] that produce responsibilities" (Tronto, 2012: 308). Such corporeal vulnerabilities are vital in thinking about animal research. Indeed, that animals are so often used as models for human bodies (Ericsson et al., 2013), viscerally illustrates the way in which vulnerabilities are shared across species. In the animal research context, caring about such animals is intimately entwined with caring for ourselves.

In articulating ways in which research animals and non-human animals more broadly may be cared for and about, some Mass Observers directly challenged normative obligations to care first and foremost for humans. Such Observers were critical of the prioritisation of human needs as represented through the biomedical use of animals. For some, in enacting beneficent care, such as charitable giving, who they care about might be structured in explicit contestation of the obligations expected towards humankind, as the following Observer's (R5682) charitable practices suggest –

> I don't like the idea of any animal suffering and if I support/give to any charity it is always animal / environment related. Makes me sound horrible but I would never give to a charity related to humans. We're too selfish and have caused most of the problems in today's world! (Mass Observer R5682)

That this Observer (R5682) justifies their aversion to donating to charities "related to humans" by deeming the human species at fault for "most of the problems in today's world" suggests the invoking of notions of deservingness in enacting care boundaries. Such musings on the activities of humans as a homogenous collective are problematic, neglecting cultures which do not practice ontological separations between humans and animals (Salmón, 2000) and disregarding how the category of the 'human' is infused with unequal power distributions (Wolfe, 1998: 43). However, given current emphases on the negative impact of humans as 'a force of nature in the geological sense' (Chakrabarty, 2009: 207), such articulations of care perhaps reflect shifting relationships and priorities of care in the Anthropocene, a cultural epoch in which human exceptionalism may, for some, begin to lose salience.

Overall, this analysis suggests that some Mass Observers want to know more about animal research and to care better for those implicated in its practice, actively *responding* to the issue in some way. In such writing, Observers speculate on ways to resolve the moral discomfort that the scientific use of animals causes, suggesting a desire for ways of knowing about the practice which enable intervention into it and modes of caring which may radically improve the lives of non-human animals, in science and elsewhere. As well as this, some Mass Observers relate to their membership of the human species, revealing how caring about animals involved in practices such as scientific research can play out on a macro scale and lead to demand for change to the ways that 'we', collectively, enact care.

Conclusion

This paper has argued that relating to animal research is a process of both knowing and caring. In demonstrating this entanglement, I have introduced the novel concepts of uncomfortable care, strategic care, and responsive knowing and caring. In the first section, the concept of 'uncomfortable care' was used to discuss why animal research can be an acutely uncomfortable topic, touching on the competing tensions it raises between different care relations. This expanded on Rayner's 'uncomfortable knowledge' to more precisely account for why such knowledge is uncomfortable in the first place. Looking at how the uncomfortable topic of animal research is mediated in the everyday, the second section looked at Mass Observers who do not want to care or know about the issue. Here, McGoey's notion of 'strategic knowledge' was used to interpret discussions of turning away from the topic. Accounting for strategic practices of caring, McGoey's concept was extended with the notion of 'strategic care', drawing attention to how some care relations are deliberately prioritised over others. The final section attended to Mass Observers who want to respond to animal research through modes of what I have called 'responsive knowing and 'responsive caring'. Following Haraway's notion of 'response-ability', these concepts suggest that knowing becomes *responsive* when it allows one to actively *respond to* the issue and be *responsible for* what one comes to know. In this way, responsive knowing should lead to responsive caring.

Overall, this analysis suggests that the controversy of animal research is irresolvable by increasing the availability of information alone. Indeed, as Bauer and Falade (2014) write, "if Francis Bacon's late sixteenth-century notion of 'knowledge is power' holds, any attempt to share knowledge without simultaneous empowerment will alienate rather than bring the public closer to science" (Bauer and Falade, 2014: 148). For animal research and other technoscientific controversies, consideration of the varying capacities that publics have to act on what they come to know is crucial. Without this, those who care about an issue yet feel unable to act on the moral and emotional trouble it evokes may feel it necessary to turn away altogether.

In their discussion of the local ethical review process regulating animal research, Hobson-West and Davies (2017) show that the regulation of biomedical animal use is informed by societal concerns. Their work demonstrates that, in considering the impact a particular experiment may have, the ethical review process considers potential 'harms' to the human community outside of the laboratory as well as the non-human animal subjects who are directly involved. One might therefore argue that how future science-society dialogues around animal research are enacted should also be subject to similar consideration. Specifically, communication must be built upon care for how publics can make meaningful use of opportunities to know.

Furthermore, in considering the ethical and methodological implications of the analyses offered here, attention must also be turned back onto the origins of this research, the commissioning of the MOP Directive on 'Using animals in research'. Although methods like the MOP offer anonymity and generous amounts of space, time, and formatting freedom, the prevalence of discomfort in Observers' writing on animal research raises questions of whether such methods themselves evoke heightened levels of discomfort towards controversial topics and leave correspondents 'alone' at home to deal with this (Hobson-West et al., 2019). Such considerations reflect that studies of societal relations with animal research are themselves forms of engagements which ask individuals to confront the ethical trouble that the issue may generate.

To end, Limoges' (1993) point is pertinent to bear in mind for future work in this area. This is that when dealing with controversy, "the actors are not an audience, nor are they 'students' to be taught', controversies are instead 'learning processes" for all those involved (Limoges, 1993: 422-423). Acknowledging this whilst mindful of the unequal distribution of capacities to affect change in this area means that *how* the question of animal research is raised in dialogical processes is of ethical as well as methodological significance. Thus, in going forward, it is hoped that attention to the diverse positionality of publics and their varying (in)capacities to respond to complex issues might help to promote communications, engagements, and participatory processes which empower actors to contribute in meaningful ways.

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Putting Value on Extracellular Vesicles: Practical Economies of Biomedical Research and Development

Ilpo Helén

University of Eastern Finland, Finland /ilpo.helen@uef.fi

Heta Tarkkala

University of Helsinki, Finland

Abstract

Several studies over the years have paid attention to the entanglement of biomedical research and the multiplicity of expectations for scientific breakthroughs and economic gains. However, science and economy are by no means the only values attributed to the biomedical endeavour in an actual R&D project. In this article, we present an analysis of a case we studied in Finland, in which academic and commercial partners jointly studied minuscule extracellular vesicles (EVs) to develop related technologies and explore their commercialisation potential. Thus, we ask, what is the spectrum of value in biomedical R&D? Our analysis highlights that in the rapidly developing, but still immature, scientific field of EVs, the dominant value of the research project are related to the expansion of future possibilities (e.g., funding and collaborations) and the sustainability of research. The subject of our study is a new domain of biomedicine that is quite unexplored in science and technology studies (STS), and our findings contribute to ongoing discussions on valuation and economies related to biomedical R&D. We focus on the multiplicity of value, and, by doing this, critically discuss the mainstream view emphasising the dominance of commercial value.

Keywords: valuation, biomedical R&D, household economy, extracellular vesicles, bioeconomies

Introduction

In this paper, we present a case study on the assumptions of value and value creation (Birch, 2017a; Muniesa, 2017) underpinning biomedical research collaboration in Finland. In such collaborations, academic and commercial partners jointly studied extracellular vesicles (EVs), developed related technologies, and explored their commercialisation potential. EV is a general term for heterogeneous, tiny vesicles released by cells in their extracellular environments (Raposo and Stoorvogel, 2013: 373; Palviainen et al., 2017: 77; Raposo and Stahl, 2019: 509). Vesicles are usually less than 200 nm (see Figure 1), and they carry molecules such as proteins, nucleic acids, lipids, and carbohydrates, as well as RNA, as cargo (Mateescu et al., 2017: 2; Raposo and Stoorvogel, 2013: 373; Palviainen et al., 2020). For example, sweat, tears, urine, saliva, plasma, breast milk, blood, cerebrospinal fluid, malignant ascites, and amniotic fluid contain EVs. In addition, EVs have been identified as potential biomarkers for diseases (Mateescu et al., 2017: 2; Kalra et al., 2012: 2; Elsharkasy et al., 2020: 2). EVs are known to affect the progression of diseases such as cancer because they are able to transfer information between cells and can target specific cells. This opens up the possibility of using EVs both in vaccines and in the delivery of medical substances (Raposo and Stoorvogel, 2013: 380; Mateescu et al., 2017: 2; Saari et al., 2015: 727; Raposo and Stahl, 2019: 509). Interest in studying EVs has grown in recent years.[1]

Studies on valuation (see below) in biomedicine and associated bioeconomy have focused primarily on business and commercial contexts, such as venture capital investing, commercialisation, innovative R&D companies, IPRs, and the nexus between science and industry (e.g., Birch, 2017b; Lee, 2015; Roy, 2020; Waldby and Mitchell, 2006); innovation and industrial policy settings (e.g., Aarden, 2017; Ong, 2016; Tarkkala et al., 2019; Tupasela et al., 2020); patient groups or other ‘biosocial’ organisations (e.g., Gibbon and Novas, 2008); or infrastructures, such as biobanks (e.g., Beltrame and Hauskeller, 2018; Datta Burton et al., 2021; Timmons and Vezyridis, 2017). Our study on the case of Finnish EV research—a partnership consortium crossing the division between academia and commerce as well as scientific and clinical boundaries—concentrates on valuation within research practices and by hands-on people involved in the project (see Tarkkala and Helén, 2021). We focus on assumptions and expectations about EV value and utility, specifically pinpointing various scientific, clinical, and commercial interests and objectives in R&D work.

We ask *what the spectra of value and valuations are in biomedical R&D*. Studies on topics similar to ours often highlight the commercial aspects of life science or biomedicine, or they emphasise the dominance of economic framing of valuation (e.g., Waldby and Mitchell, 2006; Sunder Rajan, 2012; Martin, 2015; Birch, 2017b). In this paper, we are similarly interested in commercial reasoning and value expectations in the public–private partnership mode we study. We approach this topic through a specific project setting, and we want to find out *whether commercial and economic value creation dominates the objectives of R&D and valuation* (see Muniesa, 2017) *in the Finnish EV consortium*. However, our interest in the role

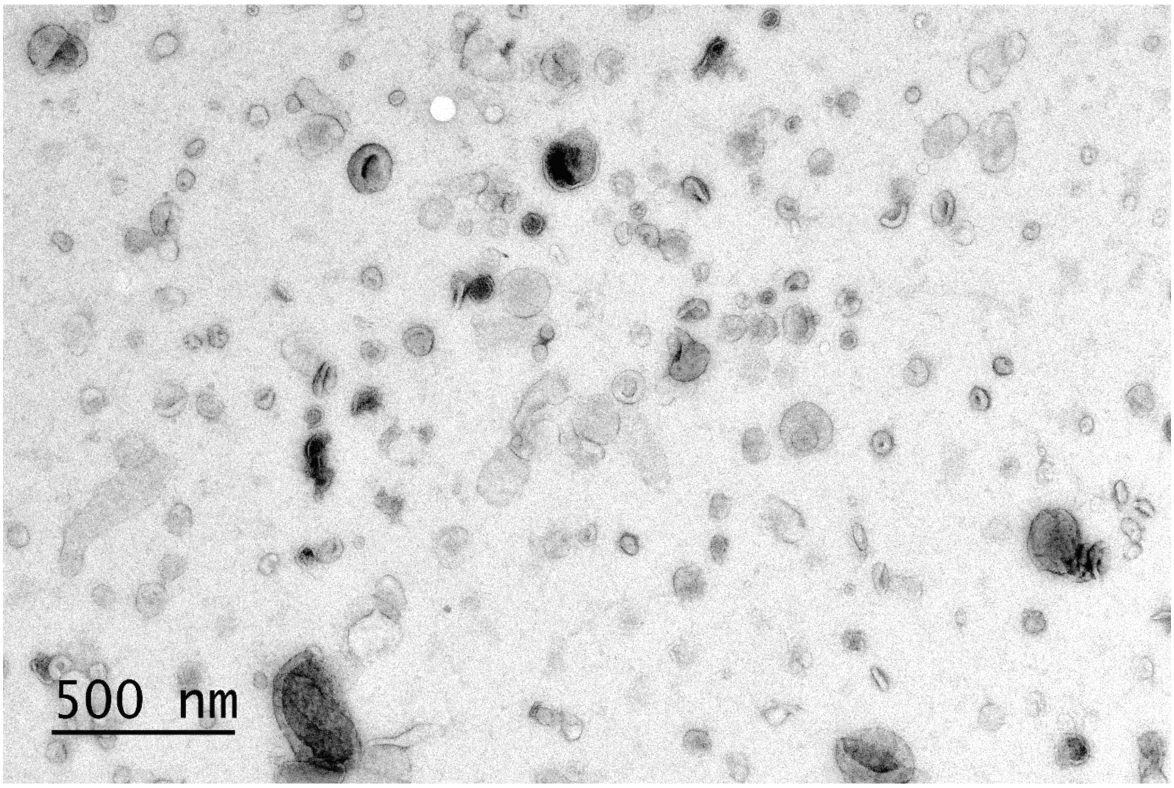

Figure 1. A picture of urine vesicles taken with an electron microscope. Image by Maija Puhka.

and modes of economic valuation is framed in this paper by our primary focus on the presence of value multiplicity among the EV researchers in their practices.

In what follows, we provide the background of our study, namely the context of collaborative science in relation to our case, and the conceptual framing of our analysis. Then, we present our research data and methods, followed by three analytical sections. In the analytical sections, we first present the value of research collaboration as viewed by the consortium partners. Next, we examine the multiple dimensions of prospective value attributed to EVs, as well as their entanglement. Finally, we focus on economic and commercial valuation of EVs and the research in relation to the concerns and efforts on ensuring the continuity of EV research through business activities. In particular, we analyse the scientists' initiatives for commercialisation as a sort of 'household economy' to serve the sustainability of EV science. We conclude our article by discussing our findings in relation to value and valuation.

Background

We based the case presented in this paper on an EV research initiative in Finland in 2014–2018. The initiative brought together experts and institutions from various branches of biology and biomedicine, biobanks, public academic institutions, and private medical companies under a public innovation promotion framework called Strategic Centres for Science, Technology and Innovation (SHOKs). The Finnish innovation-funding agency, Tekes (Business Finland since 2019), administered the SHOKs, and the Finnish government participated in funding them. Above all, the SHOKs were policy instruments to boost flagship projects in innovative technologies and business domains through public–private partnership funding and collaboration. The idea was to encourage joint projects that were driven by the needs of industry and that allowed industry to renew and innovate with the help of precompetitive research done in collaboration with academic partners (Lähteenmäki-Smith et al. 2013).

To conduct their operations, a company was formed for each SHOK. One of them was SalWe, which focused on health and well-being. Founded in 2009, 33 partners (19 companies and 14 research organizations) were involved in SalWe. The EV research consortium worked under SalWe. In 2014, SalWe launched a 30-million euro biomedical programme on personalised medicine (Get It Done [GiD]), of which the EV consortium was part. Their research was identified as a rising field in molecular biology and biomedicine, and the EV research consortium was a possible way to make Finnish EV research more compact and coherent in terms of its organisation and technology.[2] Due to the SHOK framing, it was obvious that public institutions and private businesses were actively involved in the collaboration, because a SHOK imperative required companies to bring in about the half of the research funding. Consequently, the idea was that the research would serve the innovation interests of the company partners.

The EV study was conducted among a rather small group of partner organizations (*n* = 5), which exemplifies the character of SalWe and other SHOKs quite well: The work in them remained rather small scale, it was highly focused, and the projects operated for a limited time with a limited amount of partners within the restricted funding frame. SalWe and other SHOKs appear rather modest in their pursuits when compared to endeavours to build permanent infrastructures for biomedical R&D (e.g., the Finnish biobank co-operative or transnational BBMRI-ERIC) or to undertake grand initiatives to establish innovation, large-scale public–private partnership organizations (e.g., the SweTree company in Swedish forest technology or SINTEF in the Norwegian oil industry). SalWe and other SHOKs did not aim at projects at that scale; instead, they were public funding instruments that hoped to accelerate collaboration and joint initiatives by linking academic researchers and private high-tech companies. Nevertheless, the SHOK SalWe and the EV research consortium within it were endeavours among similar others in Finland. They were born from national efforts that have taken place all over the world during the past decades to promote public–private partnerships in knowledge societies, with the underlying idea that science would serve society better when organised around collaborations (e.g., Powell et al., 1996; Powell et al., 2005;

Etzkowitz, 1998, 2008; Gibbons et al., 1994). Life sciences and biomedicine have had especially pivotal roles in the following innovation pursuits and in the commercialisation efforts for research findings (e.g., Pavone and Goven, 2017; Mittra, 2016; Powell and Owen-Smith, 1998). Simultaneously, innovation policies in many countries have promoted these developments (Miettinen, 2002; Powell and Owen-Smith, 1998). This backdrop also applies to the SalWe and EV research consortium we studied.[3]

Our analysis concentrates on a variety of value and utility—actual, potential, and promissory—attached to the EVs in this consortium. Usually, studies on these kinds of partnership projects in life sciences or biomedicine emphasise the dominance of economic interests (e.g., Sunder Rajan, 2006; Fortun, 2008; Hauskeller and Beltrame, 2016b). Our approach is a bit different. We see the EV consortium as an example of biomedical research in which scientific goals and pursuits of clinical, social, and economic utility are simultaneously present and aligned, and we do not assume economic or commercial predominance beforehand. Our point of departure is the aim presented in the consortium's research plan:

> The major objective of the partners in the program is to create standardised technology platforms for extracellular vesicle studies. The novel tools and platforms can then be applied to the basic research and R&D of extracellular vesicles and the identification of EV-derived biomarkers. In the end of the project, there will be novel tools for monitoring the quality of blood products and novel sensitive biomarker methods for development of cancer diagnostics. In addition to research tools, the utmost objective of the partners is to create an active and intense national public–private network around the extracellular vesicles that will have link to international public–private researchers. (SalWe, 2013: 101)

Other formulations of the entanglement of scientific, medical, organisational, and commercial objectives were found in the research plan as well. For example, the consortium set its task "to build up an internationally competitive research network" and to "ensure high quality research and innovations in monitoring health and disease" (SalWe, 2013; 99). Due to such a multitasking effort, EVs were in many ways seen as interesting and important life science and biomedical items. For example, EVs have the potential to generate discoveries in the life sciences, new tools for biomedical R&D, and new biotech products for clinical use and for sale, and they are considered the locus for building a research infrastructure (Tarkkala and Helén, 2021).

Many studies (e.g., Cooper, 2008; Cambrosio et al., 2009a; Sunder Rajan, 2012; Ong, 2016; Hauskeller and Beltrame, 2016a, 2016b; Aarden, 2017; Sun, 2017; Beltrame and Hauskeller, 2018) have identified and addressed this amalgamation of scientific, clinical, and commercial interests in current life science and biomedical collaborations. They have also shown that the partners in such collaborations depend on each other in terms of technical devices, finances, and epistemic authority. Such *hybridisation* characterises the organisation of research as well as its objectives, the research practices (Hauskeller and Beltrame, 2016a, 2016b; Beltrame and Hauskeller, 2018), and the research objects (see Cambrosio et al., 2009a; Tarkkala and Helén, 2021). Hybridity not only refers to the interlacing of academic and commercial pursuits (e.g., Cooper, 2008; Sunder Rajan, 2012; Ong, 2016; Aarden, 2017; Sun, 2017; Hauskeller and Beltrame, 2016a) but also implies a blurring of the conventional distinction between basic and applied science and the borders between clinics and labs or research and care (Cambrosio et al., 2009b; Cambrosio et al., 2018; Tarkkala, 2019). In this paper, we approach this practice by analysing the multiplicity of value in collaborative life sciences R&D.[4]

Our premise is that an object, a method, or even an infrastructure is currently attached by multiple value or, rather, potential value, in the life sciences (e.g., Dussauge et al., 2015a; Datta Burton et al., 2021). For example, a gene variation associated with a disease susceptibility, a method to cultivate stem cells, or consolidation of a biobank network may facilitate efforts for scientific discovery and the production of new knowledge in medical sciences, and thus have *epistemic* value. This, in turn, may increase the prestige of a research team or institution, bring in more research funding and other resources, and thus add *academic* value to the enacted item. New biomedical knowledge is expected to have the potential for translation into more precise diagnostics or new treatments that would be of *utility to healthcare*, either clinical or preventive. Many *social* values may be attached to a life science item's healthcare value. For example, for patient or disease advocacy groups that pursue new knowledge and treatments of a specific disease or for organisations (e.g., biobanks) that facilitate such pursuits, a biomedical novelty may be valuable in regards to their hopes for a cure or to relieve suffering (e.g., Beltrame and Hauskeller, 2018; Mayrhofer, 2008; Novas, 2006; 2008). For governments and health administrators, such novelty and the R&D that goes into it have potential value in terms of public health and reduced healthcare expenditures (e.g., Datta Burton et al., 2021; Mittra, 2016). Obviously, a life science item—a molecule under R&D, a new method or technical device, or an infrastructure—may have several dimensions of *economic* value creation (Helén, 2016: 266-267). New knowledge can be further developed into a product or service that can be marketed in the healthcare business and bring profit to a company. Alternatively, a novelty can acquire a patent, and the patent owner may receive income in the form of a lease. Furthermore, an innovative R&D company focussing on a promising item or technology can be an investment target because it can yield profit for investors, either in dividends or—more frequently—in capital gains when selling company shares. In the following, we show that the multiplicity described above is also characteristic of the assumptions of EV value and value creation.[5]

Following Birch (2017a) and Muniesa (2017), we approach this multiplicity from the premise that any value of the EV as an object of life science is not intrinsic to it (Dussauge et al., 2015a), and it is not only the research-related labour that creates or adds its value. Instead, multiple forms of value and utility from the EVs and the R&D work on them are created, added, made, maintained, and modified by discourses and practices of valuation. The latter concept refers to an idea that the value of things is processual; it is engendered by situated practices and discourses that attribute certain kind and amount of value to a thing or action or that order things according to their value. Enacting things usually implies their valuation in many regimes of worth simultaneously, and thus, the value of something is determined in practice (Helgesson and Muniesa, 2013; Dussauge et al., 2015b; Kornberger, 2017). From this perspective, when EVs are enacted—in everyday research practice and contexts in which research is advocated, assessed, reflected, or otherwise performed—they are attributed with value.

Because a life science item's value, such as that of EVs, is an outcome of enactment (i.e., social and political practices), the value can be malleable; that is, a variety of forms of value can intermingle, and many desirable outcomes can be present simultaneously (Dussauge et al., 2015a; Datta Burton et al., 2021). Moreover, all value types in the context of biomedicine, or technoscience in general, tend to be inexact and 'unaccountable' (Birch, 2017a: 433–434) in two senses. First, value is hard to define by calculation or accounting, and second, there is no guarantee that value or acclaimed benefit exists—or will exist—at all. Such vagueness also applies to variations of economic value and value creation (see Birch, 2017a; Muniesa, 2017; Datta Burton et al., 2021). This feature is closely related to the fact that such forms of value are mostly imaginary or 'fictitious' because they refer to and are framed by future possibilities, probabilities, and visions (see Beckert, 2016), especially in economies of technological innovation (Beckert, 2016: 169–187; Mazzucato, 2018: 189–201), including the medical bioeconomy (Birch and Tyfield, 2013; Dussauge et al., 2015a; Mittra and Zoukas, 2020). This means the value of life science items lies mostly in their potential for scientific discovery and academic fame, clinical novelties, or economic gains. In other words, any value attributed to an item, such as EVs, is prospective and promissory, almost without exception.

In the domains of biomedicine and bioeconomy, expectations play a key role in valuation—in *parlance* and practices that create, maintain, and perform value, utility, and benefits (e.g., Brown, 2003; Fortun, 2008; Tarkkala et al., 2019; Mittra and Zoukas, 2020; Ong, 2016; Sunder Rajan, 2006). Unsurprisingly, expectations and prospects are also decisive in valuing EVs; a 'machine to make a future' (Jacob, 1982; Rheinberger, 1997; Rabinow and Dan-Cohen, 2005) was launched to build around these miniscule biological entities. Obviously, 'future' here refers to the scientific exploration of the 'unknown' in the life science laboratories (Rheinberger, 1997) and the expected or promised applications of the new knowledge (Brown, 2003). In addition, it signifies the efforts to build continuity for the research groups and their work (Miettinen, 1998; Tarkkala and Helén, 2021).

The STS literature on valuation and expectations' role in advanced technoscience discussed above provides us a perspective from which to approach the Finnish EV research consortium. We study valuation of EVs and EV research as discourses and practices used by people working within this particular biomedical R&D setting. Since the consortium was a hybrid in a manner discussed above, we pay specific attention to the multiplicity and malleability of value attached to EVs and EV research in this context. We also examine the ways various value dimensions interlace. In other words, we are interested in *the variation of value and valuations that appear in life science and biomedical R&D* and *the ways in which various dimensions of valuation are entangled with each other*. Furthermore, our analysis highlights that EV research is a new and evolving area of life sciences and biomedicine, and therefore the valuations tend to emphasise the prospective value and future utility of the EVs and EV research. Therefore, the manifold *value potential* of EVs is at stake in their valuation and value creation.

Our paper also focuses on the aspect of economic and commercial valuation in the context of the Finnish EV consortium. The reasons for this emphasis are obvious. First, the consortium was a public–private partnership project that brought together academic and commercial stakeholders and their respective interest and objectives. Second, studies on topics similar to ours often highlight the commercial aspects of life science or biomedicine (e.g., Pisano, 2006; Martin, 2015), and they provide plenty of evidence that vanguard biomedicine and life sciences are profoundly conditioned by and entangled with 'bioeconomy' (Cooper, 2008; Birch and Tyfield, 2013; Mittra, 2016; Sunder Rajan, 2006) or 'technoscientific capitalism' (Muniesa and Birch, 2020). In this paper, we approach the interlacing of science and economy, or science and business, in biomedicine and life sciences by analysing the role and weight of commercial reasoning and value expectations in our case (i.e., the Finnish EV consortium). In addition, we also analyse the mode that the pursuit of economic gain and commercialization took in the consortium. We take Muniesa's (2017) claim that economic reasoning and vernacular of value creation provide the dominant framing for the objectives of R&D and valuation in technoscience as our lead, and we juxtapose the findings of our case with his view (which is shared by others; e.g., Waldby and Mitchell, 2006; Sunder Rajan, 2012; Martin, 2015; Birch, 2017b) that economic or commercial valuation dominates the landscape of biomedicine and life sciences.

Data and methods

We based this article on data collected in the context of an R&D project on EVs in Finland that was part of SHOK SalWe's GiD programme on personalised medicine in 2014–2018 (see above). For this article, we used three types of data collected between 2015 and 2017. First, one of the authors conducted 11 interviews with 10 informants who were either research partners (n = 4), company partners (n = 4), or representatives of management with expertise in SalWe and SHOK programmes (n = 2). In the text, we refer to the informants by indicating only their roles because of the low number of participants. Second, we utilised field notes based on observations in two public conferences with EVs in the programme as well as field notes on seven project meetings, in which the EV research consortium and its findings, developments, and current state were discussed. Third, we utilised scientific articles on EVs to contextualise EVs in the biomedical research field.

We analysed our data by applying systematic content analysis, with the support of the case study approach and STS ethnography (see the Methodology section in Tarkkala and Helén, 2021). The latter approaches helped us to contextualise the interview and textual data and to triangulate the results and conclusions of our analysis. A comparison of interviews, field notes, and published research papers allowed us to situate our findings analytically. The goal was to keep our content analysis inductive, so that the thematic emphases and the patterns of reasoning in research materials would first become eminent to us. Yet, even when our priority was to start from the data, we conducted our analysis in dialogue with literature discussing the (bio)economies of the life sciences and biomedicine, especially regarding value creation and the character of public–private partnerships in these domains. Given this approach, we first organised the research interviews with the help of the Atlas.ti program. Then, we systematically read the interviews and other material, focusing on the participants' discussions about the importance, benefits, and utility of EVs and the research on EVs in the context of the consortium's work and objectives. With this reading, three recurrent valuation themes or, rather, configurations came to the fore: interlacing of a variety of value dimensions around the scientifically promising EVs, the prime value of collaboration enabled by the consortium, and the foremost significance the EV Core facility service as a major outcome of the consortium. In our second systematic reading of the data, we took a closer look at the participants' reasoning about these configurations, with special attention paid to their comments about value, the potential of the EVs, EV research, and the work of the consortium. With this reading, we were able to obtain a glimpse of the way a variety of value dimesions are entangled with each other in valuation of the EVs, juxtaposing the 'basic science' efforts and technical expertise of the consortium with prospects of medical utility and commercial value creation.

Valuing EVs

In this section, we analyse the EV valuation within the research practices of the Finnish EV consortium. In our previous study of the consortium (Tarkkala and Helén, 2021), we showed that in the public–private partnership milieu for life science R&D, the EVs are enacted as an object upon which continuity and sustainability of an emerging life science domain can be built. The same concern over ensuring continuation of scientific research is also prominent when it comes to valuation of the EVs. In our analysis, we focus on concrete items or activities such as collaboration, expertise based on specific craft in laboratory techniques and work, and availability and quality of tissue material and data that the consortium partners considered essential to EV research enduring in a competitive scientific and business environment. These same aspects form the bedrock for value potential of the EVs, which we present in the following sections.

Collaboration as an asset

Exploring EVs requires many types of scientific and technical expertise. The consortium partners reasoned that the most pronounced value, or utility, of the EVs was their power to gather experts together across institutional and disciplinary boundaries, which is congruent with the observations that transdisciplinarity is characteristic as mingling of science and business in most areas of new technologies (e.g., Svalastog, 2014). In both public academic labs and private companies, researchers emphasised that the expansion of opportunities for collaboration is this endeavour's most important asset and is the most likely to add value to their work:

> Well, it is a win–win. Synergy. Like, when people have different viewpoints, different angles and different needs (…) then we just get more done. There are more people with a joint interest in doing things and, on the other hand, knowledge and other resources. So, we are stronger than we would be as a single group, or what is worse, as competing groups that just fiddle around with their own thing and jealously look around at what others are doing. (Research partner)

> This is purely about networking. We are a company partner and yet it is very important for us that we have contacts with basic research, and this is a very good way to create a wider network we would otherwise not necessarily come into contact with. (Commercial partner)

A number of aspects should be noted in consortium partners' reasoning that collaboration is beneficial for both their efforts and the entire EV research field. First, they saw that the scope and volume of research activity and expertise on EVs extend because of the collaboration. The joint R&D programme made larger and more diverse pools of samples available, which all partners considered to help them to obtain more sophisticated and reliable results. Extension of sample availability was particularly important for commercial partners. Collaboration with academic groups provided them a steady supply of research material. Moreover, collaboration brought complementary scientific expertise and technical expertise to each participating academic and commercial group, which reinforced their work in their individual subspecialties and allowed them to work widely in the EV research domain. A commercial partner reasoned:

> As a small company, we can't do everything by ourselves, and (…) we are not particularly eager to establish a big scientific set-up of our own (….) Therefore, we try to get this collaboration to work as well as possible, so that the academic partners would do things that would also benefit us—and the whole consortium, of course. (Commercial partner)

Consortium partners not only talked about the extension and increase of their personal expertise but also emphasised that collaboration reinforced and widened the scientific and technical expertise of the entire Finnish EV field, which was beneficial because it increased Finland's significance in the international EV domain.

> All of us [Finnish EV researchers] started by developing studies and methods on our own. Now, when we know what we have in common and are all together, we have noticed that the situation is quite good, in fact, and we are quite competitive internationally in our research. During the ICEV meeting, we noticed how efficient we are together (…). As compared to what others do, we can look at and examine vesicles in so many ways, and due to that, our results are stronger. Others rely mostly on one or two techniques they happen to have in their own labs, yet some element is usually missing; but we have them all. (Research partner)

This is closely related to another aspect of utility in collaboration that the participants emphasised. Academic and commercial partners repeatedly said the joint programme added value to their work by opening up a wider range of opportunities for scientific, R&D, and commercial collaboration. Many interviewees highlighted alliances between unexpected parties that would not have otherwise formed. The consortium's core alliance intermingled two research laboratories from biomedicine and biosciences, which had separate technical specialties. In addition, the meeting of 'basic' science and companies with commercial pursuits was considered 'unique' and beneficial:

> SalWe makes possible joint research that was otherwise quite unlikely to take place in the academic world. Without Tekes funding or the like, we hardly were in collaboration with these [names removed] or other companies. The university is poor, and the companies are interested in scientific results, so there is always an overlap that will make both parties interested (.…) I suppose that this joint research [on EVs] enables development of some sort; yet, we are very much involved in basic research in this SalWe project, this is not yet very applied research or oriented to develop products. (Research partner)

The increase of collaborative relations and activities contributed to the integration and coordination of the Finnish EV research and development. This was seen as beneficial because the weight of their expertise started to increase internationally, which in turn opened the partners to more 'interfaces' for collaboration abroad. The management of the SHOK programme highlighted the same:

> I have realised the value of collaboration; it's just the same if you seek export collaboration. Anyway, it is better to do things together with another company or companies than alone. In all activities, collaboration is unbelievably valuable because together, you deliver so much more than by yourself. This is what I learned in SalWe. (Programme representative)

The participants also talked about collaboration utility in terms of economy. The academic and commercial partners predominantly framed the work done in the EV consortium as 'basic research' or 'basic science', with an emphasis on development work in terms of, for example, standardisation and technology (Tarkkala and Helén, 2021). Commercial partners were quite content with this orientation, and they readily acknowledged that they should not expect results that could be commercialised immediately. Rather, they reasoned that participation in the joint programme was a long-term investment. Thus, the consortium was, in practice, impregnated by an ethos of 'basic research' (Tarkkala and Helén, 2021). This could be said to define the baseline for all EV valuation because all of the participants acknowledged the need for technological and scientific stabilisation before any of the EVs' potential commercial utilities could be actualised. The research plan already underlines that there will be no "solid and reliable diagnostic and clinical applications" without first developing "the basis of the EV technology and characteristics" (SalWe, 2013: 99).

In this context, commercial partners quite often reasoned that, for their R&D with commercial objectives, a significant form of value from hybrid collaboration was nevertheless *scientific*. The 'basic' science of academic partners could provide firm facts and valid methods and techniques, as a solid backbone and guidance for their own more practical work to develop marketable products and applications (see also Lee, 2015). A discussion between two commercial partners exemplifies this:

> Partner A: By approaching this from a basic research perspective, we cannot go wrong. … In any case, we have displayed unequivocally that the vesicles are there—for instance, in the preparations—and they increase. They have significance.
> Partner B: This is not just in our heads!
> Partner A: But whether it makes any difference and whether it brings any utility in an applied or medical sense—that, we do not know. But one of our goals is to find out what happens there—basic research.

One of the collaboration benefits for academic partners was related to research financing. The alliances with other academic groups and commercial partners resulted in further joint funding applications. Notably, the EV consortium's academic partners saw benefits from the funding provided by the GiD programme. The funding invested by the company partners allowed the academics to conduct investigations and experiments focussing on the EVs' basic biology and on developing basic research techniques and methods. Many of our interviewees lamented that this sort of work was unlikely to attract 'more scientific' public research funding (see Tarkkala and Helén. 2021). This tendency was especially underlined by researchers for the 'storage study' work package, which focused on the EVs' quality and functionality, such as in red blood cells and platelets from urine during and after storage. The task was rather practical: to search for "advanced indicators of the functionality of blood products and their condition" (SalWe, 2013: 100). Yet, the participants were unanimous in saying that, in practice, their work in the storage study was about "trying to find out and clarify what really happens in the bag [of blood product] from the perspective of the vesicle; quite basically, that's what this has been all about" (Commercial partner). They also shared a view that life science research proposals must show novelty. A researcher noted that their research plan, which continued this line of research, was rejected because of the seeming lack of novelty, even though there was still much to study, so the lack of novelty "was a true misconception" (Research partner).

The collaboration with a commercial partner provided the academic partners with necessary resources for the storage study. In particular, partnership funding within the GiD programme allowed them more time to perform follow-up analyses and to keep more people involved in the project than usually possible (Tarkkala and Helén, 2021).

The above reasoning that hybrid collaboration brought vital benefits regarding what the research funding would allow was closely related to the value of collaboration in reinforcing the institutional and financial sustainability of EV research and its technical infrastructure in Finland. The academic and commercial partners shared the value of continuity and concern over future possibilities to proceed with ongoing (and unfinished) work. This became particularly evident in the context of the work package focusing on antibody and biomarker research (see below). In 2016, the researchers told us that government funding for the GiD programme was reduced and that its duration was cut by a year. Due to this, the

EV consortium and this particular study needed to focus more narrowly, and some research lines had to be dropped (Tarkkala and Helén, 2021). In such a setback situation, the researchers involved hoped that the academic partners could somehow carry on with the topics they considered scientifically interesting, while the researchers simultaneously admitted that, outside of the GiD work package, there might not be any funds with which to continue. The academic partners saw that the programme cuts may lead to a situation in which no funds for salaries would be available. This would affect the EV research considerably because the specific craft expertise (on the importance of craftsmanship in the life sciences, see Meskus, 2018) could disappear as people move to other organisations and labs. In addition, the situation was dire for the commercial partners, making their prospects of continuing the work on EVs uncertain. They were dependent on their academic partners, as, for example, the supply of EV material was difficult to obtain without a collaborative tie to the university group. The vital value of collaboration as facilitating continuity in research, expertise, and technical infrastructure was especially highlighted when our interviewees discussed the EV Core facility's establishment at the University of Helsinki as the consortium's most remarkable achievement. We discuss the EV Core in detail later.

Multiple intermingled values

When consortium participants talked about the value or utility of EVs and EV research for biomedicine, they repeatedly attached multiple dimensions of value to their research object. This is unsurprising because the intermingling of scientific, clinical, social, and ethical valuations with the potential for commercial profit or other economic gain seems to be a common feature of hybrid partnership projects in current life sciences (e.g., Beltrame and Hauskeller, 2018; Brown, 2003; Datta Burton et al., 2021; Prainsack, 2017: 107-135; Sharon, 2018). The commercial goals attached to scientific research tend to direct it to more applied and utility-oriented objectives (e.g., Etzkowitz, 2004; 2008; Glenna et al., 2011). This tendency was apparent in the EV consortium's research proposal (SalWe 2013), but as we have shown (Tarkkala and Helén., 2021), our interviewees framed the project as essentially and predominantly 'basic research':

> At the same time as we produce utility or try to search for something the companies could utilise, we have to set up certain things so that we understand, methodologically, what we have. We cannot just take something and say that this is how it is; we have to know it exactly. And as these methods are very much in their early stages, at the same time, we have been interested in EVs in general, what they are and what they do, and why. All this knowledge has been valuable to us. (Research partner)

The above quotation addresses multiple aspects of EVs' value and utility simultaneously and intertwined. Almost without exception, the EV researchers saw their work with EVs being of great utility for molecular and cell biology and biomedical science. Then, this scientific value is immediately attached to EVs' possible clinical utility and commercial potential. Their reasoning was not parallel valuation; scientific, clinical, commercial, and social value existed side by side and were represented by partners with different interests. Rather, valuation appeared as a hybrid performative act, in which scientific, clinical, and commercial dimensions of value and utility were simultaneously addressed and inseparable, regardless of a partner's interests and objectives.

Such a hybrid valuation was particularly clear in the work packages related to identifying the biomarkers of prostate cancer and to developing an antibody as a candidate product for a commercial partner. The EVs' expected scientific, clinical, and commercial utility was sought simultaneously in joint research efforts, but the same potential results concerning antibodies and what they identify were valuable for the different partners in different ways. For example, cancer researchers hoped to discover if EVs could be a source of biomarkers for prostate cancer; they also were interested in discovering whether urine was a better source of biomarkers for early stages of cancer and whether plasma was a better source for later stages, as well as whether EVs can help to differentiate slow-growing from aggressively growing cancers (SalWe, 2013: 101). In the eyes of a commercial partner, success in this line of research would open up a variety of diagnostic possibilities:

> There's plenty of hope that there exists something new [in EVs] that would help, for example in the diagnostics of certain diseases—that we'd find a biomarker like prostate-specific antigen (psa), for instance. Vesicles are hoped to be a quite wide source of biomarkers, not only for prostate cancer. Would it become possible for us to see that a group of patients have this sort of EVs, and this sort of content in EVs, and then think about if we could start to treat this group and how? And then, after the treatment, would we see that the [bio]marker has vanished and the cancer has been cured? (Commercial partner)

Finding specific markers for specific cancer types or specific diseases was not the only interest of the commercial partner that developed and sold antibodies. For the company, a well-known and functioning antibody could allow further development of a potential new product, regardless of whether it was specifically related to prostate cancer or not (Fieldnotes, 2016). For the academic partners, precise identification of an antibody and what it recognises could be a good result that would help to advance EV analysis techniques. An antibody, once standardised, could become part of scientific exploration in a technical sense—that is, as part of the basic research equipment (Tarkkala and Helén, 2021).

Despite these differences, researchers from different branches considered the research effort holistically and saw the different dimensions of potential value as entwined.

> There are two views ahead: if we could find an antibody that would function as a proper marker to discriminate vesicle populations from each other, or identify them, or something, then we could hopefully develop it further in the future. Moreover, if a product with diagnostic or clinical significance could be developed from such an antibody, well, and a company [name removed] could benefit with a good [commercial item], for example, that would be awesome. (Research partner)

> The study on biomarkers of prostate cancer is proceeding well, it looks promising, and the antibody study is also well in progress; hopefully, it will deliver something and also some business (…). We have used the samples from the Helsinki Urological Biobank [in the antibody study]. They are prostate (cancer) antibodies. Hopefully, and then—if they really are prostate cancer antibodies, or even vesicle antibodies—we could use them in some kind of technology application (…). If they were specific to prostate cancer, they could be used in diagnosis, or they would allow for detecting the pathological condition better. Or, if they were just general vesicle antibodies, they could be used in some assay kit, as part of a purification method. So, it remains to be seen what they really are; investigation is ongoing (…). For sure, this will be a good result, and I reckon that these antibodies will be good for [a company; name removed] also, because it may develop business based upon them and sell them. This is how it should be, and this is the purpose of SalWe, in fact. (Research partner)

As we see, for the partners of the Finnish EV consortium, the value of the EVs—in any sense—is not exact nor calculable, and their utility is not precisely focused. The EV valuation comes with expectations and promises. Their potential for biomedical discoveries, clinical use, or making profitable medical products is what is valuable. Within biomedical R&D, the EVs' prospective value takes on various modalities. The EVs are considered an 'epistemic thing' (Rheinberger, 1997) with the potential for scientific novelty (Tarkkala and Helén, 2021). As potential biomarkers, they carry promises of clinical and commercial utilisation; as a stimulus for developing research techniques and methods, they facilitate sustainability of Finland's entire EV domain. That the EVs are seen as valuable predominantly through their potential and expectations reflects an overall orientation in biomedical R&D towards choreographed future making (see Rheinberger, 1997; Rabinow and Dan-Cohen, 2005). Therefore, all sorts of forms of value attributed to the EVs are indefinite and imaginary. Yet, this same vagueness allows for the hybrid valuation of biomedical objects and their research (i.e., addressing the EVs' expected scientific, clinical, social, and commercial utility as simultaneous and intertwined). The Finnish consortium partners acknowledged their work as, more or less, just taking first steps in the new domain, which is why they largely emphasised scientific value and utility as primary.

Despite the emphasis on 'basic research', there was also rhetoric on future uses and benefits, which brought diagnostic and clinical utilisation into the research focus. Scientific work was believed to meet simultaneous expectations of 'translation', even when the EV research was in an early phase. A researcher working in the storage study commented,

> When thinking about applying for funding and so on, the applications must be very future-oriented, and so when the grant applications are written, the potential usability of the results [in the future] must be very thoroughly thought through. One always tries to consider the potential usability of the results, but especially when it comes to the specificity of this field, in which even the very basics are still part of the search, the preservation of samples is extremely important to know and explore. (Research partner)

All of the academic partners also agreed that the commercial partners' involvement influenced how the project was targeted and the work was carried out. The project's hybridisation reached the research object and everyday practices (Tarkkala and Helén, 2021), as well as valuation, which induced continuous efforts to balance the requirements of "industry-orientation" with that of producing "basic understanding and knowledge" (Miettinen, 1998: 436). Despite the strong ethos of and commitment to R&D collaboration, the balancing efforts implied potential frictions between the partners' interests and valuations. They also implied questions about how different types of potential value would be actualised, which parties will benefit from the collaborative work, and by how much. For the commercial partners, it was obvious that the joint effort should result in something that would produce revenue and profit only for them, at least in theory. Therefore, they needed to weigh the benefits of 'selfish' pursuits to extract EVs' value potential through patenting or commodification against sharing their results and technology with other consortium partners to add value potential. A commercial partner reasoned over the dilemma:

> This is related to the demarcation: what we bring to this project, what we keep to ourselves, and what is protected by our own patents. (…) But [my company] also must spot a sort of parallel supportive area that can be shared in the joint effort, which will help me to develop the business. (…) Of course, the companies realised they are involved in discovery activities in the joint consortium, and therefore, publishing [the findings] is business. If you have a scientific publication to back up your business efforts, that is the most convincing kind of business. If we consider developing our healthcare system, innovations in healthcare, or treatment of diseases, we need science as the groundwork to show that the novelties really are something. When we, a few years ago, worked on long-reaching developments in emerging research areas in [previous company], we faced the same question: should we just keep quiet and just patent quickly, or should we tell the world about the new findings as quickly as possible? It is the latter that one should do: one should make the boost stronger, so that the world will start to look at Finland. (Commercial partner)

The EV field's future orientation and relative immaturity helped to prevent potential tensions from escalating. Because the route to commercialisation was not evidently quick and straightforward, it would have been premature to agree on the matters related to that step. Moreover, the SHOK framework had its own set of rules for commercialising and patenting, meaning that each stakeholder would be provided a possibility to benefit from the potential findings. Thus, these sorts of issues could be suspended during the actual working period. In parallel, the focus on the technicality considerably helped to maintain unity and the solid conduct of the consortium's work, despite their multiple interests and valuations. The work aligned scientific pursuits, efforts to develop items or methods with clinical or commercial use, and activities to organise a facility for providing biomedical research services. They emphasised that the work on EVs was primarily about technology and methods. Consequently, value expectations and prospect actualisation were subordinate to the technical dimension—or technical valuation—of EV research. Technicality provided a common ground for all of the consortium partners' diverse pursuits and valuations. As a dialogue between commercial partners summarised,

> A: The configuration has been good in this [work] package because we all have clear interests of our own, but we do not have worry about this situation at all. We can share the whole technology topic and many things.
>
> B: And the results we will achieve.
>
> A: Yes, because we know that we all have our own domains, but there is also an intersection zone.

Core as a service—a business model

For many, the collaboration's most notable result was the EV Core facility's founding. The Core, operating at the University of Helsinki since 2016, is presented on its webpage as an analytical technology platform (see Figure 2), providing "infrastructure, state-of-the-art and emerging EV-technologies for research groups, hospitals, companies and authorities in the EV-field". In addition, the Core offers "diverse EV isolation, purification and characterization services and (…) contacts to various downstream analyses in other core facilities based on optimized EV-protocols" (https://www.helsinki.fi/en/researchgroups/extracellular-vesicles/ev-core, 12 Dec 2020)**.**

Undoubtedly, the current life sciences are technosciences. Yet, the craft of experimental laboratory work—specific tacit capabilities for handling tissue samples, other biomaterials, new devices, and techniques and for managing unexpected occurrences at the bench—is still elementary for conducting experimental science and achieving novel results (Meskus, 2018). When the EV Core was planned and founded, this life science craftsmanship became highlighted. At the centre of the EV Core's formation was special equipment, such as Apogee A50 flow cytometry and an electron microscope, as well as the expertise to use these devices.

Many consortium participants thought that their joint efforts gave Finnish researchers a precious asset because the efforts enabled them to develop advanced craft expertise in EV analysis. The Core's key persons saw that this craft expertise could be commercialised as a 'service' to academic and private 'customers' for a reasonable price. Such reasoning emphasised the EVs' commercial value in an entirely new way. The commercial aspect no longer means that academic partners collaborate with private companies or that companies are expected to develop marketable products. Now, 'basic' EV research and, especially, technical expertise on methods and equipment of EV analysis—their specific craft—were seen to have commercial value potential as a service. A key academic partner at the Core expressed this new view by saying that the facility service's founding meant that "one could do small business and,

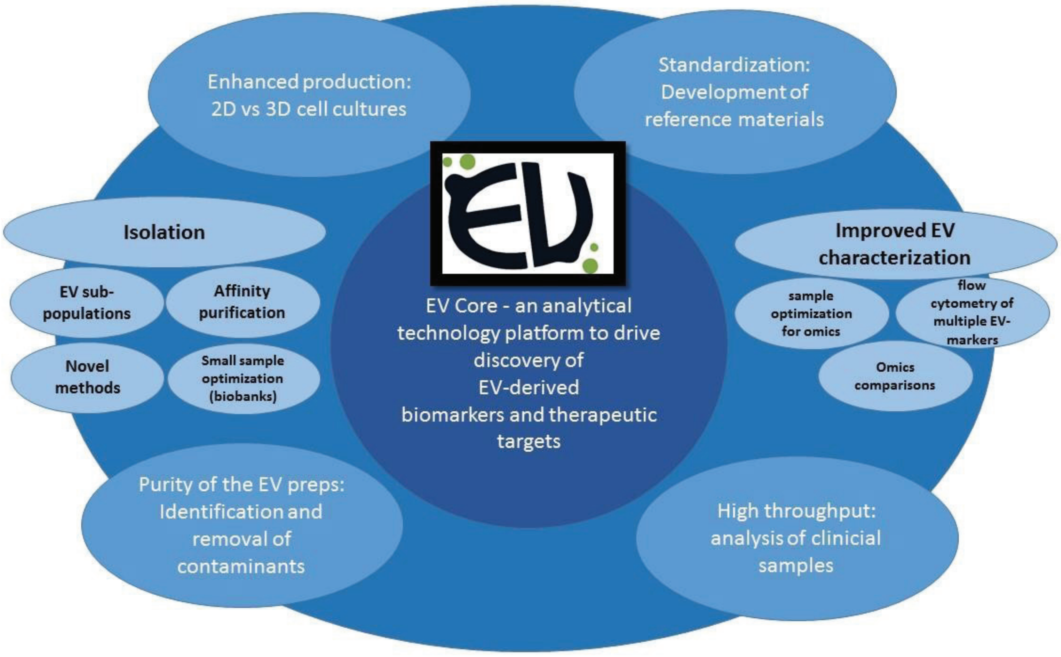

Figure 2. Core facility, as presented on their homepage in 2018 (7 September) (https://www.helsinki.fi/en/researchgroups/extracellular-637 vesicles/ev-core)

perhaps, guarantee oneself a more stable income", instead of trying to collaborate with everyone. Notably, the planned commercial collaboration at the EV Core was not comparable to the collaborations related to biomedical infrastructures like biobanks (Tupasela et al., 2015; Helén and Lehtimäki, 2020) or with biobank research consortia like the Finnish FinnGen (Tupasela, 2021: 113-124). The Core was seen primarily as a continuation of the work done in the EV consortium and other projects, and the scales of the business and its profitability were very modest.

The business aspect and commercial prospects were highlighted at the time of the EV Core's launch, when it was presented as a potential "export platform" at Tekes's innovation meeting and was pitched at the major technology start-up event SLUSH. In this context, EV research was redefined in entrepreneurial terms as innovation in business and commercialisation. It was also influenced by familiar models and 'choreographies' (see Mason et al., 2019) of the innovation economy involving direct transformation of academic discoveries into a marketable product or a start-up company. This line of action and the increased weight of commercial value expectations became more eminent with the R&D project FastEV, which the key persons of the EV Core initiated later. The FastEV was promoted as "a novel, simple, fast, scalable and cost-effective method for EV isolation [that] produces a pure EV preparation with versatile applicability in both biomarker studies and therapy" (SPARK pitch, 2018). With Business Finland's funding, the project was aimed at improving "the commercial maturity of FastEV by identifying the most promising customer segments, applications and commercialization strategies" (SPARK pitch, 2018) and sought "collaborators and partners (…) for proof-of-concept testing of the FastEV isolation and downstream analysis" (Biospace, 2019). In 2018–2019, FastEV was actively pitched at large start-up events in Finland and the rest of Europe. In these forums, the Finnish team promised to "offer our early stage partners a great position to benefit from a ground-breaking technology. For them, FastEV provides means to get ahead in the EV race" (Biospace, 2019).

With the founding of the EV Core, the value potential of EVs and EV research gained more prominence in biomedical business. However, this shift did not mean that commercial valuation would have subsumed other value aspects of the EVs. The 'business model' of the Core facility was based on an idea that Core did not have to make profit per se (Palviainen et al., 2017: 78), as long as it could "sustain itself" (Research partner). Thus, service provision as a business was explicitly seen as instrumental because possible revenues and profits were sought only to maintain the biomedical research infrastructure, which would allow advances to be pursued in basic and clinical EV research. Similar reasoning can be found from numerous academic and public life science infrastructure projects seeking 'commercialisation', with biobanks being the clearest example (Beltrame and Hauskeller, 2016a; 2016b; Timmons and Vezyridis, 2017; Lehtimäki et al., 2019).

Thus, EV researchers considered commercialising EV-related techniques and craft expertise via the EV Core as instrumental. This reflects the fact that the consortium partners' valuation focus was on the continuity of EV science and R&D For them, the most important value and utility of the EV Core were the prospect that it would provide a more stable ground for sustaining and developing EV research in Finland, as well as continued awareness of the latest developments (see Tarkkala and Helén, 2021). The founding of the Core service can be seen as a parallel action of doing research and ensuring the continuation of research (see Miettinen, 1998). Doing 'small business' by providing services involving expertise and specialised craft is considered an activity that should serve the continual pursuit of basic science. Therefore, it is merely one dimension of a general effort to make EV research more sustainable in Finland.

Although models and ideas of start-up and academic entrepreneurship became more eminent in the Finnish EV research domain with the EV Core's founding, people involved in the Core and EV research saw such commercialisation as an element of the 'household economy' of academic biomedical research. By 'household economy', we refer to a situation familiar to most academic research groups and laboratories in the life sciences, in which they constantly apply for and try to acquire funding (often short-term) from multiple sources to cover the expenses of equipment, facilities, and personnel costs, while permanently rearranging their activities and budgeting to ensure research continuity. In interviews, academic research partners repeatedly commented about the precarious condition of the vanguard life science, in which concern over continued funding and a sort of involuntary parsimony were permanent features of the work. One research partner described how an academic group responded to this economic challenge:

> We sail at sea with our tiny EV vessel (…) Well, I had the SalWe money and a grant from the Academy [of Finland], and neither of them would have been enough alone, but together, this funding has supported my work so that, in terms of scientific research, this has been the most rewarding period of my life. (…) I've had an opportunity to become involved in plenty of activities, and it has been utterly awesome; for this reason, it would be heart breaking if all this collapsed. I am very satisfied. The Core wouldn't have come true if I hadn't hired an extra postdoc to build it. (…) I've been gambling, putting all my chips in the middle of the table, and I don't regret it. It is our team; it has been so marvellous, all these people; and now that they have learned to work together, these three postdocs (…) they are extremely talented persons to continue this work, and we have reached the phase in which the work is beginning to be productive, as when there are a lot of papers in the pipeline, some of them related to R&D. We have launched new research and found collaborative settings (…) [For the sake of all this,] we've been franticly seeking funding, and therefore, I haven't been able to conduct research because half of my working hours are dedicated to teaching, and the rest of my time is dedicated to applying for money. (Research partner)

Such efforts engendered the mentioned household economy as a distinct framing for commercialisation. Within it, the EV Core's economic value did not lay primarily in the revenues and profit that businesses providing technical services may produce. Rather, it lay in expectations that the Core would provide more solid and visible bases for EV research and, especially, for the technical expertise it requires. Thus, the EV Core's most important value was related to ensuring sustainable EV research (Tarkkala and Helén, 2021), which would result in collaboration that is more intense at home and abroad and help the Finnish EV researcher groups to acquire funding in the highly competitive environment of global life sciences and biomedicine. This was also acknowledged on the commercial side of the Finnish EV domain, which was reflected in a commercial partner's evaluation that the EV Core brings international visibility and national stability to the field.

In a way, then, despite the multiple dimensions of valuations intermingling, the prime value in the EV Core's founding was in keeping up and staying in the game.

Conclusions

In this paper, we present a case study on multiple forms of value and value creation in a Finnish interdisciplinary research consortium studying extracellular vesicles (EVs). The consortium was part of a research programme on personalised medicine (GiD) funded by the main Finnish public innovation funding agency in 2014–2018. Within the GiD programme, funding was directed to collaborative projects between public research institutions and private companies, with the goal of combining scientific research with commercial R&D. In our study, the Finnish EV consortium is an example of a hybrid life science in which a scientific endeavour and pursuits of clinical, social, and economic utility are aligned and simultaneously present (Tarkkala and Helén, 2021). As Francis Lee (2015: 222) said, "The tropes of medical development, economic innovation, and scientific progress are all present in the biosciences, and scientists perform and relate to all of them at different junctures".

The participants saw EV research as being in an early stage, as both a domain of science and a biomedical market. In this context, the EVs were attributed with forms of value associated with expectations in terms of potentiality and continuity. Our analysis shows that valuation in hybrid life science is characterised by the dynamics of value expectations, in which the scientific value opens pathways to other kinds of values: clinical, commercial, social, and so forth. However, the scientific value was not considered absolute or independent from other kinds of values; instead, the potential scientific value of EVs for biomedical science appeared entangled, or hybridised, with other types of value in the consortium partners' speech and reasoning. This resonates with a conventional understanding of basic science as an initiator of all things new.

The SHOK SalWe and its GiD programme provided the Finnish EV consortium's funding and institutional framework, making it a public–private arrangement quite typical in life sciences today. Many studies claim that economic and commercial interests and value predominate such R&D configurations and determine the ultimate research objectives. Among others, Muniesa (2017) presents a general claim that economic valuation dominates today's technoscience. According to him, the reasoning of 'value creation' concerning technoscience consists of multiple interlaced value dimensions, yet economic vernacular and reason form the most significant frame of valuation, which subsumes scientific, social, clinical, and ethical value.

Our findings are at odds with Muniesa's view, to some extent, and our analysis suggests a more complicated view of value hierarchies and of commercial valuation being entangled with other value dimensions in the emerging domain of EV research.[6] Obviously, the commercial value potential of EVs and EV research is continuously present in the Finnish consortium's discourses and mundane work; nevertheless, economic types of value form just a dimension of expected value creation and are interlaced with other valuation dimensions. Furthermore, the consortium partners shared a 'basic science' approach (Tarkkala and Helén, 2021), which implies a sort of temporal order of value expectations: pursuing science and developing specific technologies were widely considered primary because they were seen as indispensable for reaching clinical applications, marketable products or services, or other economic gains. Such dynamics of valuation reflect the Finnish EV research domain being situated in a specific niche within the global biomedical economy (see below).

What, then, is the weight of economic valuation, and what are the role and mode of 'commercialization' in our case? The influence of a technoeconomic rationale (Muniesa, 2017; see also Birch, 2017a) and the prominence of commercial valuation in the Finnish EV consortium were most eminent in the EV Core facility services at the University of Helsinki and its spin-off projects. The EV Core's business model exemplifies a specific formation of an academic bioeconomy, namely a kind of household economy in which business involving EVs in the biomedical R&D market is conducted to ensure the sustenance of scientific research. The idea that EV research is a biomedical science and that R&D primarily serves the 'common good' and will create value and utility for people and society is closely attached to such an instrumental view of business. This business model is not unusual in commercialisation rationales among academic research organisations and infrastructures, such as biobanks (Turner et al., 2013; Timmons and Vezyridis, 2017; Beltrame and Hauskeller, 2018; Lehtimäki et al., 2019). In this model, value creation—or, rather, value potential—is associated with two things. First, it refers to making money through a service business based on specific expertise to guarantee the continuity of a research unit and its research. Second, it means keeping up with the new domain's development, being aware of new knowledge and technology, and sensing 'weak signals' from the science and market domains. This reasoning highlights the value of craft expertise specifically in life science (see Meskus, 2018)—EV research, in our case—for doing business and staying on pace with the field's vanguard endeavours.

The household economy of Finnish EV research is interlaced with multiple biomedical economies and, obviously, is not detached from the global biomedical business domains, which are dominated by the technoscientific assumptions related to capital investments and market analyses (e.g., Hopkins et al., 2013; Mirowski, 2012; Pisano, 2006; Styhre, 2015), assetisation and rent extraction via the patents and IPRs (Birch, 2017b; 2020; Birch and Muniesa, 2020)', and innovation policy and its ideas of ecosystem economy (e.g., Mittra, 2016; Ong 2016; Aarden, 2017; Tarkkala et al., 2019). This academic household economy is a bioeconomy niche, perhaps situated in an embryonic phase of the value-creation chain or in a 'pre-competition' zone. Within it, the expert scientists and their allies conduct 'small business' with EVs and their own craft expertise, and they attach forms of economic value—or value prospects—to EVs and align them in a particular way, considering economic pursuits as instrumental so that seeking revenue or profit from their EV expertise business is a means to sustain their scientific work and academic careers. The emergence and existence of such niches and such business reasoning indicate the condition in which scientists and researchers are conducting basic R&D in the world of science, ruled by expectations of economic gain. Thus, turning the specific scientific expertise and craft into a small business, often called 'commercialization', becomes a reasonable strategy with which to secure the continuity and quality of their own scientific work and its prerequisites.

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Notes

1 A search by the term 'extracellular vesicles' in the PubMed database returned 2054 publications published in 2016. In 2020, the term 'extracellular vesicles' had 4296 hits (see https://pubmed.ncbi.nlm.nih.gov/).

2 We presented this research programme more comprehensively in Tarkkala and Helén 2021.

3 The SHOK did not stand on a particularly firm ground in the Finnish innovation policy. Since 2013, SHOKs were under political fire because they were seen as serving the interests of large companies too closely, not being crosscutting enough, and having too complex IPR model, to name a few examples of criticisms they received (Lähteenmäki-Smith et al., 2013: 27-28). For SalWe, GiD remained the last program, and it was finished some 6 months before it was due to end because the government gave up on the SHOK model and closed the companies by the end of 2018. In addition, the EV consortium had to make considerable adjustments to its work plans due to the premature ending of the project (Tarkkala and Helén, 2021).

4 For a more detailed discussion on the hybrid character of the Finnish EV consortium, see Tarkkala and Helén 2021.

5 STS studies focused on technology domains that are very different from ours highlight the simultaneous presence and intermingling of multiple value dimensions. For example, studies on waste management and recycling services (Gregson et al., 2013; Corvellec and Hultman, 2014; Olofsson, 2020) have an approach to value creation that is similar to ours. Those studies underline the importance of performativity and potentiality in valuation of waste and waste management technology, the emphasis of which is congruent with our approach to rather different items, namely EVs.

6 Our analysis and argument are not intended to deny the findings and insight of the studies on economic and commercial rationales in different technoscience domains (e.g. Birch, 2017a; 2020; Birch and Muniesa, 2020; Pavone and Goven, 2017) or studies on biocapitalism as the main frame of current life sciences and biomedicine (e.g. Cooper, 2006; Cooper and Waldby, 2014; Sunder Rajan, 2006). However, our study on EV research in Finland, as a hybrid mode of life science (see also Tarkkala and Helén, 2021), did not take the dominance of economic or commercial objectives in research practices as a default assumption, and we did not consider the reasoning of the people involved as some sort of ideological coverage or justification for their business engagement or pursuit of economic gains (cf. e.g., Johnston, 2008). Instead, our approach was first to take what EV researchers and others involved said or wrote about EVs, their work, and its worth at face value and then to analyse their discourse and reasoning in the proper context. By doing so, we were able to glimpse the manifold dimensions of valuation and multiple economies in which research in life sciences and biomedicine are embedded today. In our mind, this picture complements, rather than contradicts, the findings and arguments of the abovementioned studies.

Genetic Racial Profiling

Extended DNA Analyses and Entangled Processes of Discrimination

Isabelle Bartram

Institute of Sociology, University of Freiburg, Germany

Tino Plümecke

Institute of Sociology, University of Freiburg, Germany/tino.pluemecke@soziolgie.uni-freiburg.de

Susanne Schultz

Institute of Sociology, Goethe University Frankfurt, Germany

Abstract

Over the last two decades, the analysis of DNA traces found at a crime scene have expanded the already established forensic DNA analysis for identification to include new techniques intended to predict a criminal suspect's externally visible characteristics, such as eye, hair and skin colour ('forensic DNA phenotyping'), or his or her ethnic, continental or regional origin ('biogeographical ancestry'). In this paper, we conduct a dispositive analysis to investigate how extended DNA analysis in forensics catalyses inherent processes of racialization at three different levels: 1) in the categorizations that are integral to this technology, 2) in the images of the 'dangerous other' combined with inflated expectations regarding these technologies' effectiveness that have framed discourses regarding the legalization of this technology, and 3) in the biases and stereotypes which often guide investigative practices using these technologies. We demonstrate that this is an example par excellence of how the interaction between different practice dimensions can exacerbate unintended discriminating, racialising and racist effects.

Keywords: DNA, forensics, racialization, discrimination, minorities, racial profiling

Introduction

Forensic DNA investigation methods have been expanded rapidly over the last two decades. Previously established DNA profiling techniques used DNA samples found at a crime scene in order to *identify* an individual (so-called genetic fingerprinting). In contrast, some newer techniques focus their DNA analysis on characteristics that are shared by whole groups of people in order to *attribute* statistically likely characteristics to an unknown suspect. These newer techniques predict visible characteristics of the suspect – such as the pigmentation of skin, eyes and hair (forensic

DNA phenotyping) – as well as the continental, regional and group-specific origin of the suspect's ancestors (biogeographical ancestry).[1] Since very different and sometimes misleading terms are circulating in scientific literature and the political debate, we follow the practice of some (mainly German) authors and subsume these methods under the term 'extended DNA analysis' (EDNA).[2]

Extended DNA analysis technologies have already been used in countries such as Canada, the UK, the Netherlands and some US states (Sankar 2010, 2012; M'charek et al., 2020; M'charek and Wade, 2020; Wienroth, 2020a). In other countries, particularly in most of continental Europe, the use of such investigation tools in criminal cases is either highly restricted or explicitly prohibited due to data and privacy protection regulations (Koops and Schellekens, 2008; Samuel and Prainsack, 2018). In the last three years, however, certain continental European countries such as Germany, Slovakia and Austria have approved the use of some of these methods for police investigation work, and in some states like Finland, Switzerland and Spain new legal regulations are being considered or under consideration (cf. Schneider et al., 2019).

In this article we will demonstrate how these technologies contribute to the reproduction of racialisations in forensic investigation practices based on DNA. For this purpose we start from the general observation that the concept of biological race is persistent and resilient (cf. Pollock, 2012). What we consider striking in the development of EDNA methods is a renewed explicitness in the use of racial(ising) categories as well as a current reinforcement of biological boundary-drawing to differentiate humans into groups based on typological concepts. This resilience of the biological and now molecularised race concept counteracts the broad scientific consensus that biological race concepts are invalid (Livingstone, 1962; Lewontin, 1972; Marks, 1995; AAPA, 2019; Fischer et al., 2019) and that race needs to be understood as a sociocultural category of othering and selfidentification.

To explore how EDNA-usage contributes to the continuation and re-expansion of a biological understanding of race, we examine the recent debates regarding EDNA legal reforms in Germany and Switzerland and the application of these technologies in prominent cases in different European countries. To this end, we draw on the analytical concept of 'racialization' in order to shed light upon the interdepencies, institutional settings, practices and underlying historically sedimented images which reinforce essentialised categories and create divisions between groups (Hopman and M'charek, 2020; M'charek et al., 2020). Accordingly, with reference to Miles' and Brown's definitional framework, we employ the concept of racialization "to denote those instances where social relations between people have been structured by the signification of human biological characteristics in such a way as to define and construct differentiated social collectivities" (Miles and Brown, 2003: 101).[3]

Even though the concept of racialization has been subjected to numerous criticisms (e.g. Goldberg and Essed, 2002; for an overview see Murji and Solomos, 2005), it seems to us to be most useful for analysing the practices of EDNA technologies because, firstly, the concept "moves research and political argument away from the unproductive debates about whether any particular individuals, propositions, claims, and doctrines are simply 'racist' or 'non-racist'" (Rattansi, 2007: 107). Secondly, it fosters interpretive social research by shifting the focus away from conceptually fixed entities (like race or ethnicity) and directing attention to the particular temporal and local settings in which people are classified (M'charek et al., 2014; Balkenhol and Schramm, 2019). In this sense the focus on racialization, that is, on the practices of boundary work, on the processes of constructing, homogenising, and naturalising human group categories, enables us to contribute additional insights to studies on 'scientific racisms' (Carter, 2007), 'racial formations' (Omi and Winant, 1986) or 'groupism' (Brubaker, 2004).

With a focus on biological human classifications, we are not only interested in determining whether and how racializations take place but also in clarifying how this is related to forms of discrimination (Skinner, 2020), stigmatization (Machado and Granja, 2020), criminalization (M'charek et al., 2020), and securitization (Maguire, 2012; Amicelle et al., 2015) and how these forms became entangled. While several problems related to EDNA forensic practices have already been addressed and investigated in a number of studies (e.g. Bolnick et al., 2007; Duster, 2009; Lipphardt V, 2018; Skinner, 2018, 2020; Zentralrat Deutscher Sinti und Roma, 2018), these have usually focused on particular fields such as law, media discourse or law enforcement agencies. From our point of view, these fields should also be analysed with respect to their relationship to each other, to their similarities, to their mutual stabilization and sometimes even contradictory objectives. For this reason, we centre our analysis on three interrelated dimensions:

1. the racialising procedures already inherent in the design and functioning of these technologies;
2. the racialising and racist substructure of public debates regarding the introduction of EDNA;
3. the potentially discriminatory, stereotyping and racialising effects of criminal investigation practices.

Racializations occur in all three dimensions, but in their own specific heterogeneous forms and modes. To investigate these three dimensions – technology, discourse and practice – we use the methodological tool of dispositive analysis (Foucault, 1980; Jäger, 2001; Jäger and Maier, 2015). Foucault's description of the "strategic function" or "strategic imperative" of a dispositive helps us work out how these three dimensions interact, support and stabilize each other. The first main point is that a dispositive is organised around a common strategy without there being a strategist. This common dominant strategic function arises, according to Foucault, from the response to an "urgent need" in a specific historical moment (Foucault 1980: 194, 195). The second main point is that unintended and unforeseen effects result from the arrangement of "a thoroughly heterogeneous ensemble". For Foucault (1980: 194) such ensembles consist of "discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions". The dispositive must therefore be understood as the "system of relations", in the French original "the network" (*le réseau*), which is established between these elements (Foucault 1980: 194).

Dispositive analysis enables us to look at the field of extended DNA analysis from a broad perspective, which we assume will help us perceive the problems related to EDNA more accurately. In addition, it enables us to locate the causes of racialization beyond these technological tools, the discourses surrounding them, investigative practices or even the intention of the actors involved, in order to comprehend these elements' entanglements. From a methodological perspective, a dispositive analysis has to be sensitive to heterogeneous sites, actors and narratives, as well as their potential links, mutual dependencies and/or effects on each other (cf. Jäger and Maier, 2015). Furthermore, the dispositive concept allows us to capture the effects of these technologies at the three levels central to Foucault-inspired power analyses – the levels of knowledge, institutions and individual preferences for action – all three of which we consider useful for this analysis.

We adopt different theoretical and problem-related perspectives for this analysis, drawn from our diverse disciplinary backgrounds – genetics/molecular biology, political science and sociology/STS. Widening the analysis using these different perspectives seems particularly necessary because today's continental European societies describe themselves as 'post-racial', such that technology-driven racialization processes usually remain unnamed and hidden and race thus tends to manifest itself as an 'absent presence' (M'charek et al., 2020; Skinner, 2020). This means that racializations continue to exist, but their presence and their impact become largely invisible. This happens, for example, when scientific technology is represented as neutral and objective in its development, functioning and effects.

Furthermore, we use the term 'racial profiling' as a heuristic tool to understand how the societal acceptance of EDNA has exacerbated racializations in investigative practices and how EDNA can increase the risk, especially for minorities, of becoming the subject of police investigations and possibly associated stereotyping. Using the term racial profiling, we will discuss how images of the 'dangerous others', as well as emotions and hopes with regard to a “technological fix for fear and anxiety” (Buchanan, 2019), hinder a debate on sufficiently considering the risks and social costs of this technology. As an analytical term, racial profiling has been established in the last three decades as a keyword for a wide range of anti-discriminatory research (e.g. Glover, 2009; Fassin, 2013; Davis, 2016; Plümecke and Wilopo, 2019). While the term is commonly used to describe police activities such as identity checks, monitoring, surveillance and investigation that are conducted on the basis of a person’s skin colour or alleged ethnic or religious identity, for the objectives pursued here we understand this more broadly in terms of investigative practices, in which specific racialised population groups are criminalised and particular crimes are racialised (cf. Lee, 2005; M’charek et al., 2012).

In the following, we first provide an overview of the current technologies of extended DNA analysis and reveal the selective and discriminatory procedures inherent in their design and function. In order to reconstruct the historical constitution of technological artefacts and technological practices we refer to a large corpus of relevant history of science and STS studies as well as to primary sources, especially information and research articles by the main scientific developers of EDNA technology. Second, we focus on two case studies (Germany and Switzerland) in order to grasp main aspects of the current legitimising public, political and juridical discourse. We recur here to already existing academic case analysis but also analyse integrated primary sources such as important media articles,[4] parliamentary debates and other political documents concerning the approval of EDNA for police work. Third, we present specific cases, in which EDNA was known to be utilised, and analyse them with regard to their racialising, stigmatising and responsibilising effects by referring to media coverage and existing academic literature on specific cases. As these sources where not enough to fully understand the exact events and motivations surrounding two cases in the Netherlands where bio-geographical ancestry (BGA) was applied, we additionally draw on an interview we did with one of the geneticists responsible. Finally, we will argue that these three dimensions interact to create a dangerous, technologically conveyed racial profiling instrument.

EDNA technology: Classifying humans in a ‘post-racial era’

Extended DNA analyses are by no means as new as they are often presented in the media, especially by its proponents. Instead, they reference a historic branch of classical genetics research that has developed categorizations of humans based on race, ethnic group or population.[5] The first EDNA methods were based on insights from population genetics, which since the mid-19th century has repeatedly identified differences in the frequency pattern of genetic variability according to geographical distance (Dobzhansky, 1973). However, until recently, DNA analysis in forensics has been limited to the identification or exclusion of individual suspects and to the determination of someone’s chromosomal sex. For the identification of individuals (so-called DNA fingerprinting), the analysis focuses on regions in the human genome that contain so-called ‘short tandem repeats’ (STRs), patterns of nucleobase repeats that can be found on several regions on each human chromosome and are often highly variable between unrelated people (Lynch et al., 2010; Wienroth et al., 2015). STRs were chosen not only for such methodological reasons, but also because they are part of so-called ‘non-coding’ sequences of the DNA that in contrast to ‘coding sequences’ do not store information for the construction of proteins, the body’s building blocks. Thus, they were thought to be ‘information free’, meaning they could not reveal any intimate information about a person. In the 1980s and 1990s there was a broad consensus that the use of DNA profiles should be limited due to general concerns about data protection and the private information in DNA.[6] For example, the German Federal Constitutional Court ruled in 1995 that an analysis of the coding part of DNA would be a violation of the “absolutely protected core area of personality” of the respective person (Bundesverfassungsgericht, 1995). Geneticists have since stated, however, that there is no scientifically clear boundary between coding and non-coding sequences in DNA, and that there are several DNA markers located in so-called non-coding sequences that are usable to analyse personal traits (Kayser, 2015). Meanwhile, the general public and political consensus on DNA privacy has also been challenged over the last two decades by new political regulations: in 2000 in the Netherlands and in 2003 in the US, regulations permitted the extended application of DNA technologies to predict the probable racial, ethnic or geographic origin of the person whose DNA was found at the crime scene (M'charek et al., 2020; Sankar 2012). In order to reconstruct how powerful group categories have been inscribed and reified within these technologies, we will first give a short introduction regarding the development of EDNA technologies in forensics, highlighting research on genetic ancestry as well as on phenotypical attribution.

The precursors of extended DNA analysis

Probably the most important precursors of current EDNA methods can be traced to the late 1970s, when the geneticists and haematologists Yuet Wai Kan and Andrée M. Dozy researched sickle cell anaemia in the blood of Black people (with and without symptoms of the disease) and non-Black people (without symptoms). As a by-product of that research, they noticed that they might have found a "new class of genetic marker" that could facilitate a "new approach to linkage analysis and anthropological studies" (Kan and Dozy, 1978: 5631). Based on this study, the geneticist Alec Jeffreys (the inventor of DNA analysis for the identification of individuals) examined the blood of 60 people of "North European, Asian, respectively Chinese" descent with symptoms associated with blood-related diseases (Jeffreys, 1979: 9). His study not only revealed differences in the genes related to these symptoms, but also led him to speculate that his methodology would offer possible uses for investigating "population structure and origins of human races" (Jeffreys, 1979: 8). In the 1980s, with the development of new DNA analysis technologies (e.g. polymerase chain reaction) further approaches emerged to process DNA data within the fields of population genetics, medicine and forensic genetics.

It has been widely recognised in genetics, at least since the 1970s, that variations within each human group are much greater than those between them and that the distribution of gene variants is essentially a gradual continuum around the globe (cf. Livingstone, 1962; Lewontin, 1972). Nevertheless, some scientists have continued to define human populations as discrete entities with measurable genetic differences that can be determined by probability calculations (e.g. Baker, 1974; Nei and Roychoudhury, 1982; Rushton, 1995). In this context, it is not very surprising that in a 1989 meeting on *DNA Technology and Forensic Science* the geneticist Kenneth Kidd and the forensic expert Jack Ballantyne discussed "population-specific allele frequencies" and postulated that it could be possible to determine a persons' "precise racial data" or "racial origin" (Track et al., 1989: 344). A few years later forensic experts in the UK proposed that a single marker could be used to classify individuals along racial group categories of "Caucasian" and "Afro-Caribbean" with an 85% match probability (Evett et al., 1992). And, at the beginning of the 1990s, the already mentioned geneticist Jeffreys predicted that "in the not too distant future, it is conceivable that DNA tests yielding information on, for example, ethnicity, hair colour and eye colour might become available" (Jeffreys, 1993: 210).

Bio-geographical ancestry: Defined localisation of gradual frequency distribution

Indeed, as Jeffreys predicted, by the 2000s forensics had developed technologies which analyse DNA traces from crime scenes in order to calculate probability assertions regarding the geographical, racial, and ethnic ancestry of potential suspects. Currently, there are three such technologies, each with their specific limitations and potential: the analysis of genetic variants in mitochondrial DNA, in Y-chromosomal DNA and in the remaining chromosomes (autosomes) (for an explanation of these technologies see Brubaker, 2017). Figure 1 visualizes an example of how the distribution of a particular mitochondrial DNA pattern is presented to investigators.

In the 1990s the biological population differences which forensic scientists sought to capture were still commonly referred to as 'race', 'ethnicity' or 'population', but since the beginning of the 2000s it has become more common to use the

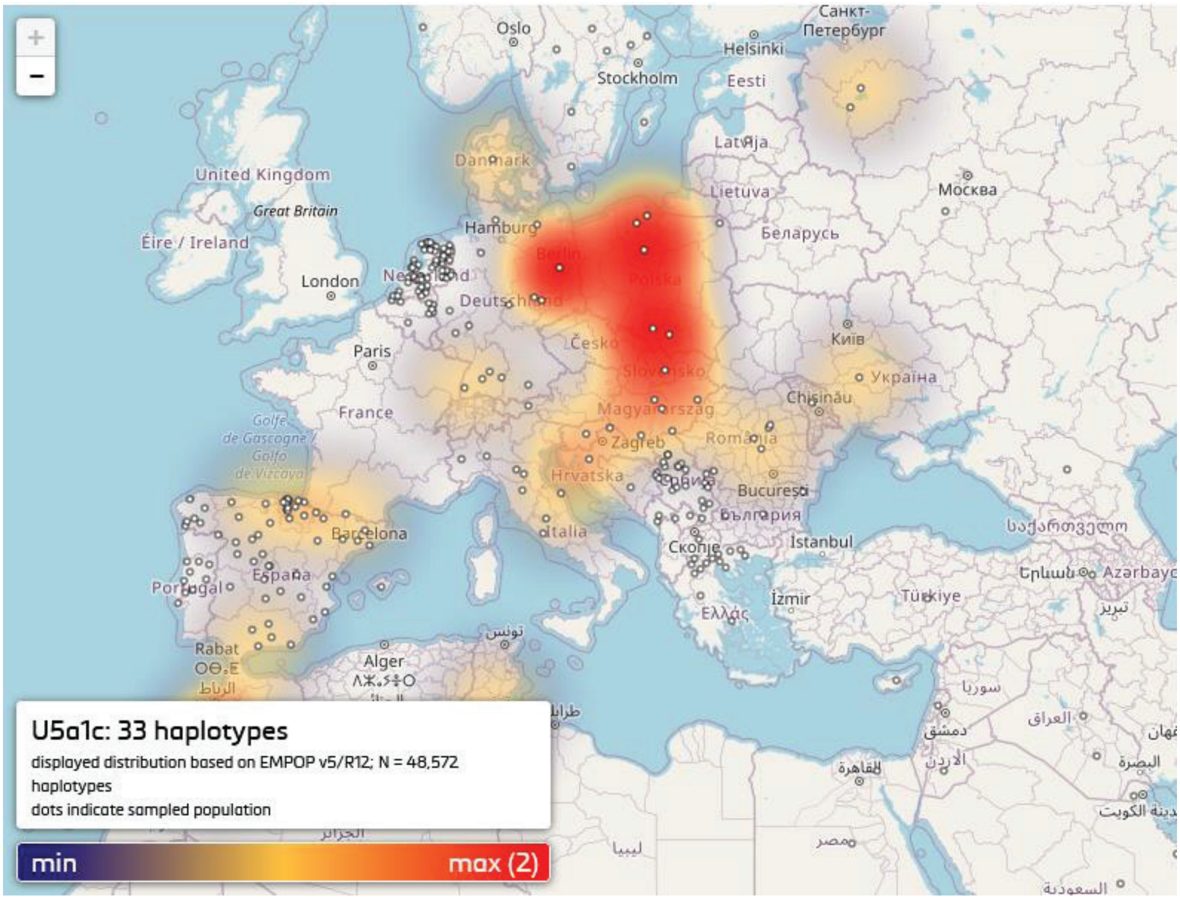
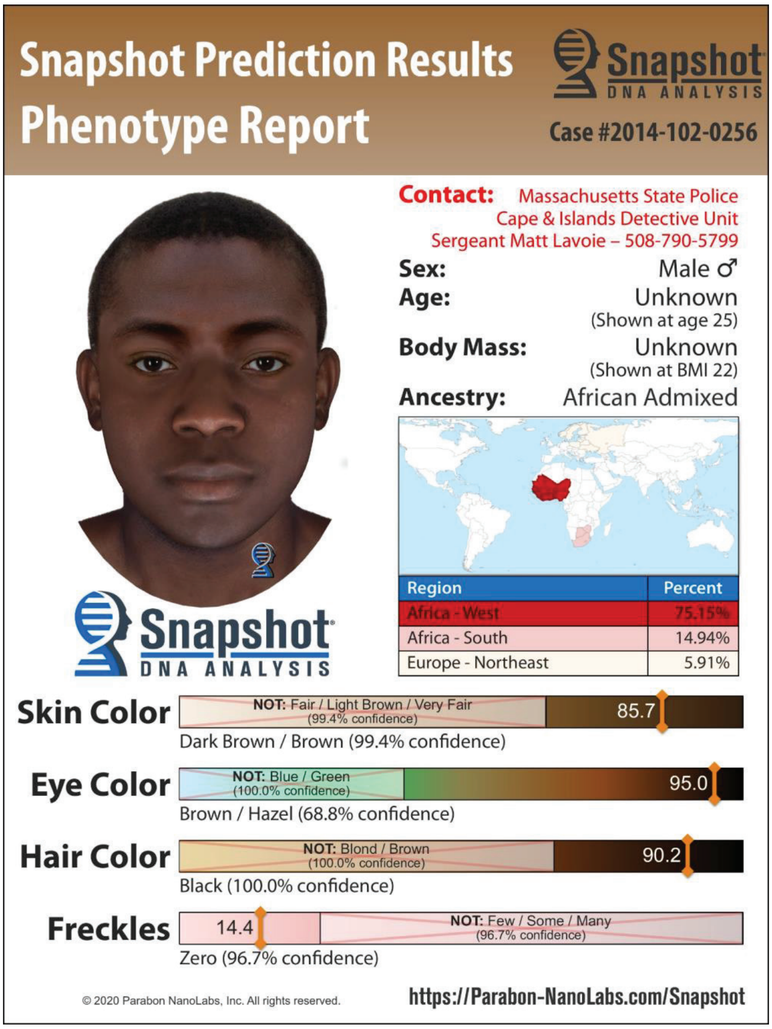


Figure 1. Example visualisation of a specific variability pattern of mitochondrial DNA, called haplogroup U5a1c, taken from the database EMPOP (https://empop.online/hg_tree_browser). As can be seen from the sampling sites (dots), there are large data gaps for many countries and regions. The mtDNA sequences collected in the database are used to make frequency calculations and BGA estimates, as in the case of the "Phantom of Heilbronn".

terms 'ancestry' and especially 'bio-geographical ancestry' (BGA). This shift in terminology has, however, not really reflected a clear differentiation in the underlying meaning, as shown by the usage of the biological anthropologist Tony Frudakis and the population geneticist Mark Shriver, who coined the term BGA, referring to it in a patent application in 2004 as the "heritable component of 'race' or heritage" (Frudakis and Shriver, 2004: 1; cf. Gannett, 2014).[7] It is noteworthy that they use the term race not to refer to the currently hegemonic understanding of it in English-speaking countries as a socio-cultural category, but rather try to highlight its biological foundations.

In its application, however, BGA falls short of a scientifically sound, biological categorization since their analyses are often based upon contemporary US and European race and ethnicity concepts which are actually the product of political debate and negotiation (Gannett, 2014). And in any case, the way in which BGA was operationalised by Frudakis and Shriver cannot be understood as a purely biological specification of human diversity, since their implementation of continental, racial, national, ethnic, religious or language-related group designations always involves categories based on social and cultural classifications (Bowker and Star, 2000). Nevertheless, the term BGA has been used in many contexts – including forensics – to at least create the impression that we now have a concept that reflects the natural measures of human diversity.

Nowadays there are several nationally and internationally operating companies for BGA analysis, which offer everything from DNA analysis to evaluation and the creation of detailed profiles. They, too, have undergone the shift in classification terminology from 'race' to 'ancestry' and 'biogeographical ancestry'. In 2000, for example, the company *DNAPrint genomics* promised the



Snapshot Prediction Results
Phenotype Report

Snapshot DNA ANALYSIS

Case #2014-102-0256

Contact: Massachusetts State Police
Cape & Islands Detective Unit
Sergeant Matt Lavoie – 508-790-5799

Sex: Male ♂
Age: Unknown (Shown at age 25)
Body Mass: Unknown (Shown at BMI 22)
Ancestry: African Admixed

Region	Percent
Africa - West	75.15%
Africa - South	14.94%
Europe - Northeast	5.91%

Skin Color NOT: Fair / Light Brown / Very Fair (99.4% confidence) 85.7
Dark Brown / Brown (99.4% confidence)

Eye Color NOT: Blue / Green (100.0% confidence) 95.0
Brown / Hazel (68.8% confidence)

Hair Color NOT: Blond / Brown (100.0% confidence) 90.2
Black (100.0% confidence)

Freckles 14.4 NOT: Few / Some / Many (96.7% confidence)
Zero (96.7% confidence)

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https://Parabon-NanoLabs.com/Snapshot

Figure 2. Example of an FDP and BGA estimation as carried out by the US company Parabon NanoLabs. Source: https://twitter.com/ParabonSnapshot/status/1237488967370539008/photo/1 (accessed 3 June 2021).

"deciphering of an individual's race" from crime scenes' DNA traces (Gaskin, 2000), while since 2013 the company *Identitas* (www.identitascorp.com) has been offering its DNA Witness 2.0 to "deduce bio-geographic origin […] from genetic information", and *Parabon NanoLabs* as well as *Illumina* have designated their classification findings as "bio-geographic ancestry", abbreviating this as "ancestry". What is meant by bio-geographical ancestry in this context is shown, for example, in Figure 2, where the "ancestry" of a suspect is projected onto large geographical regions with seemingly high precision, as demonstrated by the two positions after the decimal point.

In addition to private, company-owned and national databases forensic investigators worldwide use two databases located in Germany and Austria, which own today's most comprehensive reference samplings in the world. Both databases are not just a repository for DNA data and sampling locations, but link individual marker data with further classifications, such as ethnic, racial, regional, national, religious, language specific, skin colour-based information. Furthermore, both databases also cluster individual samples into larger groups, which are called 'metapopulations'. In this way the "Mitochondrial DNA Population Database" (EMPOP), operated by the Institute for Legal Medicine of the Innsbruck Medical University in Austria, organizes its data according to the meta-populations "African, Western Eurasia, Asian, American, Oceania", and the residual designation "Admixed", categories which echo classical racial classifications.[8] The database is freely accessible to everyone. Investigators worldwide can therefore enter data obtained from an analysis of mitochondrial DNA into the database, connect the data by means of probability assignments to specific populations and even create a world map which displays how frequently the determined DNA marker combination occurs in the existing, regionally distributed set of database samples (see Figure 1).

Another important database is the Y Chromosome Haplotype Reference Database (YHRD) at the Charité hospital in Berlin, Germany, which contains the Y-chromosomal genetic information of over 320,000 individuals from 917 sampling locations. The database stores data not only according to these sampling location categories but also to nationally specific classifications such as racial categories in the USA ("European American, African American, Hispanic American" etc.), skin colour categories like in Brazil ("Pardo"), ethnic ones such as those in China ("Uighur, Tibetan", etc.), nationalities such as those in the United Kingdom ("Afro-Caribbean, British Indian, Bangladeshi, Sri Lankan"), language-related group designations (like "Romani, Bulgarian Turks, Basque") as well as religious ones (like "Ashkenazi Jews" or "Druze"). In addition, the various local, ethnic, etc. classifications are grouped into metapopulations (as in EMPOP) – currently in thirty-two (Willuweit and Roewer, 2015; https://yhrd.org). Thus, even though both databases do not primarily aim to provide racial classifications, racial categories are already present in the data.

Furthermore, racializations are also generated as a result of the sampling strategies. Often only a specific selection of persons is included in forensic reference databases for estimating the BGA. The genetic data selected for these reference databases is not collected to represent a cross-section of a region's population, but rather only those individuals with four grandparents born in the same region. While this approach might make sense for research into historical migration and settlement development, it clearly limits forensic application since a large part of the current genetic population diversity (for example those with migration history) is not represented and the differences between the differentiated groups are exaggerated. This problem has also been raised by two of the most prominent proponents of BGA, the above mentioned Mark Shriver and the geneticist Rick Kittles, who see it as a possible concern that in genetic ancestry analysis, "the genetically defined ancestral categories […] could be misinterpreted as indications of 'real' racial divisions, even if they are explicitly acknowledged as being continuous and, to some extent, arbitrary groups" (Shriver and Kittles, 2004: 616).

BGA is therefore not something that can be found in the reality of the current population but is rather the product of how reference databases and the classifications they provide were constructed. Rather than a realistic representation of the population in a geographical location, BGA is the sum of a series of complex and contingent assumptions, not only concerning how the categorizations are developed or which decisions have been made regarding the location of sampling but also in the number of samples considered relevant, what kind of designations of the respective groups are preferred over others, how individuals are assigned to particular groups and how the reference databases are constructed (Pfaffelhuber et al., 2019; Lipphardt V et al., 2021a; Fujimura et al., 2014). In effect, the very technology of databanking and static mapping of a sample in many cases produces an essentialised and homogenised image of human groups.

Forensic DNA phenotyping: Messy categorizations of physical characteristics

Another set of EDNA technologies in forensic genetics is "forensic DNA phenotyping" (FDP), which analyses externally visible features such as facial shape, hair, eye or skin colour as well as further physical features such as biological age (in this case via the analysis of epigenetic markers; see Figure 2 for a visualisation of such an analysis). The FDP analyses of genetic variants statistically associated with pigmentation of hair and iris currently have a higher predictive power than those for age or the pigmentation of the skin. Nonetheless, the degree of accuracy outside the controlled research environment is an object of ongoing scientific debate (Staubach, 2017; Caliebe et al., 2018; Buchanan et al., 2018).

Regardless of which characteristics are being predicted, the accuracy of FDP (as well as BGA) analyses is considerably lower than the predictive value of the established DNA-fingerprinting techniques. For example, in a statement that became central to the German debate on EDNA, the "German Stain Commission" (*Spurenkommission*), an association of German forensic institutes, claimed that hair colour, for instance, can only be correctly detected in about 75% of the cases (Schneider, 2016). Other scientists have pointed out that even these numbers are misleading (Buchanan et al., 2018; Lipphardt V et al., 2021a) and that this technology's real-life accuracy in the field is significantly lower, since the statistical values called 'area under the curve' describe the performance of the methods under laboratory conditions (WIE-DNA, 2019; Buchanan et al., 2018; Taylor et al., 2021). Even the team of Manfred Kayser, a leading European FDP technology developer and major proponent of the legalization, acknowledged that "since the etiological understanding of FDP-relevant appearance phenotypes is still incomplete, so are the prediction models used" (Caliebe et al., 2018).

While in the context of a criminal case, the goal is to find a specific individual suspect with unique features, FDP is only able to narrow down the possible visible characteristics of the person based on a statistical probability calculation related to groups of people. The result is not an individual set of characteristics but rather a category of the population with a more or less wide range of characteristics. Since a range of possible characteristics is rather unhelpful to law enforcement agencies, scientists and companies offering FDP analyses try to accommodate the needs of practitioners by implementing classifications in the technology that are as unambiguous, mutually exclusive and clear-cut as possible. For example, the system *HIrisPlex-S*[9] by Manfred Kayser's group divides eye colour into three types (blue, brown and intermediary), hair colour into four (blond, brown, red, black) and skin colour is presented as one of five possible options (very pale, pale, intermediate, dark and dark-to-black). The decision to divide skin colours into five types is, of course, arbitrary. Other FDP systems categorize with more, others with fewer divisions. In reality, phenomena like eye colour are much more complex and often not easy to group into a small number of divisions, as evidenced, for example, in the different ways researchers have assigned DNA data to eye colour varieties (Liu et al., 2010).

What further obscures the problems surrounding FDP is that both scientific and media representations of EDNA methods do not sufficiently clarify the differences between BGA and FDP technologies. Although there is a technical overlap between the two forms of analysis (because some gene regions related to physical features are also used for the analysis of BGA), it would be misleading to subsume both technologies under one term, since BGA analysis does not provide information about the appearance of an individual. Doing so would lead to an imagined connection between "ancestry" and "visible characteristics", thus suggesting a traditional, racialised typology.

Unfortunately, the discursive and practical confluence of these two technologies also plays into the political realm's and the public's false and exaggerated expectations about what BGA really offers (cf. Schultz and Bartram, 2017; Lipphardt V, 2018). In both science and in the media, EDNA is often misleadingly referred to as a "DNA composite sketch" or a "composite profile", or it is repeatedly translated in a similar way into another language, for instance into German as a "genetic facial composite" (*genetisches Phantombild*), suggesting that this would have the same accuracy as artist drawings based on eyewitness' memories of a suspect (e.g. VISAGE, 2020; KKWT/ED and Bundeskriminalamt, 2017). The company Parabon NanoLabs also presents its product as a "composite sketch" or a photographic "snapshot" (see Figure 2). Since 2015 this company has offered DNA analyses of unknown suspects that included information on gender, ancestry, skin, eye and hair colour as well as the predisposition to freckles. It should be noted that the image meant to represent the analysis findings is not, as might be the impression, generated from existing DNA data, but from racial-typological stereotypes using a database of images (cf. Wienroth 2020a).

Contextualising EDNA: Debates in Switzerland and Germany

At the time of finishing this article, a parliamentary debate is taking place in Switzerland regarding an amendment to the law concerning the approval of extended DNA analyses for police investigation procedures. Up to now, analyses of DNA traces have only been allowed for identity verification and for the determination of the chromosomal sex of crime suspects. All further analyses were explicitly excluded in the DNA-Profile Act, which was passed in 2003 and came into force in 2005, stating that the "DNA profile [...] is obtained only from the non-coding sections of the genetic substance DNA" (Art. 2 Para. 1, our translation) and that "no research shall be conducted concerning the state of health or other personal characteristics with the exception of sex" (Art. 2 Para. 2 DNA-Profile Act, our translation).

In the Swiss legislative process concerning the regulation of 2003, all political parties shared in principle the view that DNA data should be given a high protection status, as their analysis and storage would constitute a severe violation of personal rights. In the original draft of the law, the analysis of DNA coding sections was allowed in exceptional cases and by order of a judicial authority, e.g. for the analysis of "genes that determine the colour of eyes, hair or skin" (Schweizerischer Bundesrat, 2000: 37; our translation). However, the opinion that such examinations should not be permitted, not even in exceptional cases, prevailed in the Swiss legislative debate at the time the law was passed. Policy makers attempted to counter the risks of DNA analysis procedures by implementing relatively strict regulations with the aim of preventing the identification of "highly sensitive personal data" as well as "information on ethnic origin" in order to avoid "the public stigmatization of entire communities characterised by their cultural, ethnic or racial identity" (Dardel, 2002; our translation).

In December 2015, however, the existing regulations in the DNA-Profile Law were again put up for debate by Albert Vitali (National Council for the liberal Free Democratic Party, FDP). The aim of Vitali's initiative to revise the law was to allow investigative authorities to use DNA testing methods in order to determine people's phenotypic and further 'personal characteristics', such as their probable 'geographical, racial or ethnic origins' or that of their ancestors. The initiative referred to the rape of a 26 year old woman in Emmen near Lucerne in July the same year. Vitali's text explaining why the law should be reformed was written in a dramatic tone and presented EDNA as a blessing for investigative work. The parliamentary proposal was titled "no protection for murderers and rapists", and claimed that police officers rely on "methods from the last century". Vitali complained: "[...] murderers and rapists must not walk free only because not all scientific options are used." (Vitali, 2015; our translation) One should emphasize here that this particular case was not suitable at all for arguing in favour of allowing phenotypic and ancestry-related investigations based on DNA traces because the severely injured woman was able to make statements about the perpetrator. Among other things, she testified that the perpetrator had black-brown curly hair, spoke broken German and called himself Aaron (SDA and SRF, 2015; SDA and NZZ, 2017). It is at least doubtful that EDNA would have been able to provide additional useful information to facilitate the search for the perpetrator. Given the specific charge of the case with the topos of the 'dangerous foreigner', the question arises whether Vitali would have chosen this as a reference case if the injured woman had given a description had referred to a white Swiss as the alleged perpetrator suggesting that the culprit was a white Swiss man.

One possible explanation why this case triggered the debate on EDNA in Switzerland is that EDNA-technology is quickly linked to historically sedimented images of the 'criminal immigrant' and the 'dangerous' or 'sexually unrestrained other' and, at the same time, it also raises expectations of being able to precisely determine the origin of migrants and refugees. This interpretation is supported by the observation that after the crime case in Emmen, racist associations were quickly voiced in the Swiss debate in the social media and local newspapers. For instance, only two days after the crime, the local police had to remove a call for potential witnesses to come forward on their Facebook page because several "racially discriminatory" comments were made (SDA and bih, 2015). Four days later, Hans Fehrn, National Councillor of the right-wing populist Swiss People's Party (SVP), stated in an interview: "This act is absolutely incomprehensible. That is why we have to control immigration" (DAG and VRO, 2015, our translation). And the next day, posters and stickers of the nationalist party National Orientated Swiss (PNOS) were displayed in Emmen with the slogan "Violence by foreigners is not tolerable! Support the PNOS now" (SAM, 2015, our translation). The crime committed by an individual person was thus generalised in these public commentaries as a problem generally related to immigration or foreigners. While on the surface the discourse is about a crime, these public statements all refer to the racist stereotype of the 'violent other'. Criminality is thereby equated with migration, and genetic tests to determine external characteristics and ancestry are presented in this logic as the supposed solution that will make it possible to identify and prosecute migrants and thereby combat crime.

Very similar discussions took place in Germany, starting at the end of 2016 after the 19-year-old Maria Ladenburger was raped and murdered by an initially unknown perpetrator in Freiburg (see e.g. Vogel, 2018). Step by step this discourse led in 2018 to state-level legalization of BGA and FDP in Bavaria's police law and then in December 2019 to the national-level introduction of FDP as a technical instrument for police investigations in the reform of the German Code of Criminal Procedures. The case of Maria Ladenburger attracted national attention because right-wing social media presented it as a result of the so-called "refugee crisis" of 2015. As in Switzerland, just a few days after the crime a right-wing group expressed their opinion in a leaflet distributed to city households, claiming that "nothing is as easy to determine by DNA analysis as race" and that the criminal prosecution authorities' hesitance to use these investigative techniques is due to their bias in favour of the suspect "because of his race" (Bund gegen Anpassung, 2016). In the following weeks, articles in different newspapers made comparable statements. For example, a comment in the right-wing weekly newspaper *Junge Freiheit* claimed "it would be possible to narrow down the number of suspects through an analysis of DNA for origin, hair colour, eye colour and size. But it is not allowed. Because of falsely understood political correctness." (Krautkrämer, 2016; our translation) The next day the regional daily newspaper *Badische Zeitung* published an editorial titled "Limitations of DNA analysis: a law that protects murderers" (Heidegger, 2016; our translation).

An analysis by Sarah Weitz and Nicholas Buchanan (2017) of the German media discourse on EDNA revealed that the majority of media reports constituted more or less a promotional campaign for the legalization of EDNA. In this debate, an atmosphere was created in which calls to consider these technologies' limitations and social risks were hardly visible at first and then later on presented as complicit with the perpetrators. Strikingly, for a long time even the experts did not regard it as necessary or appropriate to intervene, for example to correct the completely exaggerated hopes and false probability statements circulating in the debate. A more balanced discussion began only after an initiative of a multidisciplinary group of scientists, social scientists and ethicists (WIE-DNA) published a statement against the rapid and unregulated introduction of EDNA, and after civil society organizations further questioned the legislators' positive presentation of this technology, arguing that it would have racist effects (Lipphardt V et al., 2016; Zentralrat Deutscher Sinti und Roma, 2018; Gen-ethisches Netzwerk, 2017, 2019). Nonetheless, exactly one day after the murder suspect had been caught, the Baden-Wuerttemberg Minister of Justice introduced a law reform proposal at the federal level to legalize FDP analysis (Lipphardt V, 2018). The fact that the later convicted perpetrator had been caught using other, already established investigative methods apparently did not matter. Only much later did the geneticist and vehement advocate of FDP Manfred Kayser declare that the case wasn't well suited to argue for a law to allow DNA phenotyping. "It was the wrong case to make that claim" he said (Kayser cited in Vogel, 2018: 842).

Overall, it becomes clear that inflated expectations regarding this technology, quick associations with migration and even blatantly racist images were the guiding principles of these Swiss and German political and media debates. Many people evidently associated EDNA with desires that go far beyond its technical possibilities and fit into current developments on 'crimmigration', in which questions of crime control and questions of migration have increasingly become intertwined (Lipphardt V, 2018; Wienroth, 2020b; van der Woude et al., 2017).

Cases of real-life EDNA-analyses and situation-specific effects

Internationally, there are no data on the scale of this technologies' use, and there is no register, national or international, in which specific cases of EDNA application are recorded. Consequently, no systematic data are available on its outcomes or its broader effects. The information that is available is almost exclusively limited to press releases on specific cases of EDNA use by investigating police or the public prosecutor's office. Some of them have been referenced heavily in the current debate and have been subject to a number of (re) interpretations. In the following, we present some example cases, focusing on the questions of how EDNA has been applied, which discourses framed this usage and which racialising effects can be observed.

The Vaatstra case: The first forensic EDNA investigation and the uselessness of the designation 'white'

Probably the most prominent case in which EDNA has been used in a criminal investigation, is the very first one, that took place in 2000 in the Netherlands. Paradoxically, EDNA proponents often reference it, even though the BGA analysis did not facilitate the search for a suspect. The investigation took place after the rape and murder of 16-year-old Marianne Vaatstra in 1999 in a rural area in the northern Netherlands. Immediately after the crime became public the residents of a nearby home for asylum seekers were placed under suspicion, and the media and politicians justified this suspicion with the murder method, claiming that cutting someone's throat with a knife was "non-Dutch".[10] Soon after, the suspected asylum seekers were all exonerated by a comparison of their DNA profiles with DNA from the crime scene. Due to the lack of further clues, the Attorney General eventually decided to use the DNA traces found at the crime scene for a BGA analysis, even though this was clearly prohibited under Dutch law.[11] In June 2000, the forensic expert and geneticist Peter de Knijff was commissioned to analyse the available traces with a technology that was currently under development using markers on the Y-chromosome to predict the probable ancestry of the person who left DNA at the scene. De Knijff stated that the resulting marker combination was prevalent in Northwestern Europe and rare in the asylum seekers' countries of origin (M'charek, 2008; de Knijff, 2006). This probability statement was translated by law enforcement authorities as a classification of the wanted offender as "white". In this way, a misleadingly homogenised variant of race was created. Many men of colour also have the same markers, especially due to colonial history. While it was possible to use this information to counter the racist propaganda and stigmatization of asylum seekers at the time, it was of little use to the investigating authorities as the Northern European criterion included too many possible perpetrators. The anthropologist of science Amâde M'charek comments in this regard: "Dutchness or whiteness does not make an informative population category for police investigation" (M'charek, 2008: 525).

Nevertheless, the Vaatstra case led to revisions of Dutch criminal law in 2003, which legalised the genetic prognosis of chromosomal sex, externally visible personal characteristics, such as eye and hair colour, and also of race.[12] The case itself was not solved until 2012. Using one of the most extensive conventional dragnet searches conducted in the Netherlands, police were finally able to identify and convict the suspect, a farmer living in the immediate vicinity of the crime scene. As we see, in the Vaatstra case EDNA results were too broad to create more than a vague suspect population and seem to be actionable only when they point to a (supposed) specific and distinct minority.

The British "Night stalker" case: Putting pressure on a whole community

The potential social impact of EDNA in police investigations can be clearly exemplified in the British case referred to as the "Night Stalker", in which entire population groups were placed under suspicion and racialised. This case involved a London citizen of Jamaican descent who broke into mostly elderly women's homes, raped and robbed them; he was eventually held responsible for 203 crimes in the London area between 1992 and 2009 (Dodd, 2011). DNA of the perpetrator was found at several of the crime scenes, but it was not possible to find a match for it, neither in the British police's DNA database, which had been compiled since 1995, nor in the DNA sampling of several thousand men from the London area.

In 2004, as there were no further clues to narrow down who the suspect could be, the British police decided to call in the US company *DNAPrint Genomics* to perform an EDNA to predict the origin and appearance of the perpetrator based on his DNA (Sankar, 2012; M'charek, 2018). The BGA analysis carried out, called DNAWitness^{TM}, produced a quite specific "maximum likelihood estimation" that the perpetrator's ancestry was "82% sub-Saharan African, 6% European, 12% Native American, and 0% East Asian" (Frudakis, 2008: 604). Based on this information, the involved epidemiologist and statistical geneticist Paul McKeigue deduced that the suspect would be of Afro-Caribbean origin, and the detective chief inspector thus concluded that the unknown offender most likely came from an island that was a former British colony (Frudakis, 2008; Sankar, 2012).

This origin estimate was apparently received with such euphoria that the investigating authorities, together with one of the contracted geneticists, considered it realistic to further narrow down the results to a specific island in the Caribbean. Although the technical director of the US company involved stated that this would not be possible, as did the already mentioned geneticist Jeffreys, the investigative authorities "persuaded 200 African-Caribbean officers to submit samples to DNAPrint for comparison". Their "donated" DNA was meant to optimize the tests that had been validated initially for a US population (Adam, 2004). The specified analysis then concluded erroneously that the suspect's ancestors were from the Windward Islands, specifically Trinidad, leading to a suspect population of 21,000 men in the neighbourhoods where the crimes took place. All of these men were asked to give DNA samples, and while this was framed as voluntary, authorities sent "threatening letters to men who refused to take part" (Greenwood, 2009). The actual "Night Stalker", Delroy Grant, was arrested five years later in 2009 – not due to EDNA technology, but to conventional investigation methods such as the evaluation of surveillance camera recordings and the determination of car license plates after he withdrew money from the bank account of one of his victims at an ATM (cf. M'charek and Wade, 2020). What becomes obvious in this case, is how EDNA technology cannot keep its promise to reveal precise characteristics of a suspect, but rather proves to be error-prone in real-world applications outside the laboratory. As a result, a large group of innocent citizens, a whole minority community, were designated suspects via DNA racial profiling and held responsible for helping solve the case.

The "Phantom of Heilbronn": German Neonazis and a contaminated cotton swab

While the problematic effects of EDNA in the Night Stalker case were widely discussed in the British media, a German case of an early BGA analysis in 2007 received inadequate attention, even though in this case racist stereotypes led to false interpretations of the DNA data and to racial profiling. The investigations had started because identical DNA profiles had been analysed from traces in widely scattered locations in France, Germany and Austria, and from various types of offences. The investigative authorities focused on female members of vulnerable groups, such as magazine pushers, homeless people, sex workers or "people with frequently changing residence", the latter being used as an internal code for Roma and Sinti (Lipphardt A, 2021: 231). Since some of the crime scenes were located in Austria, where BGA analysis was allowed, an ancestry analysis was performed using the mitochondrial Database EMPOP, and this suggested that the suspect's ancestors had come from Eastern Europe or neighbouring countries of the Russian Federation. Probability assignments of DNA data to specific geographical and national areas are typically visualised, as in this example in Figure 1, an image from the EMPOP homepage. The haplogroup depicted here is not identical with that of the suspect, since this is confidential according to data protection laws, but it does illustrate how a wide spatial distribution of certain DNA variants is used to attribute a specific origin to a suspect.

The police believed this information confirmed their suspicion that the perpetrator must be of Roma or Sinti ethnicity (Lipphardt A, 2019). An anonymous investigator was quoted in a newspaper saying "we are also investigating intensely in the Gypsy milieu" (Eißele and Nübel, 2004; our translation). Indeed, racialising and criminalising stereotypes of Roma and Sinti were the basis for the following police investigations, as well as media coverage (Lipphardt A, 2019; Kleffner, 2014). Until 2009, the so-called "Phantom of Heilbronn" was thought to be responsible for around 40 offences between 1997 and 2009, including the murder of police officer Michèle Kiesewetter in April 2007. As the anthropologist Anna Lipphardt reveals in her research, the state criminal investigation office in Stuttgart searched for a woman based on an operational case analysis that included the anti-gypsyistic idioms "vagabonding, parasitising, stealing, and roaming" (see Figure 3) (Lipphardt A, 2021: 228, our translation).

It was not until 2009 that it finally became clear that during the production process, the cotton swabs being analysed had been contaminated with the DNA of a worker at the cotton swabs manufacturer. Until then, the EDNA analysis had given weight to the racialising perspective of the investigative authorities and resulted in resource-intensive investigations and dragnet searches, in which the police had ordered DNA samples from thousands of persons on the basis of these suspicions. While this dramatic error led to a revision of forensic laboratory standards and the adoption of a strict quality management strategy to avoid future contaminations, no comparable measures were taken to prevent the racist dynamics that had let to the wrongful investigative focus (Stenger, 2017). On the contrary, some police representatives are still using the case to claim the alleged usefulness of BGA analysis since the cotton swabs factory worker, in fact, turned out to be of Eastern European ancestry. But the case was not closed at this point. After the self-disclosure of the German neo-Nazi terror group "National Socialist Underground" (NSU) in 2011, it became clear that it was they who had murdered the above-mentioned police officer in 2007. However, it took another five years until this case was also discussed in the German media as an example of the extreme damage that can be done with forensic EDNA analysis. Only then it was discussed how the BGA analysis reinforced the already racist focus of the investigation, contributed to the victim-perpetrator reversal (which characterised the investigation of the other NSU murders) and unjustifiably subjected thousands of minority women from discriminated groups to police investigations.[13]

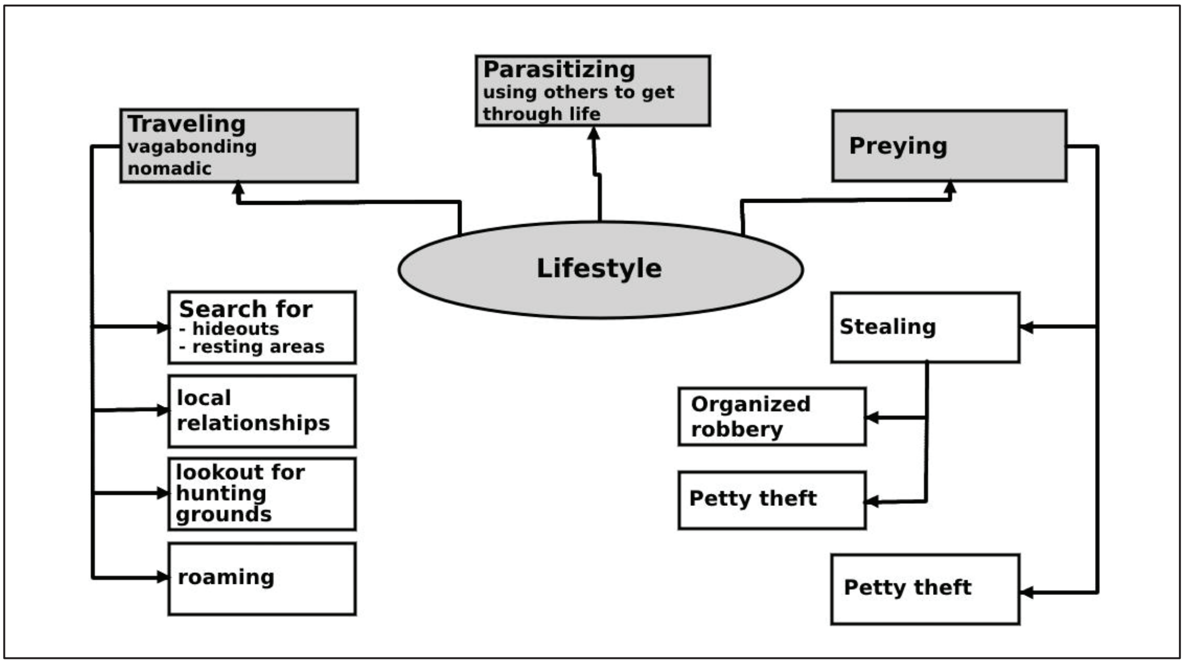

Figure 3. Suspect profile report used by the State Office of Criminal Investigation of Baden Wurttemberg, Germany in the case of the Heilbronn Phantom filled with all kinds of anti-gypsyist stereotypes. Translated and redrawn by us. The German version is in Lipphardt A. (2021: 228).

The Milica van Doorn case: Constructing a suspect population responsible for solving a criminal case

The Milica van Doorn case also took place in the Netherlands, in the municipality of Zaandam near Amsterdam, where the 19-year-old Milica van Doorn was raped and killed in June 1992. In the following years, the police investigation was unsuccessful, because there were no useful clues aside from a witness testimony of a couple who had seen a "Turkish-looking" man on the evening of the crime riding a bicycle near the later crime scene. The DNA profile from the crime scene did not lead to a match in the DNA database of the Netherlands Forensic Institute, and neither did further investigations in 2001 nor voluntary DNA testing from 2002 to 2004 in the vicinity of the victim (Peters, 2018).

Eventually, in 2008, the Procurators General authorised a BGA analysis of the crime scene DNA, revealing that the suspected perpetrator's DNA profile was more common in Turkey and North Africa. Based on this, a group of 75 men of Turkish descent between sixteen and thirty years old at the time of the crime were asked to contribute their DNA to the investigation (Toom, 2010), but this also did not result in a match. Finally, in 2017 a DNA dragnet search was carried out following a change in the law, which allowed so-called familial searching[14] utilising DNA analysis. This time the group who was asked to give their DNA consisted of 133 men of Turkish ancestry who had lived near the crime scene in 1992 or who were family members of these residents. According to the police's statement and the media reports of the time, a comparatively cautious approach was taken (cf. van Oorschot and M'charek, 2021). It involved police communication with representatives of Turkish-Dutch and Kurdish-Dutch religious communities, explaining the goal of DNA testing, asking for support and thanking the participants afterwards in several media posts for their willingness to donate their DNA for the investigation. The result was that only two of the selected individuals did not participate in the dragnet (Stoker, 2020). One of them was finally identified as a suspect via his brother's DNA and by means of a court-ordered DNA identity test. He was sentenced in court in 2018 – and at the time of writing this article a verdict for the case is still pending in a higher court.

Although the investigators tried to be cautious in several respects to avoid racist stigmatization, the case nevertheless demonstrates how EDNA application has inherent problems that do not vanish even in a best practice scenario. Above all, it becomes clear how EDNA results tend to put pressure on ethnically marked persons, grouping them in one seemingly homogenous "community" that is then asked to take responsibility for the investigation. In any case, it is hard to imagine that the search for an offender of Dutch origin would have been conducted with similar pressure on all members of the Dutch ethnic group or that "the Dutch community" would have been addressed as such by investigators. Moreover, the success of the investigation was due to a large extent to the substantial limitation of the group of suspects, which was only possible because of their ethnicity. BGA and FDP that attribute a suspect's DNA trace to minorities are translated as knowledge about a "suspicious population", and the formulations of forensic experts such as "the DNA profile is more common in Turkey and North Africa" are turned into generalising statements such as "the perpetrator is a Turk" (M'charek and Toom, 2011; cf. Cole and Lynch, 2006). A similar approach would probably not be adopted towards a suspect believed to be of so-called autochthonous Dutch origin, firstly because there are far too many people of this population group living in the urban area concerned, and secondly because the search for a single perpetrator of Dutch origin would not lead to all white people being addressed as a "suspect population" or to the demand that they as a population group assume responsibility for helping solve the case. This case is therefore yet another example of how EDNA contributes to the strong structural targeting of minority groups by investigating authorities and, beyond that, how a group framed as "ethnical group" is put under pressure to take responsibility as a "community" only because of a common ethnic or religious background.

First BGA analyses in Germany: No minority characteristics, no investigative use

Meanwhile, since the legalization of BGA forensic analysis in the state of Bavaria, Germany in 2018 for the vaguely defined purpose of “danger prevention” (Rath, 2019), two such cases have drawn public attention. The first EDNA was performed on the DNA of a serial rapist, referred to by the media as the “Allgäuer Triebtäter” (The Sex offender of Allgäu), who had attacked at least six girls and women between 2000 and 2011. The BGA analysis did not elicit the anticipated investigative success, since the ancestry of the perpetrator was predicted to be “European”. “For a manhunt this description is simply ‘not enough’”, a newspaper article quoted the Federal Criminal Police Office in charge of the investigations as saying (Rath, 2019; our translation).

In a second case, Bavarian police commissioned a BGA analysis to find the suspect in a murder case from 2013 referred to as the “Isarmord” (Isar murder). In this case, a male suspect had stabbed the 31-year-old Domenico Lorusso in Munich with no apparent motive. A DNA dragnet search with 6,500 men revealed no matches. At the beginning of 2020, an EDNA was carried out which predicted that the offender was very likely to have brown or light brown hair, brown eyes and medium skin colour. In addition, he would probably come from Europe, and he himself or his male ancestors would come from northern Ukraine, Russia or Belarus (Hans, 2020). While the lead investigator told a newspaper that the DNA analysis “outperformed his expectations”, the author of the article points out that “the description more or less applies to the average Munich inhabitant” and “millions of Europeans” (Hans, 2020; our translation). No suspect had been arrested by the time this article was written. This confirms what M’charek already stated for the Vaatstra case and the first EDNA analysis carried out there, namely that in most European contexts ‘whiteness’ does not constitute an informative finding for a police investigation (M’charek, 2008: 525).

Conclusion: Racializations are incorporated in and reproduced by EDNA

In employing the analytical model of dispositive analysis, we have examined the reality of EDNA in three analytical dimensions – that of EDNA as a technological instrument, EDNA in media discourse, and real-life cases of EDNA application in forensic investigations – revealing different types of racialization in all three dimensions. First, we were able to reconstruct how the development of this technology has been marked by very selective sampling strategies, by homogenising within group categories and overemphasising the differences between them, by classifications based on existing, (culture- and nation-specific) constructed ‘race’ and ‘ethnicity’ categories and by the reduction of gradual genetic diversity to a few categories. Second, we examined how public discourse regarding the legal approval of these technologies in Germany and Switzerland is characterised by undue faith in its effectiveness as well as by racialised and often openly racist images about the ‘criminal immigrant’ and the ‘dangerous or sexually unrestrained other’. Third, our analysis of applications of EDNA technology revealed how real-life EDNA analyses can lead to racialising and racist attribution of crimes to particular populations and can thus lead to the consolidation of

Table 1. Overview of the results of the dispositive analysis of the different dimensions examined

Dimension of analysis	Forms of racialization and their outcome and effect
1. Design and operating principles of EDNA technology	• Reduction of gradual variability into distinct typologies • Naturalization of cultural- and nation-specific classifications • Homogenization within groups and emphasis on difference between them
2. Media and political discourse on the introduction of EDNA	• Massive intertwinement between the debate and crimmigration narratives • Use of essentialising group assignments • Racist images of the ‘dangerous other’
3. Cases of EDNA application in forensic investigations	• Creation of suspect populations, criminalization of populations • Assignment of responsibility to minority groups and communities • Danger of stereotyping, stigmatization and racial profiling

racist ideas. Our investigation has also shown that EDNA entails the danger of reinforcing stereotypes, can impose a special responsibility for investigations upon minority groups and, above all, makes already often marginalised groups even more vulnerable to racial profiling.

In the cases investigated here, it is quite obvious that the idea of race has by no means been overcome but rather remains very persistent, mobile and mutagenic; it shifts and changes. While the term race has been largely absent in recent years, the concept persists and reappears intermittently in discourse as well as in some praxis fields (cf. M'charek et al., 2020). This can be observed in the case of EDNA technologies, which target not individuals but rather human groups, which therefore have to be constructed using various selection practices. However, EDNA technologies should not be interpreted as an intentionally racist project, and the actors involved, such as politicians, media advocates and police practitioners, do not pursue a common racist strategy. Structurally, however, racialization remains a constitutive force in the problematic process of dividing people into manageable group categories, since researchers and investigators can escape neither the typological classifications of population groups which they were socialised to perceive nor the historically charged connotations associated with particular phenotypic characteristics and geographical spaces. Even if predicting someone's race is not the aim of the analysis, and even if explicit forms of racialization are actively avoided, reinscribing race and a racialising focus on minorities remains intrinsic to EDNA technologies.

Furthermore, we revealed in our study that the three dimensions examined do not stand independent of each other but are interwoven and mutually supportive without a directed causal relationship. To this end, the dispositive concept, as we outlined it in reference to Foucault (1980) and Jäger (2001), served us as a very useful analytical model to grasp the interconnectedness of these technologies, discourses and practices. In addition, this concept allows us to focus on the complexity of the problem, showing clearly that the negative effects of EDNA cannot be eliminated by correcting them only at one level (for instance, only with a more sound police practice, discursive or technological approach). And lastly, we were able to use dispositive analysis to identify how the application of this technology in investigative work can have very different effects in different situations.

Indeed, because the problems related to EDNA technology occur in apparently unrelated fields and because the consequences and effects of its application become invisible behind the inflated expectations regarding their results, these problems can become especially powerful and difficult to avoid. Even in cases in which attempts were made to avoid racist effects of EDNA technology through anti-discrimination measures, the risk of being profiled is mainly carried by members of minority groups.

In order to grasp this complexity of issues we use the term 'racial profiling' as a heuristic tool to highlight the structural problems that cause members of racialised groups, in particular, to be targeted by investigating authorities. The term 'genetic racial profiling' draws our attention to these effects and impacts with regard to EDNA-based police practices, which are inclined to selectively focus on minorities and thus reinforce societal patterns of discrimination and disadvantage. The example of EDNA-based forensics illustrates the paradox that in current post-racial societies biological concepts of race are rarely referred to openly, even as biological attributions to specific, historically categorised groups are all the more interwoven in such technologies, meaning that race- or ethnicity-related discrimination is merely hidden behind supposedly purely technical procedures and discursively legitimised police practices. Race is therefore both absent and present at the same time.

Finally, our analysis demonstrated that EDNA tends to have very unequal effects on majority and minority populations. This is because EDNA is only a useful investigative tool if its DNA analyses reduce the suspect group to a manageable size for investigation. In addition, the search for a wanted person reconstructs a particular minority population as a 'suspicious population' (cf. M'charek et al., 2020). Once again, these effects of EDNA in its forensic application can be linked back to the technological development of the databanks themselves, not in the past but also in the present. That's why we end this article with two examples of discriminatory practices of data collection. One very problematic development appears to be the research of China's Ministry of Public Security, which has recently been made public. According to critical observers (Wee and Mozur, 2019; Moreau, 2019), DNA samples were taken without proper informed consent and allegedly at times by force from a large number of people belonging to Tibetan and Muslim minorities in China, in order to develop EDNA research to predict external characteristics and origin from DNA. Additionally, companies based in Hong Kong and China are developing facial recognition systems for police authorities that they claim can assess whether a person is a Uighur (van Noorden, 2020). Together these technologies contribute to mass surveillance and human rights abuses of discriminated minorities (Wee and Mozur, 2019). It would be naïve to think that this operation of the Chinese state can be separated from EDNA research in the West. In fact, the studies were conducted partly in cooperation with and financed by Western research institutes, and their results have been published in prestigious international scientific journals and included in the research databases that form the basis for EDNA investigations in the international context.[15] Additionally, some European researchers engage in ethically questionable collection of data from minorities themselves. At the end of 2020 Lipphardt V et al. reported that DNA data of European Roma is frequently used without documented informed consent and often transferred from medical studies into forensic research (Lipphardt V et al., 2021b; Schiermeier, 2021). Such threats are especially prevalent for minorities and already underserved communities (Machado and Granja, 2020).

In conclusion, EDNA exacerbates an already existent structural problem by exposing people from discriminated social groups much more often to the danger of being the object of criminal investigations and criminalising stereotypes. Extended DNA analyses may thereby contribute to casting suspicion on entire population groups. In this regard this profiling not only discriminates against those directly subject to it but also their family members and communities, affecting relationships in society as a whole by creating and stabilising categorical divisions. Not only the consequences of over-policing minority population groups, but also the inflated hopes of solving complex security problems by technological means have not yet been sufficiently considered in public discourse. The effects of the three dimensions of EDNA technologies are interwoven and reinforce each other. Unquestioned, the supposedly neutral classification requirements of forensic applications, accompanied by the relatively uncritical discourse regarding the limits and risks of EDNA technologies, create fertile ground for genetic racial profiling to take place. Scientific research and a broad political as well as societal debate on the problematic social implications of these technologies are therefore urgently needed.

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Notes

1 Furthermore, research is being done on estimating people's height and their likelihood of having freckles. Some companies are also already claiming that they can estimate the age of a person using an epigenetic test procedure. Profiles for other features are in development, such as facial features, early baldness in men, ear shape, etc.

2 See for example Lipphardt et al. (2021a) and Amelung and Machado (2021) or the terms used by the Freiburg Initiative, http://www.wie-dna.de/english/. In most scientific and popular texts on the subject, the technologies investigated here are subsumed under the term 'forensic DNA phenotyping' (FDP). We consider this label to be misleading when used as a catch-all overarching term beyond the DNA analysis of probable phenotypic characteristics. For instance, when biogeographic ancestry (BGA) is subsumed under FDP it is then misunderstood as giving information about phenotypic characteristics. We therefore use EDNA as the overarching term to include both FDP and BGA. Even more misleading are other terms such as 'molecular photofitting' or 'composite sketching' which incorrectly suggest technological capacities which do not currently exist.

3 Our analysis of racialization encompasses different ways of constructing groups and is intended to be sensitive to the European context in particular, as racialising demarcations often function differently here compared to the US – less along the colour line and more linked to nationalisms, origin, migration history, language, religion and culture-related aspects.

4 We can thankfully draw on the data collected by Sarah Weitz, Nicholas Buchanan and Veronika Lipphardt in their media analysis of the debate in Germany (see Weitz and Buchanan, 2017).

5 One early forerunner Francis Galton already tried to determine race and nationalities from fingerprints using statistical methods (Galton, 1892). Furthermore, there are patterns of continuity from early genetic studies of differences between racial groups – such as seroanthropological research on blood samples in the first half of the 20th century and population genetics since the 1930s – to today's attempts to genetically predict the origin and visible features of a person (cf. Spörri, 2014; Roberts, 2011).

6 By pointing to this consensus we do not want to imply that the already established technologies of DNA profiling for identification, e.g. the technologies of dragnets and forensic DNA databanking, are uncontroversial. Data protection and civil rights concerns have been expressed regarding the massively expanded access to this highly sensitive personal data during the last two decades. See e.g. publications of the NGOs Center for Genetics and Society, Gene Watch UK, Council for Responsible Genetics, (Krimsky and Simoncelli, 2011; Lynch et al., 2010).

7 As another earlier source, the philosopher of science Lisa Gannett (2014), cites a poster presentation at a meeting of the American Society of Human Genetics by Mark Shriver and others from 2000, in which BGA was introduced in order to measure the "components of ethnicity that are biologically determined" (Pfaff/Parra/Shriver cited in Gannett 2014: 175).

8 https://empop.online/empop_stats, accessed 2 June 2021.

9 For an explanation of this technology, see https://hirisplex.erasmusmc.nl, accessed 2. June 2021.

10 This was expressed, for instance, by the right-wing populist Pym Fortuyn (de Koning, 2012; cf. M'charek, 2008).

11 Details on this and on the Milica van Doorn case were kindly provided by the Dutch forensic geneticist Peter de Knijff, through personal correspondence and an interview.

12 Following additional reforms in 2012 and 2017, the Dutch government regulation on DNA investigations in criminal cases stated in article 1 b the legalised analysis of: "a. het geslacht [sex]; b. het ras [race]; c. de oogkleur [eye colour]; d. de haarkleur [hair colour]."

13 See the extensive documentation on "Unravelling the NSU complex" at www.nsu-tribunal.de/en.

14 Familial Searching uses DNA analysis to search for partial matches within DNA profile databanks. It is based on the principle that siblings, parents, uncles, aunts and cousins, on average have more in common in their DNA profiles than unrelated persons. If this method reveals partial matches with the DNA of an unknown suspect, it is possible to investigate within the family of the partially matched person in order to search for the perpetrator.

15 One of the scientists responsible for this research is Fan Liu, a professor at the Beijing Institute of Genomics, who often collaborates with the most prominent FDP researcher Manfred Kayser (mentioned above) at the Erasmus University Medical Center in the Netherlands – not only as a member of his research group, but also as a frequent co-author (Pośpiech et al., 2018; Liu et al., 2019).

Experience Distributed in the Biodiversity Science-Base

Adrian Mackenzie

School of Sociology, The Australian National University, Australia
adrian.mackenzie@anu.edu.au

Abstract

Critics of biodiversity science and environmental governance point to exclusion and absence of diverse experience from science-based governance, sometimes effectively dividing domains of science and experience/values. This paper, following an alternate line of thought drawn from John Dewey's *Nature and Experience*, analyses a series of scientific publications on biodiversity from 1989-2020. It argues that experience abundantly populates the biodiversity science-base, although in highly distributed forms. Dewey's account suggests that knowledge of biodiversity derives from an unanalyzed continuum of experience. Reading the publications as traces of occurrences of encounters preceding, accompanying, and sometimes deriving from knowledge, the paper locates and characterises differentiated, sometimes impersonal gradients of experience, developing a figurative model of distributed biodiversity experience. It concludes that experiential diversity occurs widely in the science-base, but communication of and participation in this experience is frequently marginalised by the primacy of knowing.

Keywords. Biodiversity, experience, Dewey, knowledge, distribution

Introduction

"Listen to the voices of experience" advise the social scientist and museum curator authors of a 'Comment' in *Nature* (Turnhout et al., 2012: 454) responding to the 2012 initial meeting of IPBES, the Intergovernmental Platform for Biodiversity and Ecosystem Services IPBES (2019), in Panama. Turnhout and co-authors (2012) question the primacy of a 'science-based understanding' emphasising ecosystem services in the plans and actions of IPBES. They point to the limits of the scientific concept of biodiversity:

> There is no single scientific definition of biodiversity, nor is there one that does justice to the many ways of living with and knowing nature that human cultures have developed. The IPBES has not taken adequate notice of this and is promoting a predominantly science-based understanding of biodiversity, with ecosystem services taking centre stage. (Turnhout et al., 2012: 455)

Much of the framing discussion and policy-making, they say, presumes the coherence, unity and consistency of biodiversity science. They highlight instead the need for connections between "organized global knowledge and the many biodiversity actors operating at multiple levels and scales" (Turnhout et al., 2012: 455). They call too for acknowledgment of "monetary, aesthetic and sacred values" in the meanings of biodiversity, and inclusion of actors such as farmers, fishers, businesses and indigenous people as "knowledge-holders" (Turnhout et al., 2012: 455).

The needs for inclusion, participation and voice are widely acknowledged in conservation biology and ecology. Calls for a greater role for social science, plural values and experiences date from the first major scientific conferences and publications on biodiversity during the 1980s, and can be see in *urtexts* such as *Biodiversity* Wilson (1988). They continue through to the present (Miller, 2005; Castro and Mouro, 2016; Bonebrake et al., 2018; Stenseke and Larigauderie, 2018; Wyborn et al., 2020a). Repeatedly, however, attempts to engender everyday awareness of biodiversity (Prévot et al., 2018) or to increase public participation in or enhance democratic deliberation concerning biodiversity founder. Almost a decade later after IPBES started, it seems as though these diverse voices and actors have not been centre-stage in biodiversity science, even if the problem of their bit-part roles has long been recognised. The Convention on Biological Diversity reports in 2020 that nearly all biodiversity targets relating to participation and knowledge partnerships (the 2010-2020 'Aichi Targets') have not been met (Greenfield, 2020; CBD Secretariat, 2020).

This paper starts from the proposition that biodiversity science already bears within it many forms of experience. Important components of biodiversity experience occur in science. If we could recognise those components, problems of inclusion, participation, and the permeability of scientific knowledge infrastructures to other knowledges might be re-framed. In order to test this proposition, I suspend the assumption that biodiversity is only about knowing, or knowledge in any narrow sense. I instead ask how scientists, situated and equipped, monitoring field plots, checking the fit of a species distribution model, conducting experiments in interspecies competition or the dynamics of dispersion in a metacommunity, experience biodiversity. A letter from ecologists to *Science* calling attention to the grief of environmental scientists Gordon et al. (2019) hints at this possibility: knowledge is certainly a core component of biodiversity experience, but one that derives from embodied, affective, situated encounters between scientists, other people and other species. I suggest that the practices of ecologists, conservation biologists, taxonomists, and others is a distributed form of biodiversity experience, a distribution of experiences that invites restoration or re-introduction more generally.

Inhabiting the science-base

Seeking to bring wider experiences into knowledge of biodiversity or beginning to widen the concept of biodiversity itself (Wyborn et al., 2020b), I ask: what forms of experience occur in biodiversity science? The problem of tracking experiences of biodiversity resembles the challenges faced by ecologists trying to measure biodiversity. What to count (taxa, species, functions, genetic differences?), where and when to count them, on what scale to count them, and how to compare counts between different places: all of this makes assessment of biodiversity far from simple, especially when what is seen to be present is recorded much more than what is absent. Similarly, the occurrences of experience, their occurrence in many interconnected situations, and even what counts as the occurrence of experience of biodiversity is bound to be unevenly dispersed and shaped by many different histories, processes and events. The concept of distributed experience endeavours to incorporate some of that plurality.

In this paper, the practical approach to the question of experience in the biodiversity sciences is artificial. I assembled and worked with around 134,000 publication records collected from the ISI Web of Science in response to the simple topic query 'biodiversity', delimited by the years 1989-2020.[1] I note that the resulting *biodiversity science-base* is not as extensive as 'genome' (500k Web of Science results) or 'cancer' (2.5M results), but this is an expansive literature, roughly as great as the high-profile area of computer science 'machine learning' (125k records). The records are limited, comprising titles, authors, abstracts, cited references, keywords and bibliographic fields. They lack the density of documentation, practices and material culture of biodiversity science in its field, laboratory, analytical, knowledge infrastructure or policy/governance interfaces. I regard the publications records as analogous to observations of the presence of species in a field site. Although the observations are abundant, they give little clue to the assemblage of lives, histories, equipment, conferences, careers, institutions, funding measures, databases and research programmes of the scientists. Like any ecological assemblage, the biodiversity science-base encompasses niches, habitates and communities whose interactions and relations are not clear (Ovaskainen and Abrego, 2020: 5).

The Web of Science biodiversity dataset certainly presents, authoritatively perhaps, what Turnhout and co-authors (2012) point to as the 'science-based understanding.' But the movements of biodiversity experience through this collection of documents, documents dedicated to the communication of biodiversity knowledge, is not standardized or monolithic. The range of concerns in the science-base, its working methods, its connections to various geographies, policies, peoples and experiences are multiple and diffuse. Like scientific publication records more generally, the biodiversity science-base records the scale-shifting doings of the social (Latour et al., 2012). Traces of national and international governance, economies, cultures, media and many histories of colonisation, development and industry criss-cross it. Government policies, regulatory frameworks working at various levels of governance, conservation efforts and environmental management practices in sanctuaries, parks and other zones, popular culture and media attention such as wildlife or environmental documentaries, or everyday experiences as imaged on Instagram, in travel and tourism, or in any of the citizen science projects impinge upon it.

But there are people in the science-base pivotal to understanding of biodiversity experience in its inevitable mingling with the pressing realities of environmental management, global competition and the politics of climate change. The author list of almost 235,000 amounts to the population of a small city or the number of employees in a very large corporation. In various ways, this population must have lived during 1990-2020 through many encounters with places, habits, biomes, landscapes and species.

The analytical work on the records of titles, abstracts and citations base has several points of reference. A major influence comes from John Dewey's (1958) arguments in *Experience and Nature* for an empiricism that positions all experience in and of 'nature.' Much of Dewey's argument in this work and others such as *Reconstruction in Philosophy* (Dewey, 1957) centres on the "when and where of the act of selection" (Dewey, 1957: 30), an act that splits knowing off from unanalyzed facets of experience like a plank from a tree. There is much in Dewey's re-grounding of experience in nature that goes beyond social construction of knowledge claims or their re-grounding in the lifeworld experience.

In *Experience and Nature*, Dewey situates experience as an 'unanalyzed totality' of act and material, subject and object:

> "Experience" denotes the planted field, the sowed seeds, the reaped harvests, the changes of night and day, spring and autumn, wet and dry, heat and cold that are observed, feared, longed for; it also denotes the one who works and rejoices, hopes, fears, invokes plans, magic or chemistry to aid him, who is downcast or triumphant. It is "double-barrelled" in that it plants and reaps, recognizes in its primary integrity no division between act and material, subject and object, but contains them both in an unanalyzed totality (Dewey, 1958: 8).

Dewey's agroecological formulation lists fields and seasons before 'the one' who works or hopes. He resists the usual identification of experience with subjectivity or consciousness. Experience is a diverse, continuous hypervolume of affects, practices, expectations, things and thoughts, distributed across gradients of intensity. Much of *Experience and Nature* is directed against any splitting of experience into individual, personal or even human states of mind, and against any general ends or meaning. Although he retains the problematic term 'nature', he recasts it as the unanalyzed totality of experience. Dewey attaches experience to nature: "it is not experience which is experienced, but nature" (Dewey 1958: 4a]. 'Nature is experienced': the proposition maintains a provocative ambiguity. Is Dewey saying that nature experiences too?[2]

What happens if we substitute the term 'biodiversity' for Dewey's 'nature'? With an eye on the acts, materials and unanalyzed totality of biodiversity, I navigated the science-base using analytical techniques such as keyword occurrence, citation analysis and topic models, many of which are now highly developed in digital STS and digital humanities. I heed Christopher Kelty and Hannah Landecker's call for "highly specific empirical work on the general" in contemporary scientific literatures (Kelty and Landecker, 2009: 177). Landecker and Kelty pose the problem of how to stage meaningful encounters with scientific literatures whose scale and distributed mode of existence eludes the grasp of reading focused on cases studies or individual works. They suggest that the material actions, problematisations and plots running through the science-base can only surface through methods that combine close reading with techniques for analysis of spread and circulation. Ecologically speaking, the problem of contemporary science-bases is their complicated community composition. In tracking experience across the science-base, I make use of tabulations, counts and plots of occurrences that would not be alien to ecological research but draw also on the methodological innovations developments in recent digital sociology and digital humanities (Marres, 2017; Jockers, 2013), and from cultural sociologies that argue for nuanced interpretative work through modelling large textual collections (Mohr and Bogdanov, 2013). I seek to perform a distant but depth reading (Moretti, 2013) of experience in the biodiversity science-base.

There is one final and overarching consideration in attending to the biodiversity science-base. The concepts and material actions associated with biodiversity sciences could and perhaps should more affect social science and humanities thinking. Ecological metaphors are common in social science and humanities research, but sometimes remain abstract. Recent scholarship works more closely with ecological thought. When Anna Tsing writes "I look for disturbance-based ecologies in which many species sometimes live together without either harmony or conquest" (Tsing, 2015: 5), she affirms an ecological conceptual cross-fertilisation resting on the resonant term 'disturbance.' Notions such as assemblage, niche-partitioning, distribution and metacommunity as well as disturbance, succession, colonisation, extinction or competition, may suggest ways of re-configuring understandings of experience. Working closely with the science-base can yield conceptual as well as empirical insights. Most immediately, for instance, it suggests ways of approaching the science-base ecologically. Jamie Lorimer's (2015) account of biodiversity also offers a lead here. He approaches biodiversity as a distributed accomplishment. He writes that biodiversity "came out of and is thoroughly dependent on the embodied, affective, and technological encounters between multiple species. (…) Biodiversity happens in an assemblage. It inherits and is haunted by particular knowledges, habits, instruments, territories, and practices" (Lorimer, 2015: 58). This suggests that experience of biodiversity, even in the biodiversity science-base, will be distributed not necessarily unified in a concept.

To summarise the approach: take a path that begins by observing explicit occurrences of experience in the biodiversity science-base, contrast those experiences with material actions projected on the basis of knowledge, maps secondary or derived paths running between occurrences of experience and projected actions, and then look for the latent mixing of experience that gives rise to the biodiversity assemblage. A series of plots and tables figure these different patches of experience not in the interests of statistical rigour but in view of empirically grounding a reading of the biodiversity science-base in view of its dispersal, connectivity and nestedness.

Occurrences of experience

Experience is not always named where it occurs. Dewey (1958) observes in *Experience and Nature* that "one would probably have to search long time through reports of special researches in order to find the word 'experience'" Dewey (1958: 2). The word 'experience' is actually quite common in the science-base, just as common in fact as the term 'global biodiversity', both occurring in 4.5 thousand documents in the collection. 'Central Mexico has experienced a decline its natural

Table 1. What experiences

pre	keyword	post
Climate and grassland ecosystems likely will	experience	the greatest proportional change in biodiversity
Northern temperate ecosystems are estimated to	experience	the least biodiversity change because major
Interacting species	experience	their surrounding landscape at different spatial
Most host-parasite systems are predicted to	experience	more frequent or severe disease impacts
whether populations have also	experienced	gene flow . These questions can
Pairing scheme and control sites that	experience	similar environmental conditions (16 %
In particular, food webs	experience	‘rivet-like’ thresholds past which
All other farms, however ,	experienced	greatly reduced diversity and abundance of
China , and Africa have	experienced	the highest rates of urban land
Places	experience	forest transitions when declines in forest
Sweden and Denmark now	experience	severe seasonal hypoxia , Synthesis of
Identifying regions projected to	experience	high magnitudes of
The Earth’s terrestrial surface may respectively	experience	novel and disappearing climates by 2100
Increase the risk that species will	experience	the loss of extant climates or
some reefs have	experienced	relatively rapid recovery from severe bleaching
Based on that and on the	experience	of the projects reported in this
And those of native origin also	experienced	increased risk of local extinction after
For example , flatfishes have	experienced	little , if any , recovery
As well as the clades that	experience	them , our diversity tree provides
Butterflies	experienced	the greatest net losses , disappearing
However, in ponds that	experienced	drought , I found much higher
Biodiversity conservation and the extinction of	experience	. Biodiversity loss is a matter
Arrived at using theory and practical	experience	, include : the log series
Having	experienced	mass disease-induced mortality of the herbivorous
The new interactions and conditions	experienced	by the invader may influence both

vegetation.’ ‘Food webs experience “rivet-like” thresholds.’ ‘Some reefs have experienced relatively rapid recovery from severe bleaching.’

Experience in the biodiversity science-base corpus occurs in some obvious and not-so-obvious ways. As the first table of experience below indicates, many usages of the term are impersonal: grasslands, temperate ecosytems, host-parasite systems, populations, food webs, places, clades and communities all undergo something. In all of these occurrences, experience principally concerns a change, or a transition, often a loss, reduction or risk. ‘Experience’ here is a synonym for ‘undergoes’ or ‘suffers.’ Experiences are oriented in time. Something has happened, is happening, or will happen, and the event is dramatic, great, drastic, severe, widespread or at a fast rate. Is there anything in the biodiversity assemblage that does not experience in this sense? It is possible that biodiversity itself experiences something in this sense.

In the other occurrences, or around 25% of overall 'experience' in the science-base, experience concerns something learned or knowledge gained: 'arrived at using theory and practical experience', 'experiences of adaptive governance','own experiences of co-physiological indicators are presented', or 'past experiences play a crucial role' (see table below). For the most part, these experiences belong to human agents. Visitors, tourists, Belgians, citizens, residents, participants, or just people perceive, learn or have in interest. Scientists stand at some distance from this usage. In contrast to the impersonal experiences of the wetlands and rangelands witnessed by scientists, these experiences are marked by personal pronouns such as 'we' and possessive adjectives such as 'their.' The hallmark of attribution to human agents, or to recognisable forms of selfhood, is the plural noun 'experiences.' In this setting, experience often refers to the past. It can be 'life experience,' tradition, or the result of

Table 2. Who experiences

pre	**keyword**	**post**
The review concentrates on	experiences	of adaptive governance of social-ecological
On various knowledge systems and	experiences	for the development of a
And educated , their life	experiences	, and the options they
With a distinct dynamic and	experiences	alternative manifestations of environmental change
Here , own	experiences	on eco-physiological indicators are presented
Finally , past	experiences	play a crucial role in
The majority of conservation actions remain	experience-based	and rely heavily on traditional land
We found that many past	experiences	did not result in self-perpetuating
Applies knowledge gained from	experiences	in human and veterinary medicine
The design of powerful interpretive	experiences	. One of the aims
Memories of their wildlife tourism	experiences	and explores processes through which
Explores processes through which such	experiences	can lead to long-term changes
Strengthen these dimensions of memorable	experiences	in order to enhance visitor
Wildlife tourism ; Visitor	experiences	; Tourist behaviour ; Environmental
Developed through daily life	experiences	with the mutual relationship between
This article reviews these	experiences	, and their broader implications
Strategies build upon valuable local	experiences	and knowledge in traditional fanning
While also creating truly transformative	experiences	for tourists.
Human-modified landscapes . Southeast Asia	experiences	one of the highest rates
Common misconceptions through examining the	experiences	of two innovative approaches to
Based upon our	experiences	developing models for the state
Compare them with the field	experiences	of specialists for specific biomes
Article will discuss the Belgian	experiences	with MSP. It will
Based on our	experiences	, we recommend developing "
This paper we draw on	experiences	from this project to consider

organised activities such as experiments, projects undertaken, or policy or management practice: 'alterations of riparian', 'from this project', 'play a crucial role'. Experiences 'of/in/with nature' are common, followed by 'lessons/learning/drawing/gained from/perspectives on' something. Experience, when it is mentioned explicitly and associated with a human subject is either an encounter with action-oriented, knowledge-oriented situations such as parks, education, public engagements, ecotourism or collaborations, or a source of ideas, attitudes, perceptions, and views.

It is possible to see in the wordcloud (Figure 1.a) some of the ways in experience has been qualified when it is mentioned. 'Direct,' 'past', personal, practical and previous experience overshadow lived, less, negative, human, own and recent experience. Embodied, immersive, urban and formative experience fringe the cloud. The wordcloud derives from part-of-speech analysis of Web of Science records that mention experience. Where experience is used as a noun, I gathered all preceding adjectives, and tabulated these, including in the plot only those occurring three or more times. These qualifications of experience point to some focus of attention or awareness of biodiversity, possibly distinct from a vaguer and more extensive background field of meanings and immediate sensations or feelings. Many of these qualifiers concern a heightened focus – 'direct', 'practical', 'lived' or 'own'. It is not hard to see them also as somewhat individualizing. Terms such as 'personal,' 'first-hand', 'subjective', 'own' and 'individual' weight individuals as the locus of experience. But many of qualifiers of experience, such as 'operational', 'collective', 'empirical', 'positive' or 'aesthetic' are not specifically individual. They span times: 'past', 'prior', 'previous', 'first', 'long' and 'early' shade through 'recent' and 'ongoing' into 'new', 'present,' current, 'everyday' towards 'future'. They are somewhat dispersed in space: 'local', 'Australian' versus 'international', 'worldwide' or 'global.' Qualities of experience such as 'broad,' 'rich', 'sufficient', 'limited', 'good', 'considerable', 'vicarious', 'unique' or 'human' are similarly varied. These qualifying modes of experience – heightened awareness, identification with selfhood, connection with collective, movement along

Figure 1a. Qualifications of biodiversity experience

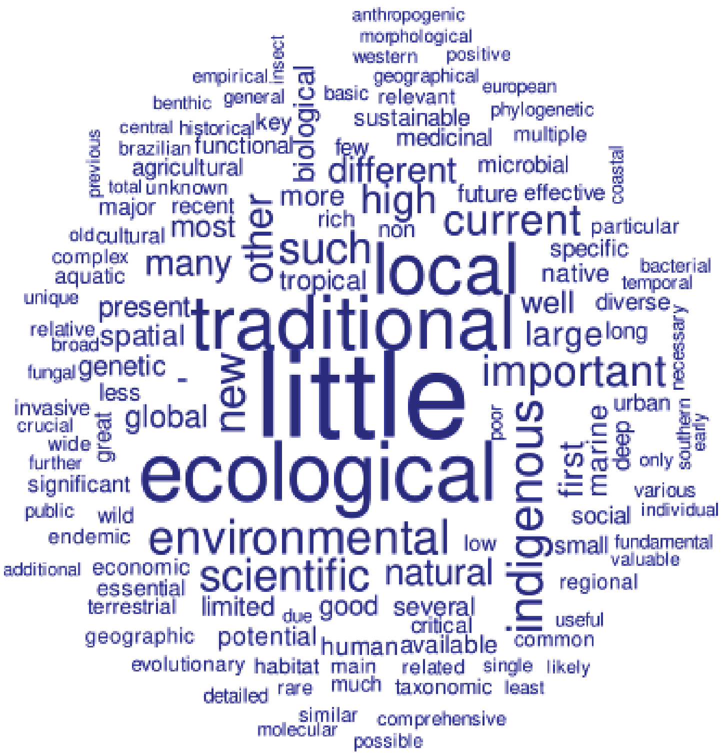

Figure 1b. Qualifications of biodiversity knowing

temporals gradient running from past accumulations to future reference, the spatial dispersion from bodily sensation to globe – are relatively diffuse, overlapping and indeterminate.

By comparison, the qualifications of 'knowledge' are less varied. The wordcloud Fig1.b shows the modifiers of knowledge in the biodiversity literature. The prominence of 'local', 'traditional', and 'indigenous' is obvious, shading off into 'native', 'social', 'European' or public. There are references to scientific knowledges in specific 'ecological', 'environmental' and 'biological' forms, but perhaps less than might be expected in a collection of documents whose primary purpose is to communicate and develop knowledge of biodiversity. It may be that knowing pervades the assemblage and only comes into discussion when there is some question about what kind of knowledges are relevant or important.

Modes of biodiversity action and their projection

Biodiversity is a concept intended order to draw attention to changes in the abundance of living things. It emerged in tandem with the institution of conservation biology as an action-oriented scientific field (Sodhi and Ehrlich, 2010). Perhaps more explicitly than many any other scientific concepts, biodiversity envisages endpoints in action. The span and scope of these actions is broad, and they run through the biodiversity science-base, as noted above, from the outset. The 1991 *Convention on Biological Diversity* (CBD Secretariat, 2011) specifies many actions on the part of nation-states only a few years after initial scientific conferences coin the term 'biodiversity' (Wilson, 1988). Planned actions include protecting public and private areas such as sanctuaries and parks, regulating industries such as forestry, agriculture, aquaculture and fishing, and monitoring of local, national and international urban, marine and land habitats. These actions run across science, industry, markets, state and society. More recent international agreements such as the Aichi Targets (IPBES, 2019) expands the scope of anticipated actions.

The implicit and explicit anticipation of action in biodiversity has been the target of much criticism. Lorimer, for instance, understands 'biodiversity as biopolitics' (Lorimer, 2015: 75), with all the connotations of governmental modes of power. Many critics point to the problems of economic understandings of biodiversity. Echoing McAfee (1999) 's earlier critique of 'selling nature', Turnhout et al. (2013) for instance suggest that an ecosystem service approach to biodiversity fragments 'social-natural relations' into calculable market transactions (Turnhout et al., 2013: 154) and forecloses more constructive or transformative engagements. Indigenous scholars point to the many difficulties in accommodating indigenous knowledges of biodiversity in ecological science (Langton, 2003) and conservation practice (Adams and Hutton, 2007). As Subramaniam (2014) points out, the defining interest of biodiversity in variations and differences has been coupled with elision and marginalisation of lived experiences of difference.

Attempts to construct international or global monitoring systems have been problematised too. In his influential article "Biodiversity Datadiversity," Geoffrey Bowker argued that attempts to merge and unify ecological data in order to construct synoptic or panoptic measures of biodiversity are likely to founder on differences deriving from localities, practices and disciplinary histories (Bowker, 2000). Writing more than a decade later, Vincent Devictor and Bernadette Bensaude-Vincent maintain that efforts to unify datasets on biodiversity knowledge platforms blurs the scientific purpose of measuring biodiversity because data accumulation tends to become an end in itself (Devictor and Bensaude-Vincent, 2016: 9). Each of these assessments or evaluations of biodiversity pick up on projections of action mobilised by biodiversity.

It in no way detracts from these critical perspectives on the biopolitical, marketising, colonising or panoptic facets of biodiversity to suggest that there may be other modes of actions at work in the biodiversity science-base. For Dewey (1958), experience always implies actions, but modes of participation and acting vary widely, from habitual response under the pressure of circumstance to a dawning awareness that "changes everything" (Dewey, 1958: 316). Even "to get a new meaning *is* perforce to be in a new attitude" Dewey (1958: 316). All experience engages a situation, acts on it and is changed in so acting. The crucial question is how. I note that Dewey's account is not species-specific, and perhaps not confined to the living:

> That an individual, possessed of some mode and degree be of organized unity, participates in the genesis of every experienced situation, whether it be an object or an activity, is evident. That the way in which it is engaged affects the quality of the situation experienced is evident. That the way in which it is engaged has consequences that modify not merely the environment but which react to modify the active agent; that every form of life in the higher organisms constantly conserves some consequences of its prior experiences, is also evident. (Dewey, 1958: 246)

Action always occurs in some organised or selected way – a niche, a habitat, a group, a community, a State, an organisation or institution, etc. Orientations to these situations vary. It may be proximity, inclusion, membership, belonging, identification, participation, contribution, watching, 'following', anticipation, etc. Action draws on practices, habits, techniques, materials and infrastructures to assemble people and things in a given situation. Who, how, when and where: these primary facets of biodiversity action are in some ways obvious, but also plural and highly distributed. Dewey (1958: 246) points to the latent but pervasive "operative presence of the self" in the acting, suggesting that all configurations of participatory experience imply an "intimate and omnipresent", but often unacknowledged agent.

Certain terms touching on the situation of actions frequently occur in parts of the biodiversity science-base. Actions can be grouped into general categories in view of how they affect situations. Starting from the 88 journals that have accumulated more than 250 publications during 1990-2020, I took a subset of around 55,000 titles and abstracts from the biodiversity science-base and coded them in two ways. I pattern-matched sets of words relating to broad actions grouped under twelve categories: care, conserve, intervene, fence, manage, market, monitor, prevent, protect, regulate, reduce, and restore. Some categories include a variety of related actions. For instance, the 'restore' category also includes regenerating, rehabilitating, reintroducing, reforesting, and rewilding actions. I also grouped the journals into

5 loose categories aligned with different situations: conservation, ecological science, general science, industry and society.

Both the action and situation groupings are problematic classifications. They do not exhaust biodiversity-related actions. An interested reading may miss action. The mention of an action – culling, restoring or weeding – certainly does not signify its occurrence, only that attention has been paid to it. The groupings collapse actions on different scales and modalities: constructing a fence is a much more specific action than managing an ecosystem or protecting a biome such as a reef or forest. Nor do our journal categories map more than roughly the differences between the situations mentioned above. I would expect *Conservation Biology* articles to have different concerns to *Zootaxa* or *Marine Policy*. Whether *Global Conservation and Ecology* falls in the conservation or the ecology category is harder to decide. Similarly, articles appear in high-profile general science journals such as *Nature* and *Science* for a range of reasons, sometimes associated with problems of global environmental governance, sometimes by virtue of catastrophic environmental change, and sometimes because it announces a technique or finding that lifts it above the specialised sub-fields of the biodiversity sciences.

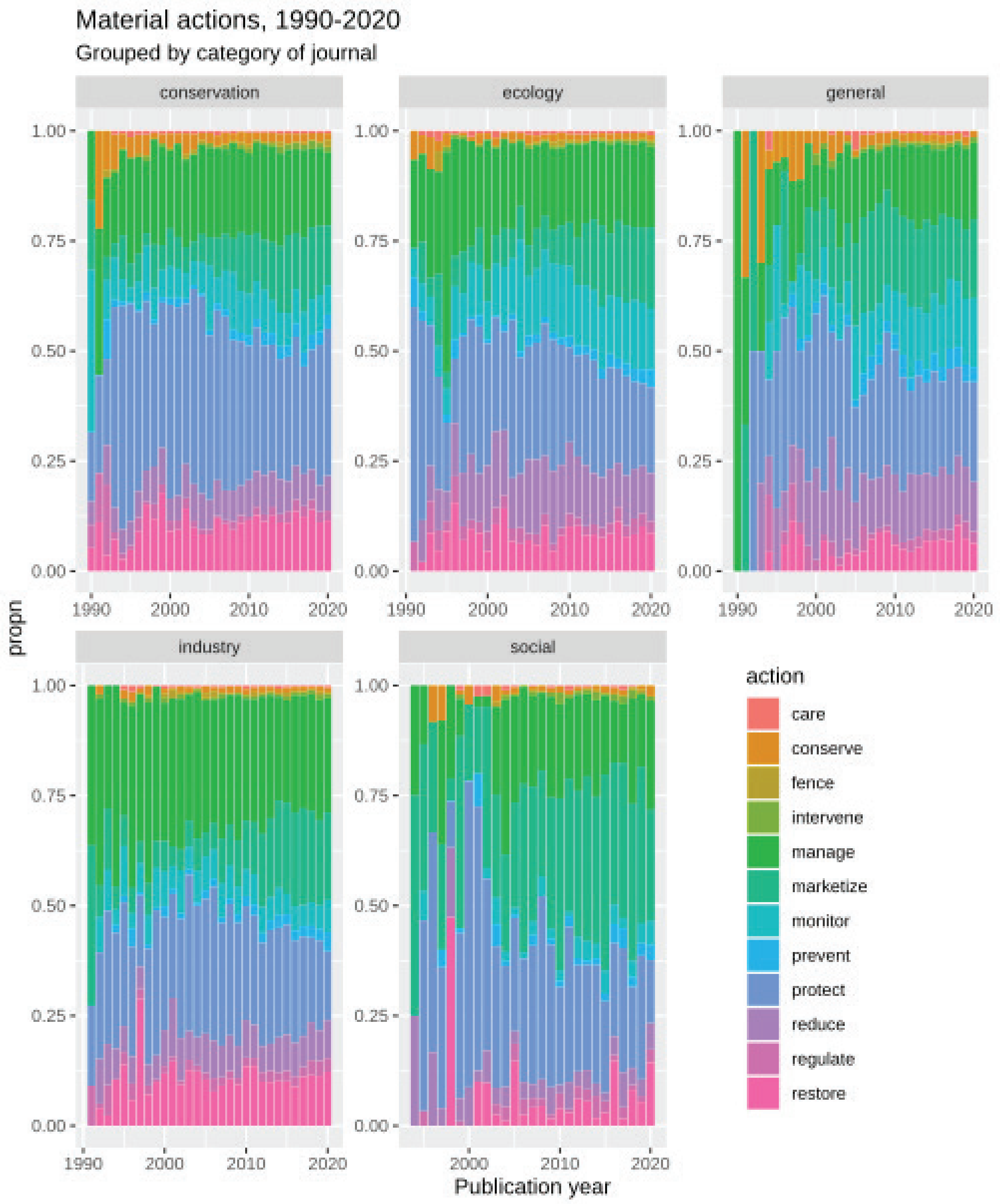

Figure 2a. Modes of biodiversity action in high-volume journals

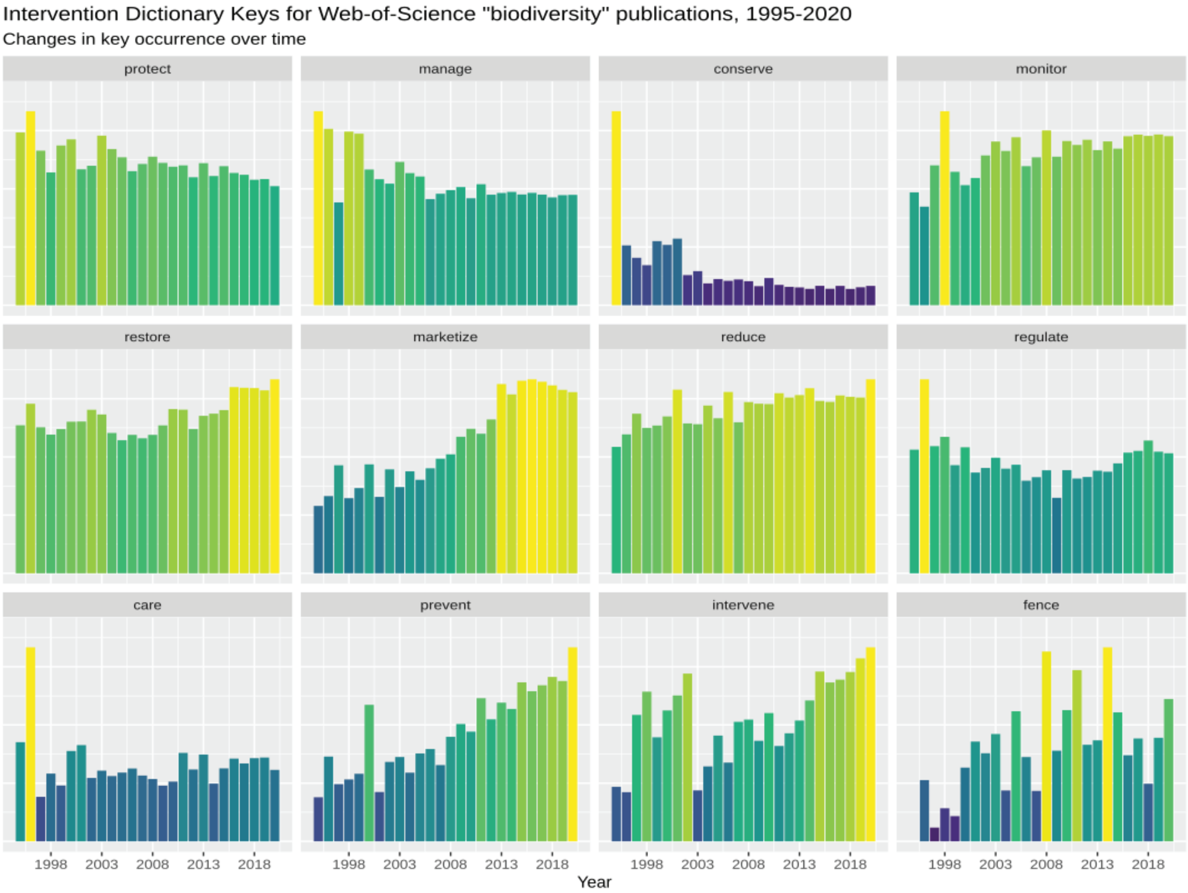

Figure 2b. Key modes of action over time

Despite these limitations, the aim in this part of the analysis is to track how actions are generally distributed across the biodiversity science-base. Figure 2a points to the varying proportions of action in the differently situated facets of the biodiversity science-base. The distribution of these modes of action, actions that we might regard as anticipated endpoints of experience, varies over time and situation in biodiversity science. As the plot of their occurrence over time in Figure 2b suggests, specific actions concerning the marketised value of biodiversity such as offsetting grow markedly as do technical actions concerning reduction. Conversely, the relative lack of variation between quite different settings of ecology, general science, industry, conservation and society suggest something about implicit projections of action in biodiversity as a conceptual apparatus.

Paths back to things

Knowledge of biodiversity lies between the two endpoints of something/someone and the action-situations I have been discussing. On the one hand, occurrences of experience in the biodiversity science-base relate to something suffered or undergone, affecting persons or places. On the other hand, biodiversity actions play out as movements in the most plural sense of that term, modifying situations as well as the active agents. Many paths run between the unanalyzed totalities of being-affected and sites of action. Some, but only some, run through the biodiversity science-base.

In Dewey's account of experience, invented concepts such as 'biodiversity' are 'refined, secondary objects', derived from systematic experimentation, testing and modelling. They work by creating new loops or circular paths in experience:

> they define or lay out a path by which return to experienced things is of such a sort that the meaning, the significant content, of what is experienced gains an enriched and expanded force because of the path or method by which it was reached (Dewey, 1958: 5)

The derived or refined object acts as a track, an “advantageous shortcut” in William James’ (1976: 65) terms back to an experience, an experience now qualified in some way by connections, relation or even continuity with other experiences that were previously distinct. These paths ‘enrich’ or ‘expand’ experience in terms of its meaning or ‘significant content.’ The enriching or expanding done by a concept is closely connected to the path and to movement along that path. What movements, what paths does biodiversity lay open?

The time-varying proportions of around 16,000 author-supplied unique keywords in the biodiversity science-base show something of the neighbourhoods of biodiversity knowing (Figure 3a).[3] In the plot, the standing concern with diversity, species richness (the number of different species in a given location) and taxonomy come as no surprise. Conservation is an anchoring constant. The growing concern with climate change, ecosystem services and sustainability have global resonance, and are affiliated with practices of management, monitoring, planning, agriculture and forestry. A series of topics concerned with change - disturbance, deforestation, restoration, extinction, fragmentation, and urbanization – are less prominent, but spread over time. Another set of keywords concerned with ecological theories and measures of diversity – beta diversity, functional traits, endemism, community structure, phylogenetic diversity, dispersal and succession – pervade the literature as the working concepts and theories of biodiversity. The keywords span scientific fields (ecology, taxonomy), abstractions (biogeography, beta diversity), processes (succession, disturbance, ecosystem function, competition, urbanization), places (forest, urban, landscape, protected areas, Australia), actions (restoration, conservation, management, monitoring), species (ants, birds, coleoptera) and institutions (IUCN). The ‘refined, secondary object’ called biodiversity coordinates the connection and intersection between many paths. It is thick concept, diversely realized, just like the situations it seeks to describe.

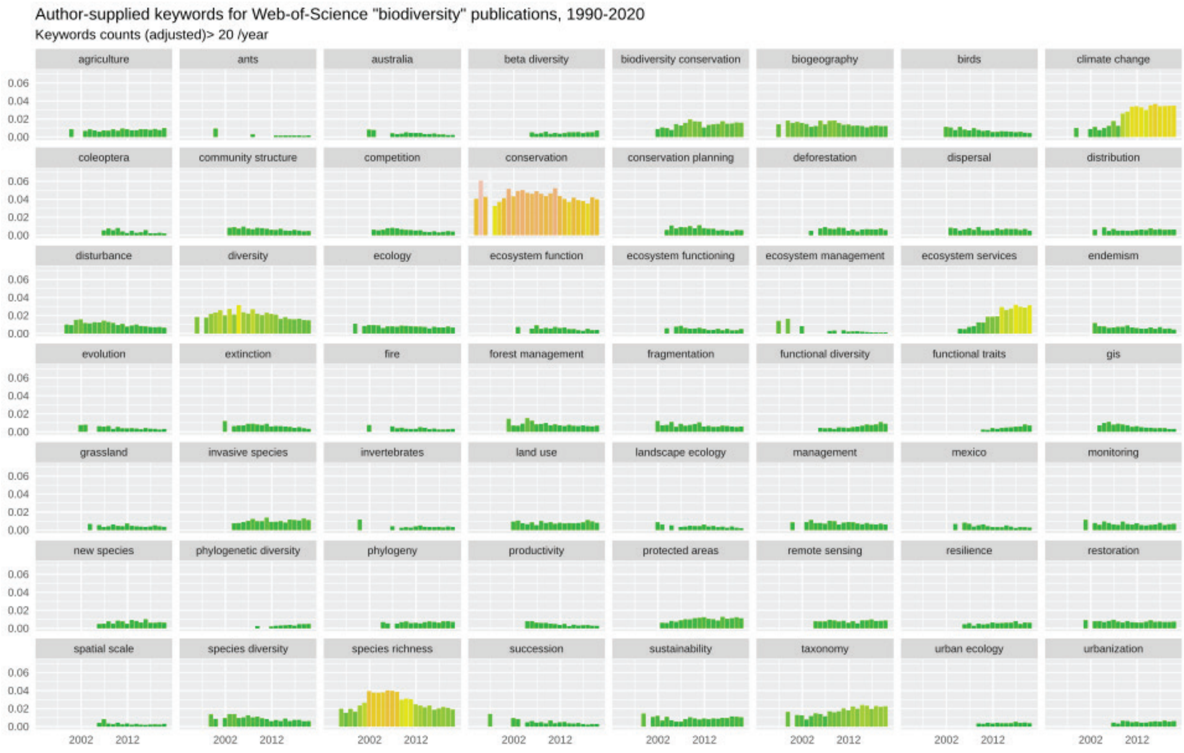

Figure 3a. Keywords in biodiversity science 1990-2019

Perhaps more significantly than their time-varying proportion, the network of associations between concepts in Figure 3.b, a network that omits for the sake of legibility almost 98% of the keywords present in the biodiversity science-base, begins to suggest just how many paths or itineraries might return to experienced things.[4] Each of the keywords shown above is a waypoint on such a path, and their appearance in the map of keywords marks a commonly taken path. Even commonly travelled paths running through conservation, ecosystem services, climate change traverse many different intermediate steps (for instance, in the many thousands of keywords not

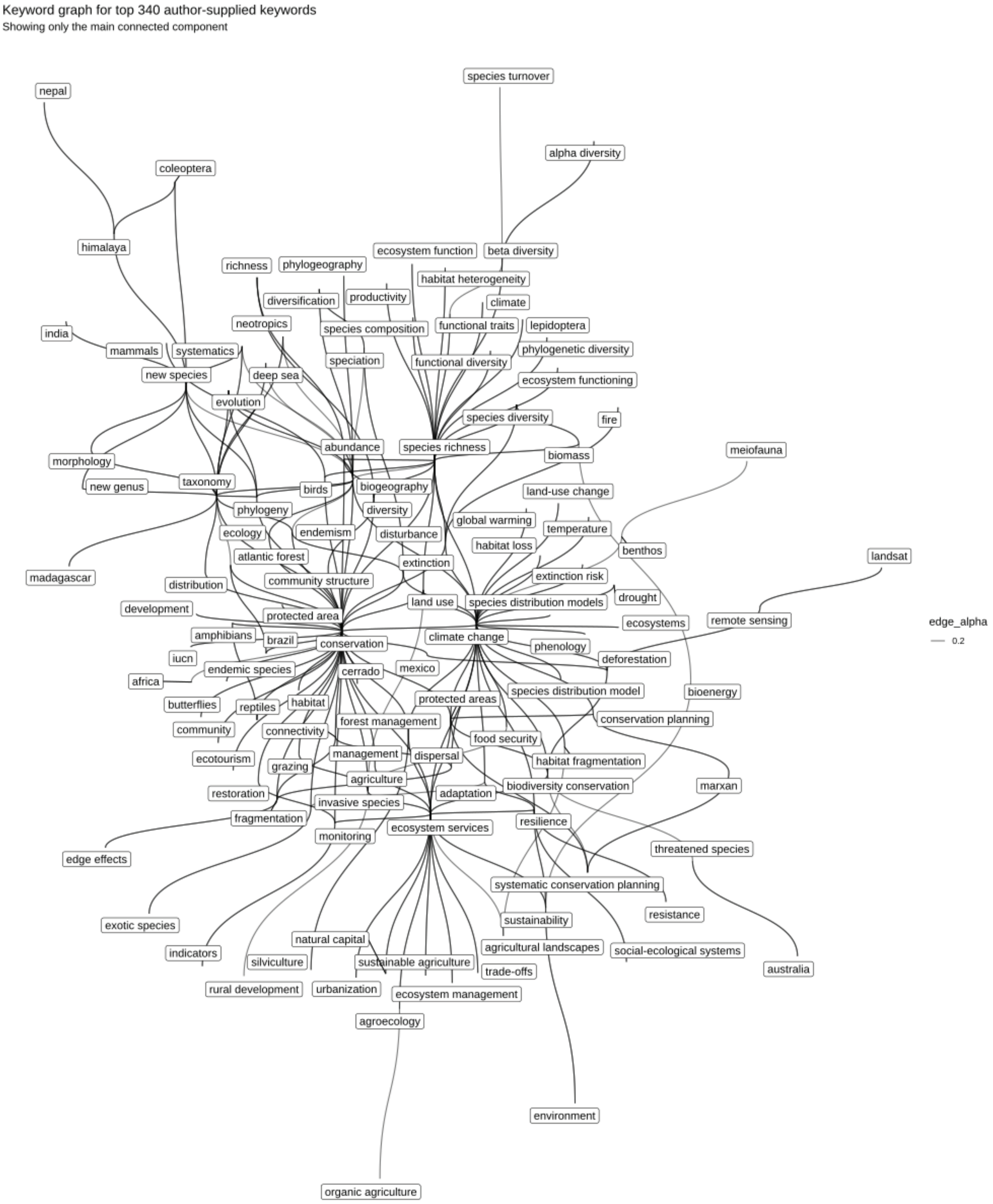

Figure 3b. Keywords networked in biodiversity science 1990-2019

plotted), as well as a manifold of experience that has not been keyworded by authors.

The plurality of differences and dimensions folded into the keywords – between living and non-living, horizons receding from particular locations such as the Cerrado or Madagascar to Earth, the references to variety and variation, the practices of measuring and observing, the biological levels running from genes to species and ecosystem, the many practices and actions – suggest that encounters with biodiversity are highly path-dependent. Major junctions such as conservation, climate change and ecosystem services in network of paths can be avoided by following paths going through taxonomy, abundance, species richness or fragmentation. This forest of connections point to the many configurations that might be experienced as 'biodiversity.'

The figure of a latent distribution

Imagine the full network of biodiversity knowing, a network in which every connection and variation in knowledge of biodiversity has been labelled and plotted in its associations. Would the vast network capture biodiversity experience? Identifying experience with what is known, or reading the biodiversity science-base in terms of scientific knowledge alone, radically curtails the run of experience. As Dewey puts it:

> What is really "in" experience extends much further than that which at any time is *known*. From the standpoint of knowledge, objects must be distinct; their traits must be explicit; the vague and unrevealed is a limitation. Hence whenever the habit of identifying reality with the object of knowledge as such prevails, the obscure and vague are explained away (Dewey, 1958: 20).

The keyword paths mark traits that can be made explicit – fragmentation, biomass, dispersal, connectivity, alpha diversity, beta diversity and so forth – amidst the plural abundance of encounters with plants, insects, mammals, birds, reptiles, fungi and fish in forests, reefs, neotropics and farms subject to fire, ecotourism, land-use change, disturbance, habitat loss, grazing, restoration, deforestation, drought and urbanization. Dewey says experience includes much that is "uncertain, unpredictable, uncontrollable, and hazardous" (Dewey, 1958: 42) mixed with "sufficiencies, tight completeness, order, recurrence" (Dewey, 1958: 47). "Refined method and products" (Dewey, 1958: 36) of knowing, such as concepts, models, measurements, techniques of observing or recording, select for regularities or stabilities in experience.

The selection of points of ordering or recurrence does not exhaust or eliminate the affects, enjoyments, hazards, precarities or intricacies of concrete experience. Actually, the ongoing refining of derived objects highlights the overflows of concrete experience. Departing from experience, they sometimes open a path back to experience with fresh eyes or a "cultivated naivete" (Dewey, 1958: 37). It is not as if uncertainty or unpredictability derives from the less real contingencies of events, and stability and predictability from underlying or inherent order. Uncertainty animates experience. Organised and habituated in predictable outcomes *and* brimming with surprise and novelty, experience mixes stability and precarity.

Are there any indicators in the science-base of this indeterminacy, beyond the negative image seen in the refined, secondary objects that run shortcut paths through experience, abbreviating or compressing variations?

At this point, I start to run up against the limits of the tools of quantitative text analysis. Statistical models of large document collections offer a slender lead. Although sometimes treated as an automated text summarization technique (Blei and Lafferty, 2007), I re-purpose topic models to assist in figuring, not modelling, the connective tissue of experience in the biodiversity science-base. In normal practice, given a number of topics, topic models seek to identify a corresponding number of sets of terms that best capture words likely to occur together in a document. Documents in the collection, from the perspective of the topic model, can be modelled as generated by topics variously mixing. The statistical intuition of the model is that a document collection, here the biodiversity science-base, is generated by probabilistic distribution of words called 'topics' mixing together as documents. Some documents will contain high proportions of prevalent topics and others may be heterogeneous mixture of relatively rare topics (Mohr et al., 2015).

This model of the generation of documents is highly artificial. It itself, viewed from the perspective of experience, is a secondary object, refined and derived from regularities and recurrences observed in the accumulation of words in a document collection. I therefore use it carefully, and perhaps against the grain.

If traces of unanalyzed totality of experience can be found in the more abstract reaches of the science-base, then it should be more easily seen elsewhere. Data gathered in field sites or laboratories often ends up in models. I sampled from the biodiversity science-base dataset all records mentioning ‘model’ or ‘predict’ in their title or abstract.[5] 33,000 publications or around 30% of the biodiversity science-base refer to models or predictions. This subset presents a significant test case for the concept of distributed experience in several respects. Modelling and predicting relies heavily on derived or secondary objects such as probability distributions, ecological theory and extensive datasets derived from sensors and databases. Researchers communicate models using a mixture of numbers (counts, probabilities), figures such as diagrams, maps and charts. Models point to results derived from calculation more than observation or narrative.

A topic model for 50 topics (k=50) roughly corresponds to the number of sub-headings on the Wikipedia ‘biodiversity’ entry Wikipedia (2020) as it stands in 2020, but the topic distribution across the documents in the Web of Science dataset presents a rather different set of processes. In the plot of topics (Figure 4a), the length of the

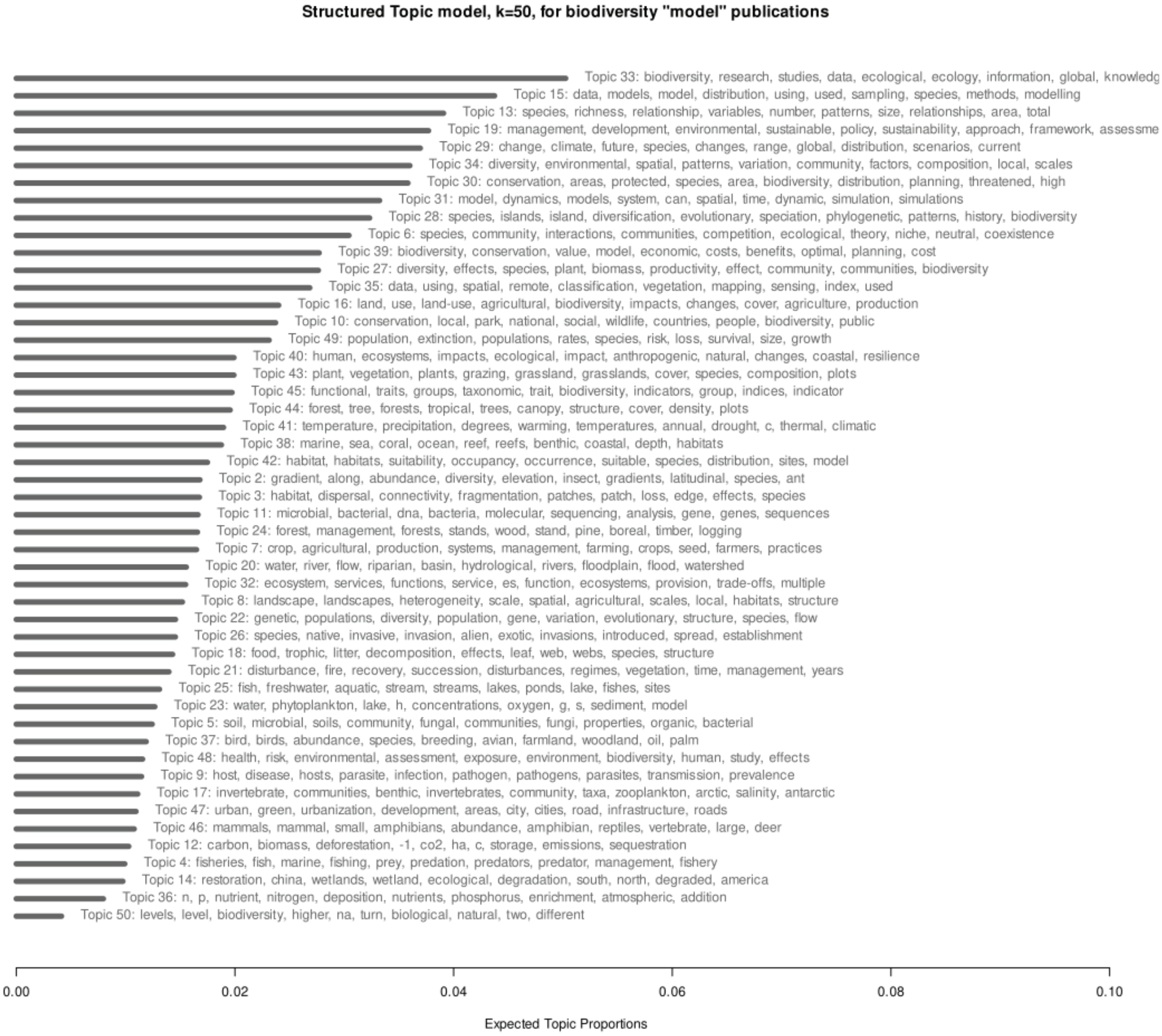

Figure 4a. 50 topics in biodiversity science modelling subset

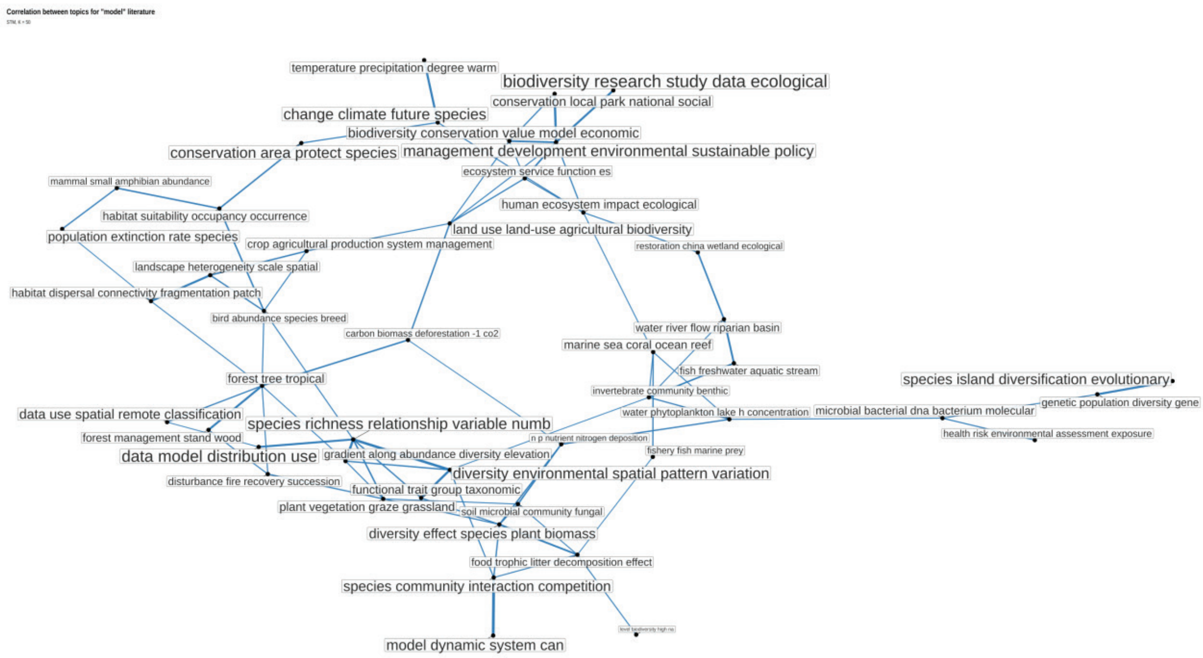

Figure 4b. Association between topics

horizontal lines indicates the proportion of the overall document topics covered by that topic. In fact, the most prevalent topic in the biodiversity science-base is precisely 'biodiversity knowledge' or ecological approaches to biodiversity, and the second covers use of models to predict species distribution. The first dozen topics all remain quite general or overarching, ranging across questions of climate change, conservation, protected area management and trophic interaction. Actions such as planning, protection, monitoring, preserving, or restoring meet ecosystem services, landscape management, invasions, and, the overarching climate-change/mass extinction topics. These high profile topics, typical of the biopolitical, marketising and panoptic facets of biodiversity science, are fringed by many specific places and concerns. Large parts of the fringes are taxon-specific: trees, microbes, beetles, bacteria, birds, fish, fungi. Some are habitats: coasts, islands, reefs, fields, forests, rivers, soils and streams. There are many habitat, niche and biome-related processes including fragmentation, disturbance, invasion, burning, wind, floods, infection and precipitation.

This profusion of processes, scales, places and problems is not exhaustive, and it could be perhaps aggregated or disaggregated into greater and smaller units in the social spaces and times of scientific research. In contrast to the topics of the Wikipedia article or a typical textbook in ecology or conservation biology such as (Mittelbach, 2012), this distribution of places, processes and problems also presents many occurrence of experience. Topics 10, 29, 41, and 47, for instance, do not show the term 'experience(s)' in the plot, but contain it deeper in the set of words composing that topic.

The network Figure 4b, like the keyword networks, shows associations between topics. (Topic proportions appear in size of node labels, and co-occurrence of topics in thickness of edges.) The mixing between topics varies in density. Some highly prevalent topics are not highly connected. The 'climate change' topic can be found in many publications, but does not mix with many other facets of biodiversity. It is as if climate change is a salient concern but not deeply integrated into knowledges of biodiversity. Taxon or habitat specific topics often lie around the edges. 'Insects and spiders', 'bacteria,' 'fire disturbance' or 'freshwater fish' connect directly to central topics such as 'species richness' or 'phylogenetic diversification'. More centrally, topics such as 'landscape,' 'biomass,' 'community dynamics,' 'species models' or 'ecosystem managing' have a much richer connectivity to both the edges of the network and to other central nodes of the network.

If the association of topics forms an assemblage, then the relation between the topics, their co-occurrences, perhaps gives us some sense of how experiences are connected, of how regularities and recurrences move along constantly evolving corridors between encounters with living things, places, histories and futures. Almost by definition, any single document appears in a topic model as a contingent mixture of topics. The topic models and network plots of topic correlation map research experiences of biodiversity.

The situation presented in the topic models, with its generative mixtures of places, lifeforms, observations, actions, institutions and apparatuses, figures something more general, the unanalyzed totality of experience in the biodiversity science-base. It suggests that biodiversity experience might be understood as a set of latent processes, varying in number, giving rise to occurrences gathered in various combinations as observations, documents, records and publications. The actual combinations derive from the distributions, but the elements of a topic mix regularities, signpost patches of dispersed variations and record specific encounters with an unanalyzable totality. This approach to biodiversity, to its conceptual connectivity as well as its fragmented measures and values, tracks gradients of different intensity running through a hypervolume of places, histories, apparatuses, institutions, concepts and actions.

Does the relational weave of topics, along with the places, species, problems and processes referred to there, help us understand something of the processes of identification or engagement entailed in experience? The gradients of regionality, intervention, distribution or change woven through biodiversity research are themselves components of biodiversity experience. They criss-cross lifeworld and societal systems of production, governance and regulation. The occurrences of research experience traced in the science-base are highly mixed, and this helps us see biodiversity science as both subject and object, matter and idea.

Conclusion

Biodiversity science begins with some experience of things – a specimen in a museum drawer, a stand of trees, a pond, a reef, a tank of phytoplankton or a city park. On many occasions it aims to wend its way back to things: a restored woodland, a newly named species, a protected area, a re-introduced population, removal of weeds or feral predators, a series of patches connected by corridors in a landscape, or perhaps in human digestive tract or a cheese rind.

It is rare to find any direct consideration of what it would mean to experience biodiversity rather than nature, wilderness or 'the environment.' Despite the frequent news of threats to and loss of biodiversity, despite the accumulation of biodiversity knowledges and biodiversity media, ranging from documentary to online image media, experiences of biodiversity remains somewhat amorphous and elusive.

How is it possible to attend to the 'voices of experience' in biodiversity science? Scientists themselves constitute nodal points in the distributed networks of biodiversity experience. Like farmers, tourists, residents, landowners or citizens, their 'mode and degree of organized unity' not only, as Dewey points out, affects the environment, but acts on themselves. The presence, largely latent, of experience in the science-base is not primarily observed as knowledge, or knowledge claims. Knowledge, according to Dewey, can be understood as a network of paths that select and connect recurrent or regular features in experience in order to project plans, strategies, interventions, initiatives, policies, priorities and programs of action. But this selection, as well as the predictions and actions it mobilises, derives from and is secondary to a more primary flow of experience, the latent fluxes of felt, intimately coordinated yet often vague or obscure qualities, the empirically ephemeral occurrences, replete with diverse but intensely immediate dependencies.

For whom would recognition of distributed biodiversity experience matter? Biodiversity is an unusual construction, difficult to concretise yet intricately woven into governance, knowledges and indeed economies (Dempsey, 2016). Unlike some scientific constructs, it lends itself to felt immediacies, situations and processes of change. Less prominently than the figures of Gaia (Lenton and Latour, 2018), planet (Chakrabarty, 2019), or Anthropocene Earth System (Steffen et al., 2011), the mixture of places, methods, practices of observation, measurement and intervention in the biodiversity science-base point to a complex patchwork of experience. Like Gaia, planet or Earth, biodiversity assembles lands, cities, water, soil, air, people, States, markets, and life-forms scaling across places and times.

Biodiversity, however, presents no single point of attachment. Gradients of biodiversity experience have a wider distribution than what is typically associated with people, with their views, attitudes, or considerable knowledges. Biodiversity overflows species and their distributions. Stakeholders, participants, citizens, indigenous, aboriginal and tribal peoples and traditions are often explicitly mentioned, but the unanalyzed experiential totality in the biodiversity science-base also includes what is reported to have undergone, suffered, tolerated, or enjoyed something. This is suggested by the figurative modelling of latent distribution of topics and their associations in the biodiversity science-base.

For anyone affected by it, the biodiversity science-base is an assemblage whose composition records many knowledges, actions, forms of awareness, and engagements, biodiversity might be understood as the conceptant (Mackenzie, 2019) that gives it consistency. Awareness, affects, attachments and beliefs or convictions animate the science-base. Although biodiversity science endemically occasions experience, such occurrences are typically unacknowledged ('we give so little heed to it'). Scientists and others encounter urban landscapes, land-use changes, protected areas, policy-making processes, public engagement, leaf litter in an old-growth forest, 'invasive weeds', ornithological records, maize fields, coral reefs, parks, LandSat imagery or iNaturalist observations, but along paths that follow regularities and recurrences amenable to sensing, observation, selection and collection.

I am calling for, and have sought to enact, an identification with the distributed nature of biodiversity in the science-base. "Only by identification with remaking the objects that now obtain", writes Dewey, "are we saved from complacent objectivism" (Dewey, 1958: 246). The work of understanding how distributed experiences occur in the science-base aims to reconstruct or remake biodiversity as an assemblage, preserving knowledges and their ongoing derivation, but also pointing to different potentialities in it.

Should biodiversity science be reconstructed in the light of distributed experience? In their recent call for collaborative biodiversity knowledge, Timothy Lenton and Bruno Latour (2018) emphasise how scientific knowledge infrastructures need to both multiply the sensors and open pathways to participation:

> This is where the scientific establishment will play a crucial role in multiplying the sensors, improving their qualities, speeding the dissemination of their results, improving models, and proposing alternative explanations to phenomena. Such an infrastructure cannot, however, be limited to scientists. (Lenton and Latour, 2018: 1068)

I suggest that recognising distributed experience in the biodiversity science-base adds a collective sensing to the sensing infrastructures. Amongst the many elements of the biodiversity science-base, some re-distribute infrastructure for multiplying, accelerating and monitoring experiences, and for restoring phenomena to experience. The mixture of topics and their associations suggests that in some ways this is already happening. The question is whether their co-occurrence there actually can be assembled as an experienced situation.

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Notes

1 Code and data supporting our analysis can be found at [https://github.com/rian39/aibiodiversity/tree/scilit/analysis]. The full dataset of Web of Science records derives from a single word query 'biodiversity'. The data was exported from the "Web of Science Core Collection" database. A search for "biodiversity" in the field "topic" on the 24th May 2020 returned 133664 records ranging in publication year from 1987 to 2020. This search was then split into a search from 1987-2013 and a search from 2014-2020 because Web of Science prevents the export of records beyond the 100000th record returned by a single search. The dataset containing all 133664 records is accessible here: Biodiversity dataset Each record contains 67 fields. Key fields used in this project are TI - Document Title, DE - Author Keywords, AB - Abstract, PY - Year Published, SO - journal title, CR - cited references, TC - times cited, AU - author name. A full list of fields can be found at: Web of Science Core Collection. I rely on the quanteda (Benoit,2018) text analysis, Structured Topic Model stm (Roberts et al., 2016) and text2vec (Selivanov et al., 2020) R packages in the analysis, combining close reading with quantitative text analysis approaches.

2 Here Dewey echoes what William James in *Essays on Radical Empiricism* had called 'pure experience' or the 'instant field of the present' James (1976: 23). James analyzed the conditions under which things and thinking can separate out into processes that can followed "along entirely different lines" (James, 1976: 12) towards, to name two salient endpoints, thinking or things. Like Dewey and indeed various contemporary thinkers, James saw this separation as a limited variety of experience, useful in some situations, obstructive in others.

3 Author-supplied keywords are more often missing in the early years of biodiversity science, but occur consistently from the mid-1990s. The plots of keywords use a yearly-weighted publication count to normalise the counting of occurrences, unless otherwise mentioned. This is to take account of the generally increasing volume of scientific publication in the last few decades. It also allows relative proportions of different concerns to become more visible.

4 The span of these keywords hint that biodiversity threads back through major ecological theories, studies and models of diversity, particularly, species diversity (Whittaker, 1972; MacArthur, 1965) dating from the mid-20th century. Textbooks of ecology and conservation biology have more technical framings, sometimes focused on measurement or modelling within specific conceptual framings. The *Stanford Encyclopedia of Philosophy* article on biodiversity, written by a museum-employed taxonomist defines biodiversity economically: 'estimating and quantifying the largely unknown variation that makes up biodiversity is one and the same as quantifying corresponding option values of biodiversity' (Faith, 2019). Regulatory instruments such as the *Convention on Biological Diversity* (CBD Secretariat, 2011). In all these settings, the underlying question of diversity or why lives vary or differ so much on earth, of why microbes leave in hot undersea vents or trees grow to different heights persist, along with the questions of significance or meaning of these differences.

5 I also sampled records in order to manage to fit topic models with computational resources readily available to us. Computers with more memory and CPUs would alleviate this problem. Records were cleaned using standard quantitative textual analysis techniques of removing very common terms ('the', 'of', 'it'), numbers and other symbols (Benoit, 2018).

Brumberg-Chaumont Julie and Rosental Claude (eds) (2021) Logical Skills: Social-Historical Perspectives. Cham: Springer International Publishing. 172 pages. ISBN: 978-3-030-58445-0

Maria Amuchastegui
mamuchas@yorku.ca

Julie Brumberg-Chaumont and Claude Rosental's edited collection *Logical Skills: Social-Historical Perspectives* (2021) reveals that it is logic, broadly conceived, that joins together the disparate fields of postcolonial studies and disability studies. For postcolonial STS scholars, the book is of interest insofar as it shows how logic has served, at different moments in history, to define certain peoples as "primitive." For scholars of disability studies, the book provides historical examples of the use of logic to cast specific social groups—including children, the intellectually disabled, and the insane—as less than human. The contributors variously define logic both formally (as inductive and inferential, or deductive and syllogistic, or pragmatic and action-oriented) and informally (as common sense, or rationality, or the capacity for abstract thought, or the avoidance of contradiction, or native intelligence). Dominique Poirel (chapter 7) relates that what would later become the dominant definition of logic—dialectical reasoning—was once a contested terrain.

The key message of the book is that the sociological study of the history of logic is a decolonizing move, one that reveals overlaps between colonization and the marginalization of the disabled. Again and again, the various contributors describe how logic was conceived of as "natural," by virtue of its inscription in the body, and yet restricted to the "civilized," the "learned," and the "sane." For example, Claude Blanckaert (chapter 3) explains how early anthropologists used brain size and a narrative of perfectibility to claim that some races are superior to others. In contrast with the Cartesians of the Enlightenment, who believed in mind-body dualism, nineteenth-century French anthropologists were positivists who believed that thought—which they called 'natural logic'—resided in the body. But whereas the "superior" races were perfectible, the supposedly "inferior" races had regressed. Similarly, Brumberg-Chaumont (chapter 6) describes the logicization of intellectual practice that coincided with the rise of the institution of the university. For thirteenth-century scholars, logic was at once an acquired disposition—a *habitus*—and the most prestigious of academic disciplines. The flip side of the valorization of logic is that it resulted in the devaluation of those who are deprived of logic, as in the case of *idiota*, the uneducated, or *moriones*, the cognitively disabled. At the bottom of the intellectual scale were pygmies.

Another recurring theme is the temporalization of logic, which was used to explain why certain groups of people fail to "progress." Christopher Goodey (chapter 9), for example, relates that the distinction made in developmental psychology between the normal and the cognitively impaired has its origins in the salvation theology of the seventeenth century. Rousseau's educational philosophy added a temporal dimension to this distinction, according to which children are temporarily disabled, and the cognitively impaired permanently so. Similarly, Roberto Frega (chapter 5) describes the evolutionary approach to logic of the twentieth-century philosopher John Dewey, according to which "primitives" fear doubt and are thus in the infancy of logic. Frega takes pains to point out that Dewey distanced himself from Spencerian progressivism and that, for Dewey, primitive thinking persists in modern societies. However, Dewey's characterization of Western science as representing the pinnacle of human progress suggests that he was a Spencerian *malgré soi*. Moreover, Dewey explicitly built upon the evolutionary approach to logic of his mentor Charles Sanders Peirce, who was an advocate of slavery (Menand, 1993).

Banu Subramaniam et al. (2016) point out that research which avails itself of the shared insights of postcolonial STS and other STS subdisciplines is undertheorized, and they call for more research on how these fields intersect. By describing how logic is implicated in both colonization and the marginalization of the disabled, the various contributors to this volume heed this call. Scott L. Pratt (chapter 2), for example, argues that 'natural logic', as defined by the nineteenth-century anthropologist Lewis Henry Morgan, underpins the project of settler colonialism. Because natural logic provided an explanation for how cultures "progress," it became a normative framework with which cultures could be assessed, and it was used to justify cultural genocide. Pratt argues that Morgan's conception of natural logic, which strongly influenced structuralist anthropology, continues to stalk poststructuralism, including the new materialism of Karen Barad. Pratt concludes by proposing an alternative, decolonial logic. His decolonial logic brings to mind Helen Verran's (2001) account of the emergent, multiple worlds that are created by "doing" numbers according to an African logic.

Much STS scholarship is based on the blurring of the distinction, assumed to be foundational to Western culture, between human agency and the non-agency of nonhumans (Callon, 1986). In this vein, Irina Metzler (chapter 8) shows that the denial of agency to nonhumans has not always held true. In medieval natural philosophy and jurisprudence, certain categories of living beings—including animals and the intellectually disabled—were considered to be lacking in rationality, as they lacked speech and thus also lacked agency. But whereas the intellectually disabled were exempt from criminal culpability, some animals were put on trial. According to the legal theory of the time, animals lacked agency. But in actual legal practice, some animals were treated as though they had agency.

Early STS scholars emphasized mathematics and the physical sciences, as these were considered to be the hardest cases in proving that science is socially determined. Logic is like mathematics in that it is abstract and assumed to be universally true; unlike mathematics, however, logic is not ontologically grounded in physical objects. By studying logic, then, the contributors to this volume take on an even harder case. Like the early STS scholar David Bloor (1991 [1976]), who proved that mathematics is socially determined by basing his analysis on empirical practice, the various contributors emphasize logic as praxis. Bloor is among the figures considered by Claude Rosental (chapter 4) in his account of the use of logic by twentieth-century social scientists to assess the rationality of the Azande people of north central Africa. Bloor, inspired by John Stuart Mill's notion of a society's common sense, argues that logic is but the institutional framework of reasoning. If the application of a rule—formal logic—threatens the stability of the institution, then the rule can be circumvented by informal logic.

Despite the many convergences between *Logical Skills* and topics of interest to STS scholars, the majority of the contributors do not explicitly cite contemporary STS research. In most cases, STS scholars who wish to draw upon the book must make the linkages themselves. In their introduction, however, the editors do an admirable job of pointing out the relevance of the book to fields that fall within the purview of STS, such as valuation studies.

The absence of STS theory from much historical scholarship is mirrored by the absence of history in contemporary STS. Although STS was originally conceived of as an imbrication of the history of science, the philosophy of science, and the sociology of science (Fuller, 2007), mainstream

STS has since moved away from the study of history. Nevertheless, history remains important within postcolonial STS. The *Postcolonial Science and Technology Studies Reader* (Harding, 2011), for example, has numerous contributions by historians; the most recent edition of *The Handbook of Science and Technology Studies* (Felt et al., 2017) does not. *Logical Skills* shows that, to better understand the shared insights of postcolonial STS and STS itself, the sociological study of history is a fruitful approach.

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Hansson Kristofer and Irwin Rachel (eds) (2020) Movement of knowledge: Medical humanities perspectives on medicine, science, and experience. Lund: Nordic Academic Press. 265 pages. ISBN: 9789188909367

Jill van der Kamp
jill.vanderkamp@ru.nl

When medical knowledge is created, may it be in the laboratory, during discussions between healthcare professionals or in a public debate, it does not come to exist in isolation. Instead it impacts the everyday living and working practices of patients and healthcare professionals related to that specific knowledge. As knowledge moves between these actors, the different contexts it exists in also shape its implications. Movement of knowledge: Medical humanities perspectives on medicine, science, and experience showcases how medical knowledge changes depending on its context. The edited volume consists of 9 chapters in which different empirical case studies, mainly performed in Scandinavian countries, are presented. In the current transition towards precision medicine, information about the body becomes increasingly detailed. Therefore, the editors of this volume call for further development of theories and methodologies within the humanities to better understand the dynamic interplay between the creation of medical-technical knowledge and everyday practices. One example is the digitalization of healthcare, for instance through electronic medical record systems for physicians or lay-people who share experiential knowledge online, making information about health and illness more easily accessible for everyone.

By combining different theories and empirical work, this book gives insight into the ways theory can be applied to study healthcare practices in real-world situations. Among these theories is the work of Sheila Jasanoff (2004), on co-production of knowledge which includes both scientific and social dimensions, for example in chapters 1 and 6. Annemarie Mol's (2002) theory of the body multiple in which she shows how medical knowledge can create multiple realities (e.g. chapter 7) and the work of Nikolas Rose (2007) on the reconstruction of medical knowledge by and for the public (e.g. chapter 5). This collection of real-world cases can be useful for scholars who want to become familiar with ethnographic research on how medical knowledge impacts the lived experience of patients, healthcare professionals and citizens.

The book's empirical case studies showcase that scientific knowledge, while often seen as objective, can have multiple meanings. The studies represent different circumstances, including various actors, spaces and times, under which medical knowledge can be created, communicated and transformed. For example, Rachel Irwin shows in chapter 2 how medical knowledge can be transformed into evidence for policy-making with her ethnographic fieldwork at the World Health Organisation. In chapter 6, authors Kristofer Hansson, Gabriella Nilsson and Irén Tiberg describe the implementation of a new care model for medical personnel, in which people with different roles, such as ethnographers and facilitators who observe and implement the process respectively, co-create new insights and use this to adjust the implementation process. Another example is chapter 7 by Kristofer Hansson, in which it becomes clear that supposedly objective values from blood tests for diabetes care hold multiple meanings and thereby influence both at home care practices, hospital organisation and doctor-patient relationships.

When medical knowledge became more publicly available through the Internet, it was expected that the citizen-patient would be better informed, experience more autonomy and therefore become empowered to take on a democratic stance in their own healthcare, creating more equality between patients and healthcare professionals (e.g. Felt, 2014). Nonetheless, Felt (2014: 190) describes that being a digitally informed patient redefines one's relationship with healthcare professionals but does not change the authority status of the doctor. Yet, chapter 9 of Movement of knowledge shows another insight. Here, Rui Liu and Susanne Lundin showcase that healthcare professionals are no longer gatekeepers for medicine, based on institutional expertise, since the internet allowed for increased patient autonomy, for example through ordering medicine online, even on less regulated markets if felt necessary. This result in doctors being perceived less as an authority figure but more as one source of information which holds similar value as other sources of information such as experiential knowledge from peers shared online.

What is absent in the book, is an overarching critical standpoint which brings all different case studies together. The introduction does describe how all chapters show different ways of knowledge interpretation and production and introduces the main theories used throughout the book. Yet, when the volume is finished the reader remains searching for a coherence between the chapters and therefore, perhaps even for a main message from the book. Also, methodologies such as ethnographic research on hospital practices has been proven to be challenging in uncertain times, such as the recent COVID-19 pandemic during which hospitals were inaccessible and healthcare professionals were often overworked. The next challenge would be to extend the perspective offered in the book to other countries or societies, where other cultural values, beliefs and policies prevail. Lastly, the main limit of this volume is how the title, abstract and introduction all create the expectation that the chapters will show how medical knowledge moves across actors, spaces and time. Yet, the way it moves and transforms during that movement is less shown. Instead, the chapters showcase how knowledge can exist in different ways at various knowledge sites where diverse actors relate to the form the knowledge takes on at that site. On the bright side, the book does show in various chapters how medical knowledge sets in motion the lived experience of patients, researchers, healthcare professionals and policy makers. For STS scholars, this book adds a deeper insight into the living and working practices of citizens, patients and professionals and into the possibilities of investigating theories in real-world situations. In conclusion, Movement of knowledge: Medical humanities perspectives on medicine, science, and experience is an inspiring book which demonstrates that medical-technical knowledge is more than an objective and one-sided entity. It shows how medical information has different meanings depending on different places, times and actors for whom that specific information is relevant.

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