



Caring for biosocial complexity. Articulations of the environment in research on the Developmental Origins of Health and Disease



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ABSTRACT

The research field of Developmental Origins of Health and Disease (DOHaD) provides a framework for understanding how a wide range of environmental factors, such as deprivation, nutrition and stress, shape individual and population health over the course of a lifetime. DOHaD researchers face the challenge of how to conceptualize and measure ontologically diverse environments and their interactions with the developing organism over extended periods of time. Based on ethnographic research, I show how DOHaD researchers are often eager to capture what they regard as more ‘complex’ understandings of the environment in their work. At the same time, they are confronted with established methodological tools, disciplinary infrastructures and institutional contexts that favor simplistic articulations of the environment as distinct and mainly individual-level variables. I show how researchers struggle with these simplistic articulations of nutrition, maternal bodies and social determinants as relevant environments, which are sometimes at odds with the researchers’ own normative commitments and aspirations.

1. Introduction

“I don’t understand it!” The PhD student is clearly frustrated as she shows her ongoing work on data from a large child cohort. For the past weeks, she’s been trying different statistical tools and indicators, yet the analysis is not yielding any associations between social status and childhood obesity. The other members of the small epidemiological research group – two other PhD students, a statistician, and the senior postdoc that supervises them – gather around her desk at the research group’s weekly meeting, which takes place in the tiny, crammed office shared by the PhD students and the statistician. They make many suggestions – they ask if she has tried this statistical approach, considered that indicator, tested for possible confounding factors – but nothing yields the expected results that link families’ social circumstances to the development of childhood obesity. One of the other PhD students asks, “Why aren’t we getting more results? Is the number of participants too low?” The senior researcher answers, “I really don’t think that’s it. If we needed larger cohorts, then the effects would be very small. This rather proves that we cannot represent complexity well through single variables”, and adds, “we just don’t have the right data for it”. The PhD student asks in turn: “If you put it that way, then you are convinced that our hypothesis is correct?” “Of course –

just look at the newspapers, or what sociological studies are showing ... And you can see it everywhere, just take a look at the streets!”

The research group, which is based at a university pediatric clinic in continental Europe, is part of the interdisciplinary biomedical research field of Developmental Origins of Health and Disease (DOHaD). While investigating how life experiences shape health and disease over the entire life course, DOHaD retains a strong focus on how environmental influences during critical periods, such as in utero and early childhood, condition the developing organism in ways that affect the risks of developing non-communicable diseases (NCDs) in later life (Hanson & Gluckman, 2014). The field has acquired traction in the twenty-first century and increasingly aims to influence public health policy (Hanson, Poston, & Gluckman, 2019; Richardson, 2015). This is partly due to how the field intersects with urgent public health priorities such as an often-reported rise of NCDs around the world (Pentecost & Cousins, 2017; Pentecost & Ross, 2019), but is also connected to recent advances in epigenetics, which proposes new molecular mechanisms that link early life environmental cues with later health and disease (Buklijas, 2018; Gluckman, Buklijas, & Hanson, 2016).

DOHaD has the potential to challenge the assumption that NCDs such as type 2 diabetes or cardiovascular disease are mainly the result of individual behavior and choice. It provides a framework for understanding how a wide

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range of environmental factors, such as deprivation, stress, nutrition and toxic exposures, shape individual and population health and wellbeing over extended periods of time, ranging from the preconception period to advanced age (Hanson & Gluckman, 2014; Müller & Samaras, 2018). Theoretically, DOHaD could situate the developing organism in environments that are ontologically diverse, comprising the biological, material and psychosocial, and that span different scales, ranging from the intrauterine environment of the embryo to social and economic structures and processes. This poses considerable challenges for DOHaD research in regard to how to conceptualize and measure these environments and their interactions in shaping the development of health and disease.

In this article, I show how DOHaD researchers are often eager to capture what they regard as more ‘complex’ understandings of the environment in their work, but are at the same time confronted with established methodological tools, disciplinary infrastructures and institutional contexts that favor an articulation of environmental factors as mainly individual-level variables and in a reductionist way. Based on ethnographic research at two European DOHaD research centers, I show how researchers are sometimes frustrated with their inability to “represent complexity well”, as the senior researcher in the opening vignette put it. By reconstructing the often quite pragmatic decisions that go into designing epidemiological DOHaD studies, as well as into pooling data from different cohorts for analysis, the article then details some of the factors that steer DOHaD research away from more complex understandings towards simplistic representations of the environment. I show how the resulting reductionist articulations of nutrition, maternal bodies and social determinants as relevant environments for the development of health and disease are sometimes at odds with researchers’ own aspirations and normative commitments. Through this, I hope to contribute to an interdisciplinary discussion of how DOHaD research can be supported to include more complex representations of the environment in its research apparatuses.

2. The ‘environment’ in DOHaD

DOHaD is part of a long and ongoing history of (bio-) medical engagements with the role of the environment in engendering health and disease (Meloni, 2019, 2021; Rosenberg, 1992).¹ DOHaD as a distinct research field developed out of a merging of David Barker’s epidemiological work with basic animal research in developmental physiology – two fields that at the time critically debated the relative role of environmental influences in pathophysiological processes (Gluckman et al., 2016).

Originating in 19th century medical statistics, epidemiology in its early days was concerned with how aspects of the social environment, such as the abject living, working and housing conditions tied to industrialization, affected the distribution of disease patterns (Parodi, Neasham, & Vineis, 2006; Rosenberg, 1992). This ecological view on disease, however, was marginalized following the so-called “bacteriological turn” (Parodi et al., 2006, p. 361), which highlighted the role of contagion in engendering disease and which became the dominant biomedical approach around the turn of the 19th century. Epidemiology was increasingly concerned with establishing itself as a ‘proper science’ studying collective phenomena with methodologically rigorous statistical tools (Amsterdamska, 2005). Whereas holistic concerns about the role of the social environment remained “a vigorous minority voice” (Rosenberg, 1992, p. 302), mainstream epidemiology after WWII increasingly became preoccupied with identifying ‘health behaviors’ as individualized risk factors for chronic disease (Armstrong, 1995). The work of Barker and his

colleagues in the 1980s and 1990s can be understood as part of this minority voice. However, their approach was distinctly novel with its emphasis on the role of past, not present environments (Vågerö & Illsley, 1995). In their studies, Barker and Osmond (1986, 1987) linked past geographical patterns of deprivation to contemporary patterns of cardiovascular morbidity, suggesting that environmental influences in utero can ‘program’ the body for later disease (Gluckman et al., 2016). The ‘fetal origins of adult disease’ hypothesis, as it became known, was attractive to a group of fetal and development physiologists that viewed physiological development (in contrast to their discipline’s mainstream) as a complex interplay between the developing organism and its environment, and not as a predetermined program (Gluckman et al., 2016). The ensuing collaborations resulted in a more formal establishment of the research field with the founding of the International DOHaD Society in 2003.

In recent years, DOHaD and related approaches such as environmental epigenetics have been, compared to the size and reach of these fields, relatively broadly debated in the social sciences and humanities. A major reason for this is that they seem to offer a ‘biosocial’ perspective that encourages a greater appreciation of how social processes and structures shape biological processes (Meloni, Williams, & Martin, 2016; Müller et al., 2017). DOHaD has been welcomed as part of a new “biology without biologism” (Meloni, 2014, p. 740) that turns attention away from locating the causes for health and disease exclusively within the body itself and offers an opportunity to introduce questions of social justice into biomedical research and care (Müller & Kenney, 2021; Warin, Kowal, & Meloni, 2020). For example, Warin, Moore, Davies, and Uliaszek (2016) argued that epigenetic DOHaD research highlights how inequalities in education, living conditions, and economic independence are linked to highly stratified obesity rates. Similarly, public health scholars Wallack and Thornburg (2016) claimed that “developmental origins is the ultimate social and health equity lens because it helps us understand how life history, sociology, and biology combine to create lifelong prospects for health and social success at the earliest stages” (p. 936).

At the same time, many (and partly the same) scholars have also argued that there are reasons to remain skeptical about how ‘biosocial’ perspectives play out in practice. Seeing individuals and social groups as ‘biologically impaired’ due to adverse early life experiences might have stigmatizing effects (Mansfield, 2012; Meloni, 2019). This can be particularly problematic in the context of global health disparities, given biomedicine’s troubled history of ‘othering’ and racializing populations (Baedke & Nieves Delgado, 2019; Penkler & Müller, 2018; Yates-Doerr, 2012). Mansfield (2012), Valdez (2019) and Benezra (2020) argued that racialized categories, despite ostensibly being challenged by biosocial accounts, are often reaffirmed and reconstituted in epigenetics and microbiomics research. Approaches that highlight the role of the environment in developmental processes may thus very well turn out to be as deterministic as classical genetic approaches (Waggoner & Uller, 2015).

Social science scholars have engaged critically with how the environment is framed and understood in DOHaD and related research approaches. Warin and Martin (2018) argued that environments tend to be imagined through a “spatial lens,” in which organisms and their environments appear as distinct and clearly bounded entities, being respectively positioned as “inside/outside, as self/non-self and as fetal/maternal” (p. 718). The notion of the environment itself is “rather loosely defined” within DOHaD and often used to describe everything that “surrounds” the organism, ranging from the intrauterine environment to the “actual” (meaning external) environment” (p. 708).²

¹ It should be noted that the term ‘environment’ itself is of fairly recent origins. According to Pearce (2010), “before the mid-nineteenth century, the idea of a singular, abstract entity – the organism – interacting with another singular, abstract entity – the environment – was virtually unknown” (p. 241). However, related ideas about the role of external conditions and influences in shaping human physiology have a long and extensive history in medical thinking (Meloni, 2019, 2021; Warin & Martin, 2018).

² See also Landecker (2016) on how DOHaD forms part of a “figure-ground reversal” (p. 157) in biomedical thinking that focuses on the relations between life and its “exterior surrounds” (p. 149) instead of trying to decontextualize the former from the latter. Landecker points to how surrounds located on very different scales (from the culture media and highly controlled living conditions of model organisms to industrial society) are often taken as substitutes for one another in experimental approaches in environmental epigenetics and related fields.

According to [Warin, Moore, Zivkovic, and Davies \(2011\)](#), DOHaD understandings of the environment have become narrower over time. While social determinants originally played a prominent role in DOHaD research, such as in [Barker and Osmond's \(1987\)](#) work on the health effects of unequal living and working conditions, this focus has given way to a preoccupation with women's bodies and behaviors as the most relevant 'environment' for the development of health and disease. [Warin et al. \(2011\)](#) argued that the "*telescoping of foci away from wider social determinants*" (p. 456) has been tied to a growing DOHaD emphasis on overnutrition, maternal obesity and diabetes – conditions that are highly stigmatized and that lend themselves easily to individualizing discourses that blame mothers for making the 'wrong' food choices. [Sharp, Schellhas, Richardson, and Lawlor \(2019\)](#) argued similarly that the focus on maternal factors "*reflects implicit, unquestioned and deeply-held starting assumptions*" (p. 219) that maternal factors are the most important determinants for their offspring's health. Focusing on mothers as "*intergenerational vessels*" ([Richardson, 2015](#), p. 219) for the transmission of disease risk reproduces gendered stereotypes and opens the door to an increased surveillance of mothers in the name of the health of their (unborn) children ([Kenney & Müller, 2017](#); [Pentecost & Ross, 2019](#); [Valdez, 2018](#)).³

Another concern has been that the social environment in biosocial research might not be the complex environment envisioned by social scientists, but a "*molecularized*" ([Niewöhner, 2011](#), p. 281) or "*ontologically flatten (ed)*" ([Landecker & Panofsky, 2013](#), p. 341) version of it. In her study of prenatal intervention trials in the UK and US, [Valdez \(2018\)](#) traced how the experimental designs of clinical trials restrict the opportunity to conceptualize environments as "*multiple, porous, scalar and spatio-temporal*" (428). [Lock \(2013\)](#) also contended that conceptualizations of the environment in epigenetics tend to focus on aspects that are easily workable for molecular research, making new forms of "*somatic reductionism*" (p. 291) a likely outcome. Studying the field of gene-environment interaction research, [Ackerman, Darling, Lee, Hiatt, and Shim \(2016\)](#) argued that molecularization is tied to a prevailing "*moral economy of quantification*" (p. 197) in which precision, statistical significance and the comparability of data are highly valued. As a result, the "*social, economic, political, and historical influences on health are rendered less knowable because they are deemed less amenable to precise, standardized measurement.*" (p. 213). [Shostak and Moinester \(2014\)](#) similarly traced how the biomedical field of exposomics, which aspires to catalogue the entirety of health exposures through big data approaches, is characterized by a molecular "*regime of perceptibility*" ... *in which particular aspects of the environment become more or less visible, appear as material objects, and populate the worlds of the lab, the clinic, and the community*" (p. 195).

How the environment becomes visible has implications for healthcare, health policy and wider society. [Valdez \(2018\)](#) argued that "*what counts as the environment influences the sites and types of interventions tested in evidence-based medicine*" (p. 429). Framings of the environment are tied to how disease etiologies are understood and how responsibilities are (re-)distributed ([Kenney & Müller, 2017](#)): are individual behaviors or social structures and processes seen as the ultimate causes of disease ([Gálvez, Carney, & Yates-Doerr, 2020](#); [Penkler et al., 2021](#))? As DOHaD insights are taken up in healthcare and guiding (global) health policies, what counts as the environment could significantly affect how chronic disease is understood and acted upon in the future.

In this paper, I trace how DOHaD scientists themselves engage with and care about how the environment is addressed in their research. I

³ While many accounts of biosocial research focus on research institutions in the Global North and their collaboration partners, it is important to note that conceptualizations of the environment are culturally situated. [Lamoreaux \(2016\)](#) shows how articulations of the environment in a Chinese epigenetics lab tend to (re-) produce non-individualized attributions of responsibility that correspond to more relational notions of personhood prevalent in everyday Chinese life.

draw on approaches from Science and Technology Studies (STS) that show how scientific observations are necessarily selective: the world's potentially limitless complexity needs to be reduced and re-configured in ways that make it workable for research practice ([Knorr-Cetina, 1999](#)). [Latour \(2004\)](#) has proposed the notion of 'articulation' to think about how research practices construct the social and material conditions in which specific forms of perception become possible. Getting to know the world, Latour argues, is about developing new capacities to be affected by the mediation of an "*artificially created set-up*" ([Latour, 2004](#), p. 209). Tracing how this set-up articulates some versions of the environment, while at the same time excluding others, is especially salient in a research field concerned with grasping the potentially limitless complexity of factors that might influence health and disease over the course of a lifetime.

3. Ethnographic sites and methods

The following analysis is based on ethnographic research conducted at two European DOHaD research centers between 2017 and 2020 (see [Table 1](#)). The first research center, which I refer to as the *DOHaD Institute*,⁴ is one of the larger DOHaD centers worldwide. It is based in the UK and comprises several dozen researchers from different disciplinary backgrounds representative of the larger DOHaD field, with researchers working mainly in epidemiology, public health, clinical sciences and various lab-based sciences. The second center, the *Children's Clinic Research Group* (CCRG), is located at a university pediatric clinic in continental Europe and smaller in size, consisting of about 20 researchers who are mainly epidemiologists, biostatisticians and lab-based scientists.

The work of both research centers is largely based on mother-child and child cohorts that form a platform for investigating a variety of DOHaD-related research questions. Within DOHaD, prospective observational cohort studies were established in the 1990s and 2000s as a means of producing stronger evidence for the developing research field. At the time, the so-called 'Barker Hypothesis' linking fetal development with adult disease was met with considerable controversy ([Vågerö & Illsley, 1995](#), p. 229). Besides the lack of a clear known mechanism that could mediate such long-term effects, one major point of critique was that evidence for the hypothesis was largely based on retrospective study designs, which are particularly prone to confounding. In this context, proponents started to plan prospective studies with the aim of providing stronger evidence for the fetal origins hypothesis. Child cohorts recruit children at a young age, while mother-child cohorts recruit pregnant women, or in some cases women of reproductive age, and then follow up mothers and children through pregnancy and childhood, and sometimes longer into adulthood. Establishing cohorts requires setting up an expansive infrastructure in order to collect a broad variety of data on environmental influences and health outcomes, mainly through surveys, physical examinations and the collection of biological materials at different stages in the mothers' and children's lives.

The DOHaD Institute has been running several observational studies, comprising thousands of participants, for what is now decades, both in the UK and, in collaboration with local partners, in countries labeled as the 'global South'.⁵ More recently, they have increasingly been conducting intervention studies, which are modelled on pharmaceutical

⁴ Research participants were ensured anonymity and confidentiality. I have altered details in the (ethnographic) descriptions in order to ensure this. Ethics approval was granted by the institutional review board responsible for the DOHaD Institute for my fieldwork in the UK. There was no comparable formal ethical approval procedure in place for social science research at my home institution (Technical University of Munich) or at my second field site in continental Europe, but I adhered to the same ethical standards in conducting my research at both field sites.

⁵ See [Pentecost \(2018\)](#) for a critical discussion of the uneven terrain of global public health, in which collaborations between DOHaD researchers located in resource-rich settings and those located in more deprived settings often play out.

Table 1
Overview of ethnographic sites and fieldwork.

	DOHaD Institute	Children's Clinic Research Group
<i>Size & disciplines</i>	Several dozen researchers in epidemiology, public health, clinical sciences and lab-based sciences	About 20 researchers (mainly epidemiologists, biostatisticians and lab-based scientists)
<i>Studies</i>	Several large observational and intervention studies in the UK and the Global South	Intervention studies with study sites in different European countries
<i>Fieldwork</i>	3.5 months of full-time ethnographic observations, 22 interviews (2017–2020)	18 months of part-time ethnographic observations, 6 interviews (2018–2019)

trials: participants are usually divided into two groups, one of which receives a health intervention (until recently typically either a nutritional supplement such as folic acid or a 'lifestyle intervention'), and a control group that receives an equivalent treatment with less expected efficacy (e.g., a placebo). There is an increasing institutional push to conduct more intervention studies within DOHaD, which is tied to the hope of providing better evidence for the still controversial DOHaD hypothesis and of identifying venues for effective intervention, thereby showing the policy and healthcare relevance of DOHaD (Gaillard, Wright, & Jaddoe, 2019). The CCRG has been running interventional studies for two decades now, with their main work focused on one large intervention study that has now followed up the children into adulthood.

Fieldwork at the DOHaD Institute took the form of two longer research stays (two months and three weeks, respectively), and three shorter researcher stays of about a week, which took place between 2017 and 2020. During these three-and-a-half months of fieldwork, I shadowed three junior researchers through their daily work routines and participated in the informal meetings of different research groups as well as in different research seminars, colloquia and workshops. In addition, I conducted 22 formal interviews with researchers at the DOHaD Institute, which were each between 40 and 90 minutes long.

At the CCRG, I conducted fieldwork part-time for a period of one-and-a-half years between 2018 and 2019. During this period, I participated regularly in the biweekly meetings of the entire research group, as well as in the weekly working meetings of the CRRG's epidemiologists. I regularly shadowed three epidemiological PhD students for one day per week, observing them in their daily work routines and participating in their meetings with other researchers. I also accompanied them to and participated in two three-day meetings of a large consortium in which the CCRG participates. I conducted six formal interviews, which were each between 55 and 130 minutes long. All interviews were fully transcribed. I employed a Grounded Theory approach (Charmaz, 2006) to analyze the data, consisting of repeated rounds of open and focused coding of my fieldnotes and interview transcripts as well as of extensive analytical memo writing.

It is important to note that the two research centers, while being influential, do not represent DOHaD as a whole. Both centers are located in the Global North, whereas DOHaD as a field is increasingly diversified, with strong and very active regional DOHaD societies in Africa, Asia, and Latin America. The two research centers are situated in a context of developed welfare and healthcare systems and well-equipped research funding, which differs substantially from the resource-deprived contexts and contrasting public health priorities in which much contemporary DOHaD work takes place.

The research reported on here is part of an ongoing engagement with DOHaD researchers, in which we collaborate on how DOHaD knowledge-making and its dissemination can be made more socially responsible in ways that promote social justice and health equity (e.g., Penkler et al., 2019, 2020, 2021). This article, then, cannot purport to be a disinterested account, but is "situated knowledge" (Haraway, 1988) tied to personal, normative and epistemic commitments on my side. Some of my informants have become my friends and I deeply care about the issues that I report on here. I am invested into the question of how DOHaD can be made more responsive towards including complex understandings of the environment in its research practices. This is a shared "matter of concern" (Puig de la Bellacasa, 2011) between DOHaD researchers and the

ethnographer, as I hope will become clear in the following.

4. Findings

4.1. Between complexity and reductionism

I am nervous before my talk, which has been announced as part of the regular series of lunchtime colloquia at the DOHaD Institute. I have presented STS perspectives on DOHaD before, but this is the first time I will speak in front of my informants. What will they think of me and my research? Will they see me as an outsider who doesn't know what he's talking about? Will they be harsh, offended, or dismissive? Will anybody even show up?

These are worries that many of us who are "studying up" (Gusterson, 1997) know too well, but in this case they were unfounded. My talk is well-attended. Around 30 researchers are scattered around the basement auditorium. I present on what I see as the most pressing social and political challenges related to DOHaD, such as maintaining the complexity of the social determinants in research and considering social contexts in health messaging (Penkler et al., 2019). One participant, who is seated in the front row – a public health doctor as I learn later – enthusiastically nods throughout the talk. She is the first to raise her hand in the Q&A. "I absolutely agree with everything", she says. "This is really, really important! At the same time, I find it really hard to integrate more complex approaches in my own work. If you read my own papers, I'm sure I myself am guilty of blaming mothers." Others join the discussion, which revolves around the reasons why this is hard. Many contributions center on how different factors in the current science and public health system drive one towards more "simplistic approaches ..., which is a real problem", as one researcher says.

After the talk, I was happy about what felt like a smooth start into fieldwork. I was pleasantly surprised and continued being so during my subsequent research, about how receptive, open and supportive many informants were towards the critique raised by social scientists like myself.

This openness is, arguably, tied to the field's history and many DOHaD researchers' self-image. While DOHaD as an interdisciplinary research field is heterogenous, there is a common shared narrative about the field's origins, especially among senior researchers. Sitting in an armchair in his study, one eminent researcher involved in founding the field told me how DOHaD struggled against a reductionist mainstream: "It was a time, a ... a frustrating time in a way, because we all ... we always felt embattled, because nearly all the major funding in those days was going for reductionist science." In his view, which is reflected in many self-depictions of the field (e.g., Gluckman et al., 2016), DOHaD in its early days embraced 'complexity' and positioned itself consciously as a challenge against the gene centricism and deterministic views prevalent in the 1990s and early 2000s, which were epitomized by the Human Genome Project and its ambition to 'decode' the human genome as the key to explaining biological processes (Fox Keller, 2000). Many members of the DOHaD community are also explicitly concerned with health equity and social justice. "You know, I have fairly leftist views", another senior researcher at the DOHaD Institute told me, which she shares with many of her colleagues. Some recount the desire to make an impact in regard to health equity as a major reason for their decision to move into this research field.

If self-representations of the field as embracing complexity and aiming to contribute to health equity are accurate – then why is actual DOHaD research practice often pushed into what DOHaD researchers themselves regard as simplistic approaches? This is a question that has stayed with me throughout my fieldwork. In what follows, I detail different factors that push DOHaD research into directions that result in more reductionist articulations of the environment.

4.2. Factors that reinforce reductionist tendencies

4.2.1. DOHaD study design

Thinking about reductionist tendencies, I keep coming back to the ethnographic instance with which I opened this article: the epidemiologists of the CCRG debating the association between social background and the development of childhood obesity, which they deemed as self-evident but were – much to their chagrin – unable to show in their child cohort data. “*We just don't have the adequate data for it*”, the senior researcher, an epidemiologist, had said, “*We cannot represent complexity well through single variables*”.

On one level, this can be understood as a comment on how available epidemiological tools are not adequate to capture the complexity of the environments in which health and disease develop. Nicole Nelson (2018) has argued that the term ‘complexity’ in the life sciences is often loosely used to denote systems that comprise many components and may or may not have emergent properties. In her ethnographic work, she showed how animal behavior geneticists often talk about the ‘complexity’ of their subject matter “*with a barely contained sense of exasperation that behavioral phenomena continually overflowed the boundaries of the experiments that they had so carefully constructed to contain those complexities*” (p. 22).

When my informants talked about ‘complexity’, it was sometimes in a similarly loose sense that expressed frustration that the tools at hand might be inadequate to capture the multitude of different environmental factors that possibly interact in shaping developmental processes. But often, their concerns with data not being able to represent the complexity of the environment were more specific: they were that the manner and quality of the specific data available to them do not allow them to capture the properties of certain aspects of the environment in sufficient detail.

In order to understand why this may be the case, it is helpful to trace how DOHaD studies are designed. During my stay, the CCRG was in the process of setting up a large intervention study on the long-term health effects of a particular type of milk. Discussions in the group meetings frequently centered on details involved in designing the study: What type of data, e.g., on parental and child behaviors or on children's living conditions, should be gathered through surveys? What kind of physical examinations should be conducted when, and how? Which biological samples need to be taken, and how can they be analyzed?

These discussions made me realize two things: first, what a complex endeavor it is to plan and build a large-scale epidemiological study. The plan was to conduct the study at three sites across different European countries. It required storage and transportation solutions for the biological materials as well as minute protocols on how to register, store and transmit data. Many different human actors such as study nurses and laboratory technicians needed to be trained and coordinated, and large amounts of resources were going to be invested. The study design also needed to be adapted to local contexts. Existing laboratory and freezing technology infrastructures at the study sites needed to be considered. Similarly, opportunities for engaging prospective study participants were shaped by different national healthcare systems. In all three study sites, (quasi-)universal health systems, in which ante-, peri- and postnatal care is largely conducted at hospital clinics, facilitated recruitment and helped to ensure that the participant burden was kept low, as physical examinations and in-person surveys could take place in conjunction with routine health appointments.

Second, I witnessed how the planning of an epidemiological study, and in particular what kind of data is gathered and how, is the result of long negotiation processes among those involved. How exactly is

nutrition going to be measured? What kind of movement trackers should be used, and how? How should survey questions about children's screen time and leisure activities be phrased? What experimental techniques for gathering data, such as MRI scans, can be applied in the different study sites?

In designing epidemiological studies, DOHaD researchers constantly have to make decisions that are not pre-determined by their objects of investigation. This brings to mind Knorr-Cetina's (1981) now classical argument that research in the life sciences is characterized by “*decision ladenness*” (p. 5), i.e. the constitutive and ubiquitous need to arrive at methodological and analytical decisions under uncertain conditions and based on competing criteria. Sometimes these criteria are epistemic (e.g., which methods are best suited), but often involve more idiosyncratic or strategic rationales, such as the availability of specific know-how and scientific instruments, career considerations, or specific forms of research evaluation (Knorr-Cetina, 1981).

Decisions about research designs in DOHaD are often very pragmatic in nature, but have consequences for what can, or cannot, be addressed in subsequent analyses. When asked if there were things that she would have, in hindsight, wished for to be included in the data, a statistician centrally involved in running mother-child cohorts at the DOHaD Institute told me:

“So, I would have liked to have gotten more information about fathers, I would have liked more information on mental health during pregnancy ... But we always try to constrain our questionnaires to be no longer than one hour and a half, just because of the participant burden, not because we weren't prepared to do longer, but – you know – if ... if you say: will you give me four hours of your time? – people say no, so – you know – it's about that balance between retention of the cohort and participation ... So, it's always a trade-off and taking strategic decisions of what to include, and what not.”

As this quote illustrates, one pragmatic consideration that is especially pertinent is the question of how much data to collect. Designing a cohort study is often a balancing act between the wish to collect as much data as possible and trying to keep the burden low on participants, not least in order to maintain reasonably high study retention rates. In planning epidemiological studies, DOHaD researchers constantly engage in trade-offs and make strategic decisions about which data to include. In this context, researchers are well aware that they are not gathering the data they personally find ideal, but “*what works*”, as the statistician told me.

This tension is well illustrated by a guest researcher at the DOHaD Institute, who presented a newly set-up large-scale interventional study in the Global South in the institute's weekly colloquium. On a presentation slide, he explicitly juxtaposed the ‘ideal’ with the ‘pragmatic’. He told the audience:

“Planning such a study is often a balancing act between what would be ideal and what can be done for pragmatic reasons. In the study that we are currently starting, it would have been ideal to focus on structural aspects – for pragmatic reasons, a lot of the data we gather is individual. The ideal would have been to have study protocols that are harmonized across all study sites – for pragmatic reasons, they are often site-specific. The interventions delivered through the study would ideally be complex – but we have settled on that they should at least be scalable.”

Pragmatic considerations influence which data is gathered in DOHaD studies, and which not. In particular, DOHaD studies tend to focus on factors that are easily accessible. An example for this is the design of intervention studies. While the intervention studies run by the CCRG focus on dietary supplements, many interventions at the DOHaD Institute focus on maternal and child behaviors, such as diet and exercise. This focus on behavior is regarded as subpar by many, but maintained for pragmatic reasons, as a PhD student with extensive professional experience in public health told me: “*There's, you know, been a shift in public*

health thinking in recent years. Fewer and fewer people believe in purely behavioral interventions any more But many interventions still focus on behavior.” As she explained to me, interventions that focus on administering lifestyle advice simply “cost less” and are more easily implemented than interventions aiming to change the social structures that shape behaviors. This is an example for how some aspects of the environment, such as individual behaviors, are easier to model and turn into numbers than others, such as the social contexts of these behaviors. This, in turn, has the potential to skew data on environmental factors in particular directions, which I will discuss in a later section.

While data limitations are a main reason for reductionist articulations of the environment within DOHaD, there are other factors that reinforce these tendencies.

4.2.2. Harmonizing data

It's my first time at a large European consortium meeting. The three-day meeting takes place in a large city and feels like a big class reunion. Everybody (but me) seems to know each other; people run into one another at the hotel, walk together to the venue, chat in a lively way to one another during the breaks. There's even a group photo after dinner.

The epidemiologists from the CCRG were kind enough to invite me to the meeting of this consortium, in which research on child cohorts from across the continent is collated to examine how early life stressors affect later life. Discussions focus on the technical, legal, and scientific issues involved in pooling data from different cohorts. A major point is progress in ‘harmonizing’ the data, where the consortium is behind schedule – “in order to be able to achieve our deliverables, we really must step up our efforts a bit”, the project coordinator reminds everyone else.

As in biomedical research more generally (Ackerman et al., 2016; Benezra, 2016), there is an increasing trend in DOHaD to pool data across cohorts. This is widely perceived as necessary in order to achieve a sufficient sample size to power the statistics involved in -omics approaches that have become more prominent in DOHaD in recent years. Aiming to pool data from different cohorts, you have to make sure that these cohorts have measured the same things in a comparable way. The problem is, every cohort is measuring phenomena like sleep duration, nutritional intake, exercise etc. in ever so slightly different ways. So, when is data actually comparable? Here is where the need to ‘harmonize’ data comes in: researchers from the participating cohorts need to prepare ‘their’ data in a way that fits agreed-upon standards and can be used in cross-analysis. As I witnessed by shadowing one of CCRG's PhD students, this is an often-cumbersome process. It not only requires constant decision-making in regard to what is and what is not comparable, but also has a number of consequences for which environments tend to be considered in the ensuing statistical analyses.

First, the need to draw on variables that are available across all participating cohorts drastically reduces the number of available variables. “This often does not leave you with very much when you want to model the social or built environment”, one junior researcher told me in a break during the consortium meeting, explaining that only the indicators that are the greatest common divisor remain for analysis. For example, when it comes to social determinants, only few indicators, such as educational background of the mother, are consistently and comparably measured and thus scale across cohorts. Secondly, relying on variables that scale across cohorts also necessitates a loss of local context when interpreting data, contributing to universalized accounts that do not account for how biologies are shaped differently in different localities, contexts and sites (Yates-Doerr, 2017).

Thirdly, some forms of data are easier to harmonize and thus to integrate into combined statistical analysis than others. In order to exemplify this, the junior researcher gave me the example of epigenome-wide association studies (EWAS), an -omics approach that is nowadays widely used in epidemiological DOHaD studies (Felix & Cecil, 2019). EWAS establish associations between an individual's epigenome and a range of outcomes. Because all epidemiological studies tend to use the same standardized arrays by the same manufacturer for producing

‘epigenome’ data, harmonizing this data is trivial. In contrast, no such standardized arrays exist for measuring environmental factors, as the junior researcher explained to me in breaktime during the chat mentioned above. As Ackermann et al. (2016) have pointed out, environmental factors quickly appear as imprecise and “soft” (p.207) when compared to the high compatibility and precision with which genetic factors can be measured. This leads to a situation in which specific aspects of the environment scale better and are thus easier to include in cross-cohort analyses than other aspects. These tendencies towards reductionist articulations of the environment are further reinforced by the contemporary science and public health systems, to which I turn next.

4.2.3. Needing to ‘sell’ and perform

“You know, in order to get attention, you really need to ‘sell’ your research. And in order to sell it, it's often good to have simple and clear messages. Which perhaps are oversimplifying ...”. I was interviewing the public health doctor in her office at the DOHaD Institute. Our conversation had turned to how DOHaD messaging might place responsibility and blame on mothers for their offspring's health. It's the current science and health policy systems that push you into such a direction, she said: in order to be successful, it's important to get attention. In order to get attention, it's good to have clear messages that appear actionable. Messaging that focuses on behavioral changes in mothers fits the bill, as it often appears as less politically contentious and more achievable than calling for system change.

The need to publish and secure third-party funding is a further factor that can incentivize focusing on more simplistic approaches. The current research system favors the ability to perform in terms of producing quantitative research output above all else (Müller & de Rijcke, 2017). Many, and in particular younger, DOHaD scholars are very conscious of how necessary it is to have a high publication output in order to forge a career. This can form a strong motivation to focus on research avenues that are comparatively easier to translate into publications and further incentivizes focusing on data that is easy to handle and collect – “hard data”, as one young scholar at the DOHaD Institute told me, such as from direct physical measurements, as compared to “soft” data from surveys, which does not scale as well and is often regarded as less reliable (see Ackerman et al., 2016). Consistent output is more easily achievable with clear-cut and individual-level variables, which steers DOHaD research away from more complex understandings of the environment and into using indicators that are well-tested and straightforward to use.

4.3. Articulations of the environment

Following Bruno Latour's (2004) theory of articulation, we can understand DOHaD studies as intricate instruments, as socio-material set-ups that allow us to perceive the world in specific ways. They provide a sensorium to register differences, thereby bringing into being specific versions of the environment. As we have seen, pragmatic considerations, existing tools and infrastructures influence how DOHaD studies register the environment. DOHaD can thus be characterized as having a specific “regime of perceptibility” (Murphy, 2006), in which some versions of the environment become perceptible and measurable, and others do not. I now discuss three (arguably more reductionist) articulations of the environment – environment as nutrition, social determinants, and maternal bodies and behaviors –, and trace how DOHaD researchers themselves grapple with these articulations.

4.3.1. Nutrition

“You have to work with the data that you have at your disposal”, a junior scholar at the DOHaD Institute told me as I sat down with her at the hospital's library to discuss the nutritional data she works on. She told me that she would wish for better data on how participants' dietary behavior is constrained by structural factors (e.g., by the easy availability and affordability of healthy food or socioeconomic factors), and also on how dietary behavior is tied to emotions and psychological factors.

However, the studies she works with mostly contain data on what and how much is eaten, framing nutrition mostly as a question of the quantitative intake of nutrients. This data is gathered using different methods. Self-reported food diaries, while being notoriously unreliable (Kristal, 2005), allow tracing of what kind of meals study participants have eaten in a fairly straight-forward way. Researchers can then calculate the intake of different nutrients by estimating the biochemical composition of meals and average serving sizes. Another used method are urine samples, which allow researchers to evaluate specific characteristics of a participant's nutrition and are often seen as a more 'objective' measure. Lastly, intervention studies allow the regulation of nutritional intake up to a certain point, for example through varying the composition of infant feeding formula or through providing food supplements. DOHaD studies thus tend to contain a lot of information on food nutrients, which can be fairly easily calculated. At the same time, data on the social and cultural contexts of eating or on psychological or emotional factors relating to eating are less frequently gathered, and available data on these aspects is often deemed less reliable.

As a result, the studies conducted by the two research groups register diet mainly as a question of the biochemical and nutritional composition of food. This tendency within modern nutritional and biomedical sciences to understand food and nutrition and their link to health primarily on the biochemical level has been described as "nutritionism" (Scrinis, 2008). The DOHaD studies I have observed embody what can be described as a nutritionist vision of food, because the tools they employ allow them to register and thus articulate nutrition as a matter of the intake of different quantities and types of nutrients, and less so as a cultural activity that is linked to psychological and emotional aspects and patterned by wider social contexts.

4.3.2. Social determinants

The contours of DOHaD's *regime of perceptibility* also become visible in regard to how social determinants of health and disease are captured in DOHaD studies. For example, the biggest cohort at the DOHaD Institute, which has been running for over twenty years, asks, in its initial questionnaire during recruitment, only a small number of questions that aim at recording the social background and circumstances of the parents. These items include the current employment status of the mother and her partner, their last occupation, household income, and education. When the child taking part in the research reaches two years of age, there is an additional questionnaire that includes questions on problems relating to housing and the neighborhood, as well as questions on household income and on which unexpected expenditures can cause financial difficulties.

However, as one epidemiologist involved in conducting the study told me, it is often not straightforward to use most of these items to model socio-economic background. "So the socio-economic status is quite challenging. Actually, for a lot of what we use, education of the mother is the most important factor. So, we tend to find we ... - you know - adjust for education rather than social class ... It's actually also much easier to ask about education." As this quote illustrates, participants are sometimes unwilling – or unable – to answer questions about income. Data on housing conditions or the neighborhood is often difficult to gather and to harmonize for cross-cohort analyses.

Social background, adversity and deprivation are thus measured and represented through a few proxy, individual-level variables that are modelled as distinct characteristics of individuals. In many analyses, one single variable – educational background of the mother – is taken to represent the entirety of socio-economic status. The complex social contexts and processes that pattern access to healthy nutrition, toxic exposures, or social stress thus tend to be represented by, and thus disappear behind, a few more simplistic variables (Penkler et al., 2019). 'Social background', as addressed in many DOHaD studies, becomes just that – a static 'background' that can be modelled on simple continuous scales, and not a complex process tied to more systemic structures of inequity.

The tendency of epidemiological DOHaD studies to articulate only a simplistic version of the environment is of particular concern to many

DOHaD researchers when it comes to intervention studies. More frequent in the past years, they are tied to the hope of producing better evidence for the DOHaD hypothesis and proving that it is relevant for healthcare and policy. However, as one recent review stated, the results of interventions "on pregnancy, early postnatal and long-term outcomes (have been) disappointing" (Gaillard et al., 2019, p. 316). By some, this is seen as an existential threat to DOHaD's future, as one senior researcher involved in designing and planning intervention studies in the Global South told me:

"I think if the whole field of DOHaD is going to survive, then we're going to need to see something soon. Something different ... [laughs]. Because I think people will lose patience with it. You know, people are quite flighty really in science. They want to be in something exciting. And if trial after trial keeps coming up with no results, then ... [laughs]"

According to this researcher, a persistent conceptual problem of lifestyle interventions tends to be that they focus on a limited number of behavioral factors, which are often studied in isolation. She told me about an intervention study they are currently concluding:

"It's finished, and we have just finished following up the children. So, we will soon know if there's anything to be seen there. I'm quite sort of resigned to the idea that there might not be. Because when you actually sort of got to know all these women, who were having this intervention, you could see the huge number of things in their lives that they were dealing with, apart from food ... And, you kind of thought, well, if this did something, it would be kind of miraculous, really."

Lifestyle interventions are often based on the idea that some aspects of people's life can be isolated, controlled, and intervened on, and that the effect on long-term health outcomes can subsequently be measured. However, against the background of how complex human lives are, expecting a measurable effect from such limited interventions might have been "too optimistic", as the researcher told me. Another limiting factor is that intervention studies out of necessity often run for a comparably short period of time, as a guest researcher at the DOHaD Institute told me: "Again, these interventions are so short ... tiny - you know - we just need to think about our own lives and what it takes to implement change".

Health interventions can only muster limited resources, which are often not sufficient to comprehensively address the complexity of human lives. As a result, many DOHaD interventions – as health policy more generally (Sanabria, 2016) – continue to focus primarily on 'lifestyle factors' and not on the wider structures and processes in which individual behaviors are embedded. An epidemiologist told me that this worries her for political reasons:

"So, you know, ultimately sometimes I get depressed, because I think what we are doing is just doing a bit around the edges and actually, if we could make it a fairer society and give people a bit more money that would have a much bigger effect. So, adjusting the bigger picture is sometimes something that gets a bit depressing, but on the other hand ... we have got to work within a framework we have got at the moment and the political change, we can fight for in different ways, but our research has to work within that framework."

Nelson (2018) has described how junior animal behavior geneticists often experience a "complexity crisis" (p. 43) when confronted with the (ultimately impossible) task of experimentally controlling the multitude of factors that might influence animal behavior. DOHaD researchers sometimes experience similar epistemic doubts about their own research, but also political doubts about the translation of their research into policy. At the same time, at least my interviewee also seemed pragmatically resigned to the fact that her research has to operate within a framework that imposes limitations on what can be achieved – arguing that, while what she can achieve in her research might be limited, she can still fight for political change in other ways.

4.3.3. Maternal factors

A persistent concern of social scientists has been how DOHaD tends to focus on ‘maternal factors’ (e.g., Richardson, 2015), and the cohort studies run by researchers at the DOHaD Institute do have a strong bias towards maternal data. Data on fathers and partners is scarce and, if existent, of comparably low quality (e.g., background information on fathers and other caregivers is usually gathered through survey questions posed to the mother). While this is of concern to the researchers I worked with, gathering data on other caregivers poses considerable logistical challenges. It is first and foremost mothers who continue to be the primary caregivers in European societies and who subsequently participate in the routine health appointments that form the primary opportunity for collecting cohort data (Sharp et al., 2019). It is also comparatively easy to focus on the primary caregiver in isolation, whereas gathering data on more complex social support structures is difficult to include in epidemiological studies.

This strong tendency to articulate mothers and the core family as *the* formative environment for children’s development is controversial among DOHaD researchers themselves: “Well, if I’m honest, I had a bit of angst about how much guilt we were putting on women about trying to – you know – focus on women and what they are doing and blaming women and I was a little anxious about it”, one senior researcher told me about her experience when she first moved into the field 20 years ago. She added: “But as someone said to me very wisely: if ... if we don’t know, we can’t do anything about it, so – you know – actually finding out whether it’s important, it’s important or not, then how you manage the implications are ... are a different thing, but not knowing is never a good scientific principle [laughs].”

“Don’t blame the mothers”, a phrase popularized by an interdisciplinary commentary piece in *Nature* (Richardson et al., 2014), has become a widely circulating catchphrase in the field and is testament to how many DOHaD researchers worry about reproductive justice. This apparent worry, however, conflicts with a continuing pragmatic focus on maternal bodies in DOHaD research, which is often rationalized by pointing out that it is still ‘good to know’ how maternal factors impact the development of health and disease. By claiming that doing research is different from managing the political implications of research, scholars sometimes resort to a form of “boundary work” (Gieryn, 1999) that depoliticizes knowledge claims. This can be seen as a coping strategy in a context where the normative commitments of DOHaD researchers are partly at odds with the institutional, pragmatic and methodological dynamics that push their research into reductionist directions.

5. Conclusions

DOHaD deals with a wide variety of phenomena that are situated on very different scales and develop over extended periods of time. How to adequately deal with and capture this complexity is an important question in and challenge for DOHaD research. This is not necessarily something unique to DOHaD: STS research has shown that natural phenomena generally “do not present themselves in neat packages” (Nelson, 2018, p. 41) but that scientific work consists of transforming resisting phenomena into objects amenable to controlled inquiry. The life sciences, especially, are often tasked with capturing phenomena and behaviors that comprise a multitude of contributing factors with possibly emergent properties that are difficult to experimentally control. As Niewöhner (2018) has pointed out, “observations with epistemic intent (necessarily) reduce contingency and complexity”, and this is “not something to be afraid of, but the essence of meaning-making, knowledge production and worlding” (p. 563). Like any research, DOHaD needs to be reductionist in order to articulate, and thus bring into being, its research objects. The question, then, becomes *what* is reduced *how*, and with which effects.

There are different factors that steer the articulation of the environment in DOHaD research away from more complex understandings of the environment. On the one hand, the epidemiological methods employed in DOHaD perform a certain type of “ontological politics” (Law, 2004) as they are better equipped for measuring discrete variables pertaining to individuals’ physical conditions and behaviors than for capturing the

environment on a more structural and collective level. Similarly, the nutritional environment captured by these tools is mostly articulated in terms of the biochemical and nutrient composition of diet, thereby reproducing a “nutritionist” (Scrinis, 2008) view that is not conducive to capturing eating as something socially patterned or culturally experienced. On the other hand, these tendencies towards simplistic articulations of the environment are further reinforced by broader trends within the contemporary science system, like the pressure to publish one’s research and to ‘sell it’, as well as by a pervasive “moral economy of quantification” (Ackerman et al., 2016). These institutional contexts further reinforce pragmatic tendencies in science and its inherently opportunistic logic (Knorr-Cetina, 1981), leading to a situation in which researchers tend to pursue what is more easily achievable.

These tendencies towards simplistic articulations have important social and political implications, as how we articulate and thus represent the environment influences the evidence base for designing, conceiving and legitimizing health care and policy interventions. In the context of NCDs, Sanabria (2016) has argued that “the possibility of reliably showing causal relations between the political and socioeconomic determinants of malnutrition and measurable health indexes is largely compromised not simply by the absence of good evidence but also because the existing parameters of good science cannot straightforwardly reveal such relations” (p. 135). As a result, public policy often “remains wedded to a mode of reading and intervening that has limited purchase on the complexity with which it contends” (Sanabria, 2016). When complex problems are reduced to what is feasible, this can lead to a neoliberal translation of DOHaD science that locates responsibility mainly on the level of the individual, even when such a framing has proven to be inadequate.

Such translations of DOHaD science run counter to the values and beliefs of many DOHaD researchers. Science as a pragmatic enterprise, because of its opportunistic logic, can conflict with what researchers themselves envision or might wish for. For many DOHaD researchers, the concerns raised by social science scholars about the social and political implications of DOHaD are a shared “matter of care” (Puig de la Bellacasa, 2011), as they are motivated by social justice concerns and how their research contributes to health equity. They are reflexively engaged – and sometimes struggling – with how their own research practices and the research field as a whole may steer into a direction that focuses predominantly on individual behaviors. In this paper, I have highlighted these struggles and the different narratives that DOHaD researchers present to account for these tensions in their work.

This reflexivity is perhaps a reason why some DOHaD researchers actively seek and engage in interdisciplinary collaborations on the social and political aspects and implications of their work. These collaborations have resulted in a number of interdisciplinary workshops, seminars, and co-authored interdisciplinary publications between DOHaD researchers and social scientists like myself in recent years (e.g., Müller et al., 2017; Richardson et al., 2014; Sharp, Lawlor, & Richardson, 2018; Penkler et al., 2019) as well as in first research collaborations that include social scientists into epidemiological DOHaD studies. Such collaborations can open up spaces for reflection and discussion and facilitate experiments on how more complex understandings of the environment can be integrated into actual DOHaD research practices. They can thus help address a central tension not only within DOHaD, but within scientific practices more broadly: how to adequately deal with complexity when much of the power of scientific practice comes from its capacity for reduction (Latour, 1999)? If there is a need to be reductionist, how can we successfully operate within this need and still enable more complex articulations of the environment?

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