Entanglement HCI The Next Wave?

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This article argues that our intimate entanglement with digital technologies is challenging the foundations of current HCI research and practice. Our relationships to virtual realities, artificial intelligence, neuro-implants or pervasive, cyberphysical systems generate ontological uncertainties, epistemological diffusion and ethical conundrums that require us to consider evolving the current research paradigm. I look to post-humanism and relational ontologies to sketch what I call Entanglement HCI in response. I review selected theories—Actor-Network Theory, Post-Phenomenology, Object-Oriented Ontology, Agential Realism—and their existing influences on HCI literature. Against this background, I develop Entanglement HCI from the following four perspectives: (a) the performative relationship between humans and technology; (b) the re-framing of knowledge generation processes around phenomena; (c) the tracing of accountabilities, responsibilities and ethical encounters; and (d) the practices of design and mattering that move beyond user-centred design.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**;

Additional Key Words and Phrases: Entanglement, posthumanism, new materialism, philosophy

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1 INTRODUCTION

Reflecting on the state of affairs in the field of Human-Computer Interaction, Harrison et al. [2007] begin with:

> Over the last few years, the authors of this paper have become increasingly aware that a third paradigm has been discussed in corners and cafes with much head nodding at the CHI conference …

A rather fitting description, I would argue, of a scientific revolution in the Kuhnian sense. Notably, however, the authors found the concept of generative metaphors by Agre [1997] a more productive lens to look at paradigm shifts in HCI than the classic cycle of Kuhn [1970]. Consequently, the three paradigms Harrison et al. [2007] identify, each put a central metaphor in focus that is driving particular research agendas, without defining them as mutually exclusive. The first paradigm stands for the idea that interaction is a form of human-machine coupling that needs to be optimised in a human-factors way. The second builds on the metaphor of humans and machines

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being information processors of similar workings that need to be connected, considering weaknesses and strengths such as working memory. Finally, the third is focused on interaction that is situated in the social and bodily complexities of a messy, real world.

Bødker [2006] describes similar waves along different dimensions: drawing on Bannon [1995], she identifies the shift from a first, human factors wave to a second wave that is concerned about well-established, well-defined communities of practice, such as the workplace. The third wave, then broadens and intermixes contexts such as private and professional life. In the words of Bødker [2006]: 'the third wave, to some extent, seems to be defined in terms of what the second wave is not: non-work, non-purposeful, non-rational'. The cultural and emotional aspects of interaction became more central to the experience of people with technology.

However one might look at these different ways of describing the evolution of HCI, it is clear that we now see a very heterogeneous field, in terms of technology, application contexts, theoretical underpinnings and methodological approaches, that grapples with the increasingly intimate entanglement of humans and digital technology in all aspects of life. Some argue, that this heterogeneity in the field is problematic as too much work finds itself in the emerging and chaotic corner, while we lack mainstream motor themes that consistently drive theory and define what it is that we do [Kostakos 2015; Liu et al. 2014]. Others are more content with the fast-paced, seemingly fragile state of the field. Blackwell [2015], for example, argues for seeing HCI as an inter-discipline in which 'technology becomes a lens through which to understand being human in a changing world'.

Maybe not surprisingly, most of these reflections around disciplinary coherence in essence revolve around epistemological questions about what and how we know and how we can build on this knowledge as a field. As Harrison et al. [2011] made very clear, the third paradigm makes epistemological trouble as it goes against the traditional engineering culture that HCI inherited. More recently, in the wake of another round of soul-searching in HCI, Höök et al. [2015b] examined the different ways of knowledge production in the field and identified a gap between what they call 'universal laws' and the highly situated forms of knowledge that increasingly were produced by third wave HCI work. In between, they argue, the field needs to intensify its efforts to develop forms of *intermediary knowledge*, knowledge that lives in between generalisable theories and single instances, or ultimate particulars as Stolterman [2008] calls the outcomes of much design practice. The argument is driven by the need to capture the interpretative and generative qualities of what we intuitively learn in Research through Design and making it explicit for the field to build upon. While in effect, I would argue that this approach has been a productive way forward, the theoretical argument is flawed and the methodological conception still hampered by loyalty to the old science [Frauenberger 2018; Torgersson et al. 2019].

Beyond the epistemological trouble, however, we are also seeing more fundamental questions being asked about the relationship between humans and their machines that are unsettling the disciplinary self-image of HCI. Historically, there were computer systems and humans and what was required was to design an interaction that was either effective or served some desired user experience. Nowadays, the boundaries between technology and humans are increasingly fuzzy: natural language processing, social robotics, artificial intelligence, cyberphysical systems, virtual reality, augmented reality or neuro-implants are all probing the limits of where the human ends and technology starts. For HCI, this quickly leads to the question of where the interface is that needs designing and more generally it points to a philosophical debate about desirable technological futures and who 'homo digitalis' should be in those futures. A debate that HCI cannot afford to ignore. After all, the extent to which digital technology shapes who we are means that whoever shapes technology, puts the chisel on humanity.

This leads to another topic in HCI that is receiving increased attention: ethics and responsibility. While the trolley problem used to be a thought experiment only known to certain circles of philosophers, the prospect of self-driving cars being the prime mode of transportation has resulted that most people nowadays have an opinion on the dilemma [Awad et al. 2018]. Equally, the collection and storage of data combined with ever more sophisticated machine learning algorithms has opened a pandora's box that looked like benign advertising and turned into a mass manipulation tool that fundamentally undermines democratic institutions and principles of equality [O'Neil 2016]. With the increased inter-dependence between humans and machines and the acceleration of both data collection (smart homes, smart cities, quantified self, etc.) and the level of 'intelligence' in the artificial, questions about who might be responsible for what have no easy answers anymore.

Motivated by the epistemological troubles, the ontological uncertainties and the ethical conundrums, I turn to what Orlikowski [2010] called *entanglement theories* which, despite their heterogeneity, have in common that they acknowledge the intimate inter-dependencies within socio-material (and consequently, socio-technical) arrangements and that consequently any attempt to study humans or technology in separation is necessarily flawed. To this end, these theories all make a radical proposition: humans and things are 'ontologically inseparable from the start' [Introna 2014]. While bringing humans and non-humans onto the same level within a *relational ontology* is far from being uncontroversial, I argue that it might be a productive way for HCI to evolve in response to a changing world. The paradigm cycle of Kuhn [1970] identifies a point where the existing frame of thought is systematically struggling to keep up with what is empirically observed—the model crisis. HCI may not yet be in a state of serious crisis, but it is certainly cracking and squealing, struggling to make sense of computers, humans and interfaces in the face of rapid technological progress, coupled with profound social change.

In this article, then, I aim to test the waters for a paradigm shift that seems to be in the making, particularly within the more design oriented corners of the field. I want to explore whether relational ontologies can provide an underpinning theoretical framework within which HCI can understand its practice and respond to its ethical, epistemological and ontological challenges.

The outcome of this project is unknown and this article necessarily is only a humble contribution to the debate. Also, many of these ideas, most prominently emerging from Science and Technology Studies (STS), have already started to filter into the field, leaving their mark in various ways. Taylor [2015] and Verbeek [2015] have both written in SIGCHI's flagship magazine on what comes after or is beyond interaction, both basing their argumentation on a re-conceptualisation of the agency of *things*. Bogost [2012] is now widely cited in the gaming literature for enquiries using Object-Oriented Ontology (OOO) and Bruno Latour, one of the central figures in Actor-Network Theory (ANT) gave a keynote at CHI in 2013. As the quote in the beginning of this article states, paradigm shifts begin in many different corners. Consequently, this article starts with a review of the core concepts and the range of *entanglement theories* and the intersections they have with HCI literature. Building on this review, I aim to start sketching what might become a new paradigm, focusing on the question of being (ontology), knowledge creation (epistemology), responsibility and purpose in the world (ethics) and what such a paradigm shift would mean for the practice of creating technology (design). I intentionally have chosen to engage these foundational themes all at once—possibly at the cost of depth—because my theoretical position leads me to argue that they inseparably collapse in what Barad [2007] has called an ethico-onto-epistemological perspective.

2 ENTANGLEMENT THEORIES

What is subsumed here under the heading 'entanglement theories' is in itself a heterogeneous range of thought on the relationship between humans and the material world. However, what

they have in common is that they seek to develop an understanding of a socio-material world that moves beyond the socio-natural and cultural-material dualisms that have characterised modernity. The dualistic notion of how the intentional mind models the passive, material world to its liking has become deeply ingrained in engineering and consequently became part of HCI's cultural heritage. With the influence of post-modern thinking, this started to change. Heidegger's phenomenology sought to overcome this mind-body dualism by moving to a notion of 'Dasein' that required an embodied mind to be present in the world [Heidegger 1967]. This embodiment became central to third wave HCI [Dourish 2001], in particular with the rise of mobile and tangible user interfaces [e.g., Hornecker 2011]. Entanglement theories take this line of thought one step further by questioning the locus of agency, asking which active contributions tools make to what humans do.

Another common feature of entanglement theories might be useful to delineate them from previous perspectives on human-material relationships: the decentreing of the social, which sometimes is labelled as philosophical *posthumanism* or *new materialism*. Entanglement theories mostly originate from the field of STS, which takes a sociological lens on the subject of science and technological innovation. Again, modernity had entrenched a dualist view that there is an external reality that the mind could empirically conquer. Increasingly, however, this positivist view was undermined by evidence that showed how knowledge was socially constructed. The seminal work of Kuhn [1970], referred to above played a key role in this. Without wanting to go into the depths of the science wars between realists and social constructivists, entanglement theories seek to reframe the problem by making things social actors, i.e., knowledge neither stems from an objective, inanimate reality, nor is entirely fabricated in the social realm or language, but describes a reality that is co-constituted in materially discursive productions. In other words, they are not denying the social construction of our knowledge about the world, but seek to emphasise that the world is no passive object in this process, but rather is intimately entangled in the knowledge production. This is what leads them to a position of a *relational ontology* that is expressed as socio-material configurations, networks, associations, assemblages, ensembles and so on.

The knowledge production debate in HCI reflects its own way of grappling with the positivist vs. constructivist perspective. Within the field's body of literature, we still see a wide range of studies that make reference to one or the other. While I would argue this heterogeneity is one of the great features of HCI, the minimal common ground in terms of underlying epistemological stances limits the cross-fertilisation between these ways of knowing. Relational ontologies may offer strategies to coherently underpin current practices without descending into new science wars.

The following takes up four streams of thought in this realm and reviews existing intersections with current HCI literature: ANT as originally developed in the 1980's by sociologists Bruno Latour and Michel Callon; Post-Phenomenology by Don Ihde, Peter-Paul Verbeek and others, OOO and its main proponents Graham Harman and Levy Bryant and the notion of Agential Realism by quantum physicist and feminist theorist Karan Barad.

2.1 Actor-Network Theory

Latour and Callon first developed ANT from a social constructivist perspective, arguing along similar lines for a view on science and technology that situates it firmly within the social realm. As a consequence, they share the concern for the context in which knowledge and artefacts are attributed with meaning. However, while other approaches have similarly invoked networks as a means to make sense of how this meaning was constructed [e.g., Pinch and Bijker 1984, and their study on the development process of the Penny-Farthing Bicycle], they held on to the categorical difference between humans and the material world and the notion that agency was tied to only one

of these—humans. Latour [1996] clarifies that ANT does not follow this clear distinction, but sees more uncertainty in terms of how agency is distributed between human *and* non-human actors.

Latour's argument starts with observing that there are no separate 'social aspects' of otherwise asocial things. Thus, he would also strongly reject the notion of Human Factors in Computer Science arguing that there is nothing in Computer Science that is not already social. Material things, e.g., computer artefacts, allow, afford, restrict or enable human activity, they are themselves sources of action and become participants in the course of this action, i.e., are actors in a network of associations between humans and non-humans. Thinking of the many ways in which mobile phones, for example, shape human behaviours and activities, exemplifies this role as participating actors. Notably, as actors they do not determine the action, which would be a reversal of the direction of influence, but they shape and contribute to the action through their association with other actors. As Latour [2005] puts it there exist 'many metaphysical shades between full causality and sheer inexistence' (p72), or in other words there is a wide spectrum from strong ordering to weakly structuring to not affecting action. ANT goes even further and argues that *anything* that has influences on an action in a way described above is an associated actor, which also includes non-material entities, such as policies, laws or societal norms.

This is made possible by evoking a semiotic definition of 'actor', separating the term from its common connotation with human intentionality:

> An actor in ANT is a semiotic definition – an actant – that is something that acts or to which activity is granted by others . . . An actant can literally be anything provided it is granted to be the source of action [Latour 1996, p. 373].

While this is a radical proposition, it is motivated by the need to account for the fact that materials, artefacts or concepts like the law or social norms can be the source of action. In his well known example, Latour [2000] discusses the Berlin key and its inscribed *program of action*: the Berlin key is a special key that has two symmetrical ends and forces tenants to lock the doors behind them. To retrieve the key from the lock, it is necessary to push it through to the other side and turn it, i.e., lock the door. While the program of action is inscribed into the artefact, the agency is the result of its relation to the tenant who is not only a legitimate inhabitant, but also has the knowledge how to use the key. Hence, the attribution of agency to the key is a network effect. Similar accounts could be told for digital technology: the well known study by Star and Ruhleder [1996] on a knowledge management system for the Worm Community not only demonstrates the workings of infrastructures and boundary objects, but also how agency is a nuanced effect of the different associations in a network of people, data, communities and the computing artefact.

Suchman [1998] argues that this agency may not be evenly attributed amongst actors in a network and warns that abolishing all ontological asymmetry between human and non-human actors may cause troubles in terms of attributing authorship and accountability. After all, any discontent of tenants with the locking system would be directed towards the landlord who chose to install it, and to a lesser degree to the key or the lock itself. Nevertheless, ANT allows to explore the middle grounds by carefully analysing the relationships between actors. As Latour [2005] reassures us, ANT is a way to conduct a *sociology of associations* by following the actors around.

ANT has been picked up in the HCI literature for different reasons: Potts [2008], for example, argues for using ANT to visualise system states and process flows as a software design methodology. Stolterman [2008] explores the notion of device landscapes, drawing on ANT using networks of connected artefacts in which users are interwoven. Fuchsberger [2011] use ANT to investigate technology non-use (also [Fuchsberger et al. 2014]) and Fuchsberger et al. [2013] review our understanding of materiality as an interactive medium, using MacLuhan's work as well as ANT. Kumar and Rangaswamy [2013] presented work that studies actors around media piracy in India with

ANT and Dörk et al. [2014] refer to ANT in their visualisation of relationships in search queries. Frauenberger et al. [2016] make use of ANT in their concept of Design Exposés, a format that emphasises the socio-material nature of co-design processes. Spiel et al. [2017a] develop a new approach to capture experiences with technology through ANT and Critical Discourse Analysis (see also [Spiel et al. 2017b]). DiSalvo et al. [2014] uses the thinking of Latour to reconceptualise HCI's role in (re-)configuring publics by designing things around matters of concern. Jenkins [2015] have a similar interest in object-oriented publics and argue against ignoring computing as a social actor with its own agenda.

In the context of Participatory Design (PD), ANT also helped to shift the perspective on the material world. Storni et al. [2012] describes a workshop at PDC'12[1] with the aim to use ANT as a lens to examine PD practices, which led to a special issue on the intersections between co-design and ANT [Storni et al. 2015]. In one of the contributions to this special issue, Storni [2015] argues that PD should design actor networks, in other words, doing PD is, or should be actor-networking. Drawing on ANT and socio-material concepts such as infrastructuring and boundary objects [Star and Ruhleder 1996], Binder et al. [2011] expand the notion of the *object of design* to include the physical artefact within its situated, socio-cultural and socio-historical context, i.e., from designing things to designing Things as Björgvinsson et al. [2012] put it.

ANT seems to have appealed to researchers in HCI mainly for its methodological affordances. It provided an effective way to consider socio-material context of interactive artefacts. It is interesting to note that, in the best tradition of HCI, useful aspects of ANT have been adopted without necessarily buying into all underlying philosophical commitments. While bringing technology and people into the same frame is methodologically convenient, the ontological, epistemological and also ethical consequences are often embraced less enthusiastically. The more political work around publics may serve as a partial exception here, as would the influence of ANT in PD.

2.2 Post-Phenomenology

Ever since Heidegger [1967] countered Descartes' mind-body dualism by a more holistic understanding of *Dasein* and discussed the different ways in which one may experience using a hammer, phenomenology has become a productive lens to explore the different roles of technologies as tools. Notions of embodiment particularly gained popularity as computing artefacts became mobile and tangible devices [Dourish 2001; Winograd and Flores 1987]. Today, the notion of *embodiment* is a household name in HCI, constantly developed further. Höök [2018], for example, brings the centrality of the body into the design process itself through somaeasthetics.

However, classical phenomenology has also treated technology in fairly abstract and passive ways as tools. This has prompted Ihde [1990] to develop its fundamental ideas further into what became referred to as *Post*-Phenomenology. In a turn towards materiality, two concepts demarcate Post-Phenomenology from its origin: firstly, it rejects the notion that tools somehow alienate or distance human beings from the world they live in. Post-Phenomenology ascribes technology a more active role in *mediating* relations between humans and the world. Secondly, it develops the concept of intentionality further and argues that subject and object are constituted in their mediated relation, i.e., any human experience of the world is mediated by material entities and both, humans and non-human entities define themselves through this relation. 'Human-world relations are practically enacted via technologies' [Rosenberger and Verbeek 2015, p. 12]. As such, Post-Phenomenology shares the notion of enacted agency in ANT and also the concept of performativity in Agential Realism, as we will discuss below.

[1]Participatory Design Conference 2012 in Roskilde, Denmark.

While Post-Phenomenology is rooted in a very different tradition of thinking, it ends up in a similar space than other entanglement theories. It also effectively is built upon a relational ontology that understands humans and things through their relation and distributes agency accordingly. As such it is materially sensitive, although Post-Phenomenology does not embrace a strict symmetry as ANT would. Post-Phenomenology overall seems to be complimentary to other styles of analysis [as Don Ihde also argues in the preface to Rosenberger and Verbeek [2015], in relation to ANT]. In particular, it adds a nuanced view on the different qualities of relations between human and non-human actors. Ihde [1990], for example, distinguishes embodied (technologies extend the body for certain actions), hermeneutic (technologies extend the natural world for certain actions), alterity (explicit interaction) and background (technologies as context for human existence) relations.

In the flagship magazine of SIGCHI, interactions, Verbeek [2015] prominently argues for a post-phenomenological move in HCI that shifts our focus away from designing interactions with technologies towards designing human relationships with their world, in which technologies play are mediating role. Drawing on the post-phenomenological argument that humans and technologies constitute each other in the act of experiencing the world, he provocatively states 'Designing technology is designing human beings'. As an example for the agency of technology in this mediation with the world, he brings up social media and how it has brought about new 'types and dimensions of social relations' and thereby contribute to 'shape human existence'. Constructing a *Mediation Theory* around this argument, Verbeek [2015] discusses the different types of relationships technologies and humans can have. Beyond Ihde's original ones from above, several more intimate relationships are added: the *cyborg* relation typifies the merging of technology with humans, for example, as with brain implants; smart environments, ambient intelligence or persuasive technologies are characterised as *immersive* relations; and our relationships with technologies such as Google Glass could be called *augmentation*. All of these augment and mix intentionality, in a phenomenological sense, between humans and machines [see also Verbeek 2008]. Interestingly, Verbeek [2015] also distinguishes different types of influence which are mapped across two dimensions: visibility and force. So, some of the mediations may be hidden, but coercive, while others are apparent, but rather weak. All of these different relationships, however, point to the intimate entanglement between humans and machines and that there is no human experience that is not mediated through some kind of technology and this shapes who we are in the world.

This also re-orients the debate around responsibility and the ethics of design. As Verbeek [2015] argues, defending human autonomy against the powers of technology may be an unhelpful framing of what responsible innovation could be. Instead he advocates for the developing responsible forms of (unavoidable) technological mediation.

Post-Phenomenology as a theoretical lens has had further impact in design oriented HCI research. In her thesis, Hauser [2018] presents two design research cases that are each critically reflected on through Post-Phenomenology [see also Wakkary et al. 2015, 2016, 2018]. As main lessons learnt for HCI, Hauser [2018] articulates the following four insights: firstly, Post-Phenomenology allows to account for the ways in which humans are not entirely autonomous agents in the world with their own, independent intentionality. This, secondly, leads to a fundamental critique of the predominant mantra of human-centredness in HCI, calling for decentreing the human. Rather than asking what the technology can do for the user, it allows for asking 'how human beings can be present in the world and how the world can be present for human beings' [Verbeek 2015], i.e., the Dasein. Thirdly, Hauser [2018] argues that, while the third paradigm of HCI has moved into the real world, Post-Phenomenology enables us to grasp the extent to which both, the human and the material world, existentially depend on the relation to each other—an argument that I would like to echo with this article. Finally, they state that this allows HCI to move beyond the concept of interaction and appreciate a much more holistic view our socio-material being in the world.

2.3 Object-Oriented Ontology

Again, Heidegger's phenomenology was the starting point for Harman and Harman [2002] to formulate a critique about how the material world was disregarded by philosophy as the passive backdrop for human activity. Rejecting Kant's correlationism, Harman argues for a realism that acknowledges the existence of objects independent of the human mind—a branch of materialism that he calls speculative realism. He writes 'The world is not the world as manifest to humans; to think a reality beyond our thinking is not nonsense, but obligatory' [p. 26 Bryant et al. 2011]. Building on this thinking [Bryant 2011] coined the term OOO, which Harman [2015] readily adopted. OOO could be considered as the most pronounced or explicit notion of a flat ontology by postulating that everything should be considered an object, 'whether human, immaterial, durable or fleeting' including 'human beings as well as dragons, stones and the Dutch East India Company' [Harman 2015]. As such it may sound extreme, but essentially is preaching the same concept of decentreing humans in favour of an ontology 'without privileging any viewpoint, especially the human, as the defining perspective for the others' [Hayles 2014]. Often this turn to the non-human is justified by highlighting how damaging an anthropocentric view is for our material world, for example as in the climate crisis [Grusin 2015].

Nevertheless, there is an important difference between OOO and ANT, Post-Phenomenology and also Agential Realism, discussed below. Insisting on the existence and the substance of objects, OOO defends their autonomy from relations, i.e., while other entanglement theories tend to focus on relations and see them as key to constituting them as entities, OOO insists that objects are not going away, just because they do not interact with anything else. OOO insists that objects passively present their qualities, although, Hayles [2014] argues that maybe Harman and Bogost are going a step to far here and that relations need to be part of the picture. As such, maybe it is not entirely fair to characterise OOO as an entanglement theory, but its ontological position and its agenda to decentre the human makes it a valuable perspective to be included here.

Bogost [2012] and Hayles [2014] take this decentreing literally and seek to explore how objects perceive the world. OOO seeks to emphasise the difference between the human-centric notion of knowing about an object and the object-centric notion of being an object. Through what Hayles [2014] calls *Object-Oriented Inquiry*, we are invited to speculate about the phenomenological experiences of objects being in the world. In the spirit of Thomas Nagel's famous essay 'What is it like to be a bat?' OOI takes the scientific evidence about objects as a starting point for speculating about their being in the world. While this might be dismissed as a fruitless philosophical exercise, it draws attention to non-human entities as legitimate agents in our collective being in the world.

Bogost, as philosopher and game designer, has applied this thinking and method of inquiry mostly to video games [Bogost 2012]. However, OOO has also been a productive lens for other materialist inquiries in HCI: Giaccardi et al. [2016], for example, argue for the productive insights a *thing-perspective* can have for the design of human-technology relationships and the corresponding practices and behaviours. Chang et al. [2017] exemplify the OOI method by first collecting sensor data, including cameras, from e-scooters and then giving it to actors to interpret the everyday-life of a scooter, to '*speak* on behalf of the scooters'. The 'interview with things' is a method that invites designers to speculate about desirable relationships. Hsu et al. [2018] draw heavily on OOO to explore notions of *plantness* through a design research approach, creating a digital artefact that shows similar needs and responses as plants.

While I subscribe to the underlying agenda of OOO to decentre the human and I also do not have any overly strong objections to the objectivication of the subject, I have two issues that limit its usefulness to the kind of Entanglement HCI that I am aiming to sketch below. One is that by methodologically reversing the perspective, i.e., by speculating how it feels like to be a thing, we

inadvertently fall into the same pattern that OOO seems to criticise the classical, anthropocentric strands of philosophy for, just in reverse. We thereby may be complicit in fostering the nature-culture dualisms that were not productive in understanding how one mutually shapes the other. Secondly, and related to the first issue, dismissing relationships or interactions as ontologically relevant, begs the question of how objects (or things) come into being and become (or change) what they are. OOO becomes inadvertently static, pinning objects to their immutable substance while we see, in particular with digital things, how anything only becomes something in relation to something else. So, while I will draw methodologically on the modes of speculation that OOO puts forward, I am more sceptical about its ontological position.

2.4 Agential Realism

Karen Barad too, subscribes to the principle of decentreing the human in favour of making the role of the material world visible, but takes a very different turn than OOO in terms of relationality. In 'Meeting the Universe Halfway' Barad [2007], a theoretical physicist and feminist theorist, develops *Agential Realism* as a performative and posthumanist ontology on the back of Niels Bohr's philosophy-physics.[2] To frame the problem of conceptualising the nature of the relationship between humans and their tools, she first moves to reject representationalism—the idea that we have discursive practices (signs, language) that describe material realities (the signified). She argues that while realism and constructivism fought a bitter war over what is truth, they both were committed to this representationalism. To leave this debate behind us, she aims to break down this dualism between language and nature and turns to performativity, i.e., the idea that nothing exists before it is produced as a discursive phenomenon. She draws here on the work of Butler and quotes Foucault with 'Words and things is the entirely serious title of a problem' [Foucault, The archeology of knowledge; cited in Barad 2007, p. 46]. As such, Barad argues the exact opposite to OOO, where things exist independent of their relations, while in Agential Realism things are only coming into existence through discursive practices. The famous two-slit experiment that demonstrates the duality of light as particle and wave depending what is measured serves as her running example.

Agential Realism has the following cornerstones: (a) the primary ontological unit of reality is not bounded entities, but phenomena that are reliably (and objectively) (re)produced by discursive material practices—something Barad calls *mattering*. (b) Things and people, as phenomena, mutually constitute each other through their *intra-action*, i.e., the boundaries between human and machines are not pre-determined, but enacted. This is what Barad calls different *agential cuts*. (c) What is possible to enact depends on the material configurations, i.e., reality is causally produced through a certain intra-action within human and material configurations. This allows her to trace *responsibility* within these configurations with rigour. Finally, (d) the world is in an *open-ended and continuous* process of mattering, i.e., these configurations constantly change and produce different agential cuts and phenomena.

This radical orientation towards relationality puts Agential Realism at the extreme end of the entanglement theories discussed here. While Latour [2005] also argues that agency is a network effect that is enacted, the extent to which boundaries of actors are continuously negotiated is taking the notion of entanglement to another level. In fact, Niemimaa [2016] discusses Agential Realism as a proponent of 'the radicals' in socio-materiality, as opposed to more conservative views such as Critical Realism [Collier 1994]. It is interesting to note that Information Systems Research as a field has embraced socio-materiality from these angles and has debated Barad and Bhaskar at length [Scott and Orlikowski 2013], while HCI has not [except Frauenberger 2016, on the possibility of a Critical Realist HCI].

[2]Niels Bohr had argued that philosophy is inseparable from physics.

Building on Haraway, Barad also takes *diffraction* as the methodological starting point to argue for performativity. Other than reflection, which produces mirror images of reality, diffraction as a method attends to the differences in phenomena. It is useful to not focus on categories, but on the processes of othering through material intra-actions. Barad here also strongly defends realism to hold on to a strong concept of accountability for the material configurations that are being created, thereby circumventing the problematic relativism in social constructivism. Drawing on feminist theories and concepts like diffraction, performativity and the negotiation of boundaries has also led to her work being categorised as *feminist technoscience*.

While in HCI a critical feminist perspective has been prominent [Bardzell 2018; Bardzell and Bardzell 2011; Pierce et al. 2015], performativity as a fundamental ontological commitment has been less so. For example, although Wiberg [2018], arguing for the *material turn* in HCI, explicitly refers to Agential Realism as a theoretical grounding of the notion of *materiality*, I would argue that he does not go as far as to embrace the full extent to which Barad's ideas shift the ontological basis upon which humans exist within the material world. While he rejects the representational tradition of HCI with its signs and metaphors, and aims to foreground materiality as the relationship between people and artefacts (or social practices and material configurations as Giaccardi et al. [2016] puts it), it stops short in recognising the uncertainty and fluidity of agential cuts that are being made to blur the boundaries of things and people.

2.5 And What About...

The above range of theories and their description is purposefully selective. Naturally, there are many more perspectives that may prove effective in driving forward this project of an HCI that responds to the need to re-conceptualise the intimate entanglement between humans and their digital worlds in productive ways. Philosophical approaches such as assemblage theory by DeLanda [2016], for example, or the materialist thinking of Deleuze and Guattari [2013] provide means to re-frame our understanding of us within the world. Arguing for a neo-animism in design through materialist philosophy, Marenko [2014] quotes Felix Guattary who wrote about being an 'idea-thief who steals from different sources to use as tools to build a *conceptual chemistry*'. She goes on to say: 'I have made Guattari's dictum my own, even more so as I reflect upon our entanglement with things from the perspective of a philosopher speculating on design'. Echoing her sentiment, I am humble about my contributions and pragmatic about my choices. I purposefully choose lines of thought to support my own argumentation, while being mindful and hopefully truthful to their origins.

In this spirit, the set of theories above provide me with the following starting points: from ANT I take the argument that there are no 'social aspects' of anything, but everything is part of a networky structure of actors that continuously enacts our life. Post-Phenomenology and mediation theory provides unique perspectives on the quality of being in the world. Its heritage in phenomenology offers a rich vocabulary to talk about what it means to be in the world, while its extensions draw our attention to the ways this *Dasein* is mediated by technology and how boundaries are blurred. Perhaps, OOO is the least compatible perspective for the relational ontology I aim for. However, it provides me with a productive entry point to discuss (material) speculation as a method, not only to design, but as a form of ethical inquiry. Agential Realism is the most appealing and convincing theory for abandoning representationalism, shifting our attention on phenomena and how they come about. In particular, the notion of agential cuts allows me to acknowledge the unstable and fluid boundaries of actors and offers a highly effective way to talk about responsibility of creating the material configurations that enact these cuts.

While I have invoked the image of a paradigm shift, the intersections of HCI with these and similar theories are already substantial. To provide a complete review of HCI literature that makes

references to entanglement theories would be out of scope for this article. Rather, I have aimed to exemplify the *different ways* in which HCI has taken each of these theories up and I recognise that much work defies such clear attribution of lineage.

For example, in the design oriented corners of HCI, the notion of *materiality* [e.g., as in Wiberg 2018] has gained traction as an evolution of socio-materialism [e.g., as in Star and Ruhleder 1996], drawing on a wide range of different post-humanist theories. In a similar vein, *hybridity* is discussed [e.g., Devendorf and Rosner 2017; Fuchsberger 2019], pointing at the co-created and increasingly blurry borders between humans and technology. In her recent book Rosner [2018] further investigates this notion through *critical fabulations*, reworking dominant design practices from critical and feminist perspectives. Redstrom and Wiltse [2018] put *fluid assemblages* in the centre of their analysis of the future of things, highlighting the changing nature of (digital) things and their networked characteristics that entangle them with our lives. They mainly draw on the concept of assemblage as developed by Deleuze and Guattari [2013] and DeLanda [2016], but also draw on Heidegger, Post-Phenomenology and Agential Realism in their conception of things.

It is common for work to not tie itself to one particular theory, but to draw on multiple to make specific arguments. Devendorf et al. [2016], for example, seek to critically analyse the role of the human in the maker movement. Using ANT, OOO and Barad, they develop the notion of post-anthropocentric maker technology, that decentres the user as the unquestioned creator of things. Howell et al. [2018] bring together Agential Realism, OOO and Post-Phenomenology with affect theory to articulate a powerful critique of the normative aspects in emotional biosensing and its questionable applications, for example in the quantified-self arena. Leahu [2016] uses ANT and Agential Realism as a lens to critically reflect on how we train neural networks, undermining the notion of categories as something static. Jackson and Kang [2014] study artists as they engage with found and defunct technologies in material speculations about agency and meaning. Drawing on a range of post-humanist thinking, they investigate issues of design and creativity around things that seem to have more than affordances and actively contribute to human action.

From different angles and with different foci all these works compose the fertile ground on which our understanding of what HCI is doing is slowly shifting. What follows adds to this body of literature, but also aims to be more than just another angle: it intentionally works broadly across the foundational themes of ontology, epistemology, ethics and practice to build a common frame that is more than a 'turn' towards materialism or hybridity in design. Instead, I want to hold on to the question of whether highlighting entanglement in this way may constitute a more fundamental paradigm shift in HCI, because it so radically re-orients the conception of our relationship with digital things. In other words, fully embracing the ontological, epistemological and ethical commitments that come with these theories, may have more serious consequences than evolving our design methods.

3 ENTANGLEMENT HCI

3.1 Who We are

In Greek mythology, Prometheus brings fire to humanity, a rebellious act that enabled progress and civilisation, for which he is cruelly punished by Zeus. Philosophers have long harnessed this myth as a way of thinking about the relationships between humans and technology. Günther Anders and more recently Stiegler [1998] argue that humans are 'born naked', a clumsy oversight of Prometheus' not so bright brother Epimetheus, and have therefore always and necessarily been defined by the tools they invented for themselves. Humans and their tools mutually define themselves and co-evolve over time. In Promethean Shame Müller [an essay from 1956, translated into English and interpreted for the digital age by 2016], Anders further observes a growing imbalance:

humans feel increasingly ashamed for the imperfections that come with only being born, and not made like their tools. Sentiments of older people blaming themselves when wrestling with the latest smartphones, and the radical ideas of transhumanism could be interpreted as instances of this shame at different scales. With smart things and smart services in smart environments, our entanglement with the digital tools we build for ourselves becomes ever more evident. We become what we build for ourselves.

Müller writes in his commentary and translation of Anders' 'Promethean Shame':

> Prometheus opens us to ways of thinking about technology that resist the intellectually comfortable position of mobilising a *false opposition* between 'humanity' and 'technology' when looking ahead into our digital future [emphasis in the original] [Müller 2016].

While certainly Anders strikes a rather dark tone in describing our relationship with technology, the image and metaphor is powerful. It resonates with the relational ontologies reviewed above and further emphasises the need for breaking with the idea that we create technologies that functionally serve the needs of people. Rather, by configuring material conditions, we design humanity. The mobile phone has not merely met requirements or fulfilled needs. It has not just extended our capabilities or opened up the possibilities for new social practices. It has made us different people. Humanity has re-defined itself through the digital tools it has devised or even more radically: our tools are us.

This intimate entanglement with our tools has several implications for the basis on which we can think about Humans, Computers and their Interaction (HCI). First, we are not designing computers, nor can we design interactions. What we seem to be doing is creating configurations that enact certain phenomena. These configurations and phenomena are situated and fluid, but not random. In fact, they are causally linked—the entirety of a configuration determines the phenomena, which has implications on responsibility, as we will see below. Configurations are hybrid networks in which human and non-human actors intra-act. These actors are not fixed representations of entities, but only exist in their situated intra-action, i.e., their relations and configurations create agential cuts that draw the boundaries between entities for the duration of the phenomena. As configurations change and shift, new phenomena are enacted and new agential cuts create new actors.

To ground these rather abstract and theoretical concepts, I will use a hypothetical case of a future technology as a running example. I borrow it from a range of technologies that we have speculated about under the banner of Diversity Computing [Fletcher-Watson et al. 2018]. The hypothetical nature of the example allows me to be free of pre-conceptions and narratives about any particular existing technology and is designed to highlight the generative power of Entanglement HCI. Further, the notion of Diversity Computing—technology that augments and scaffolds human interactions in heterogeneous groups—offers me an ideal case to foreground the unique perspectives Entanglement HCI has to offer.

Flow, the hypothetical device, displays the ease or anxiety of members of a conversation based on data from a range of sensors, including spatial, auditory, biometric and other measures. It feeds back that information to the group through its interface (i.e., how the conversation flows) as well as to individual peers through actuators, such as vibration motors in bracelets. Possible application areas include smart offices or more informal spaces such as bars or cafés.

The phenomenon enacted is a conversation that unfolds with the primary actors being the human peers, the *Flow* device and the conventions or norms encoded in the space (e.g., office vs. bar). The exact boundaries of these actors, however, are not pre-determined or fixed, but depend on the enactment. The configuration and relations between these primary actors produce agential

cuts that define the precise boundaries in the conversation. For example, the office space, the spatial arrangement of conversational peers, the organisational hierarchy, the thematic agenda, the personal traits of people, the distribution of sensors, the algorithm that assesses ease/anxiety, the feedback mechanisms of the device, the settings of the device, and so on, all contribute to the enactment of the conversation through their inscribed 'programs of action' [compare Latour 2000]. The boundaries between aspects of *Flow* and humans may become fluid: individual feedback on the status of the conversation may come to constitute an embodied sense that we intuitively use to make sense of the activity. Shared feedback may come to constitute a group sense that groups who know each other well can intuitively harness and which becomes what identifies them as a group. We may come to see others as conversational peers that have the ability of sensing anxiety, i.e., we see them as a whole, rather than using a tool. *Flow* may be an actor that interacts with the space (e.g., adjust the lighting of the office), or in other enactments may simply become integrative part of the environment. For many of these enactments, mediation theory may be the most productive lens to dissect the phenomenological influences [e.g., Ihde 1990, discussed the use of eye glasses in similar fashion].

From some distance, we may also assert that such technology makes us a different species, one that can be expected to know aspects of interactions that earlier generations of our species may not have had at their disposal. It may come to be seen as a sense, with all its benefits and faults, such as the inevitable sensory illusions that may bias or mislead our judgements. I do not wish to open up the emotionally charged transhumanism debate, but offer a much more relaxed version by pointing out that any tool, since Prometheus brought humans fire, has changed humanity in small, less often in big ways. Acknowledging how technology contributes to shaping who we are underscores the urgency by which we, as society, but technologists in particular, need to find arenas to debate visions and responsibilities.

While a relational and material-oriented ontology has been infiltrating HCI for some time, I argue that fully committing to the metaphysical stances of Agential Realism and other entanglement theories, produces a new quality in our understanding of the relationship between people and digital technology, with serious implications for the practice, ethics and epistemology of our work.

3.2 Reality and the Many Ways of Knowing

As alluded to above, HCI as a field is grappling with its knowledge production practices and their representations. While historically, the field has its roots in engineering and psychology with its rather clear cut epistemological commitment to positivism, Harrison et al. [2011] stirred up 'epistemological trouble' when examining closer the implications of the shift to the third wave. Guided by feminist philosophy of science, third wave HCI embraced a standpoint epistemology that recognised the centrality of context and a pluralism in knowledge claims—producing situated knowledge [Haraway 1988]. Such a view is fundamentally at odds with the objective God's-eyes-view that cares most about generalisability, like in the early Human-Factors days. Nevertheless, Harrison et al. [2011] are careful to argue that the three paradigms and 'ways-of-knowing' could and should be practised in mutually enlightening co-existence.

Trying to reach across the different knowledge traditions on which HCI draws, aiming to bridge the conceptual spectrum between the extremes of constructivism and positivism, various approaches have been proposed. Höök and Löwgren [2012] observe that HCI's knowledge production cycle is characterised by creating innovative interactive solutions and then evaluating these empirically through user studies. This, if all goes well, results in two kinds of knowledge: particular instances and generalised theories. However, in their own design practice, they identify a middle

ground, a form of knowledge that in terms of abstraction lies in between instance and theories. They say that

> design-oriented research practices create opportunities for constructing knowledge that is more abstracted than particular instances, yet does not aspire to the generality of a theory. We call this middle territory *intermediate-level knowledge* [their emphasis Höök and Löwgren 2012].

While Höök and Löwgren [2012] used this line of argument to support their own format of such an intermediate-level knowledge, *strong concepts*, it has since become an umbrella term for a whole range of knowledge formats that seem to be operating at the same level of abstraction, e.g., *annotated portfolios* by Gaver and Bowers [2012], *design patterns*, inspired by Alexander [1979] or *design exposés* [Frauenberger et al. 2016]. At a 2015 workshop on IxD knowledge production, Höök et al. [2015b] further identified formats such as *experiential qualities, design programs, manifestos, conceptual constructs* and *bridging concepts*. Reporting on the workshop, Höök et al. [2015a] reflect on the issue of legitimisation of such knowledge forms and point to the struggle of finding appropriate dimensions of rigour and communicating such dimensions within the field.

We are still some way from having identified the 'symptoms of excellence' [Höök et al. 2015a] that we require to properly legitimise intermediary knowledge, albeit many reviewers in the field, very likely rightfully, claim to know a well-conducted design research study when they see it. However, while the concept of intermediary knowledge may have proven to be pragmatically useful, I argue it is flawed for two reasons.

First, I think it is untenable to treat one end of the spectrum as a positivist (the universal theory) and the other as a social constructivist (the ultimate particular). Without finding a theoretical basis on which these two kinds of knowledge can be treated in the same way, it is impossible to construct a continuum or to occupy the middle ground. Second, the notion that we need to work our way up from the situated study towards the universal law or theory suggests a ranking order that is unhelpful to understand the different and complementary ways of knowing in HCI. As a result, intermediary knowledge runs the risk to be criticised from both ends of the spectrum for either being not rigorous enough (bad science argument) or loosing critical context by adhering to the principle of generalisation (irrelevant outside the lab argument). Worse still, it may revive the science wars between realists and constructivists, which continues to smoulder under the surface in HCI.

While many STS scholars naturally found themselves at the epicentre of the science wars, entanglement theories have provided pathways to re-frame the problem. Both, social constructivism and realism are seen as having much more in common than they think, in particular in terms of their static representationalism and the strong anthropocentric perspective. The notion of a *socially constructed* reality is rejected for its assumption that humans would have the agency and power to do so. Latour [2003] points out that this completely ignores the active role of the material world in ordering, resisting, enabling and mediating activity and assumes a God-like role of humans in bringing about reality from the 'invisible stuff' that is called the social [compare Latour 2005, for the argument that if everything is social, nothing is]. *Naive realism* falls short in very much the same ways: the material world is rendered the only reality that matters—and it is entirely passive and detached from the human activities that are used to inquire into the qualities of the real world. Within a relational and performative ontology, the dichotomy between social construction and independent reality is resolved: non-human and human actors enact (construct) reality, i.e., nothing is social (or everything) and nothing is independent.

Barad [2003] asks 'How did language come to be more trustworthy than matter?', lamenting that every*thing*—even materiality—is turned into a matter of cultural representation and its

construction. Every turn, the linguistic, semiotic, interpretative, cultural, seems to have brought us closer to seeing matter as the passive backdrop for our discourse. With her Agential Realism, Barad rejects this representationalism and argues instead for performativity as the central mechanism by which not only things (us included) exist, but also knowledge comes about. Consequently Barad [2007] argues for an *onto-epistemology* to reflect the fact that things not only come into existence in intra-action, but also any knowledge production is tied to this intra-action and the resulting phenomena, i.e., knowledge production is a material practice that produces facts that are reliably performed within given configurations. As such it is relativist in the Latourian sense as it is contingent on the particular configuration and its enactment, but it is not arbitrary or random in producing reality, which is why Barad is insistent on it being a (new) realism that she puts forward.

To ground this discussion, lets turn to the hypothetical example about a future Diversity Computing device from above. There are several material practices that produce knowledge here: first, *designing Flow* is an intra-action between materials, concepts, visions, designers and possibly future users that produces certain agential cuts. For example, representing users through personas makes such cuts for the purpose of design that shape, explicitly or implicitly, intended use cases. Similarly, agential cuts are made in drawing on prior knowledge, for example in terms of effective feedback mechanisms for *Flow* or in the form of existing studies on the use of body-language in groups—prior knowledge representations become actors that shape, restrict and enable the activity of design. Further, properties of materials and chosen design methods intra-act to determine what becomes imaginable, possible and ultimately made. In the process of configuring and reconfiguring actors in design, of making agential cuts and through material discursive practices, new knowledge is produced that causally links the enactment of design with the created phenomenon. This knowledge may have various formats, one is likely the artefact itself.

Flow, the resulting thing, will have inscribed programs of action [Latour 2005], or a kind of material *dispositif* [Foucault and Gordon 1980]. However, depending on the particular configurations in which it is used, new agential cuts will be made in a material practice that permanently (re-)enacts new realities to which *Flow* actively contributes. Again, knowledge is created through this *use practice*. For example, humans may learn how to configure *Flow* and its relation within given actor networks to be able to enact desirable realities. Such 'usage knowledge' may never become formalised, but may manifest itself only in people's ways of being with *Flow*.

Finally, *evaluating Flow*, typically in some kind of user study, will enact phenomena that are dependent on the configuration of the apparatus. As Barad's central case, the dual-slit experiment demonstrates, the nature of things and the reality produced is contingent on how the apparatus intra-acts with the thing to be studied. As much as one apparatus makes light a particle, while another makes it a wave, an interview study will make *Flow* a cultural artefact, a controlled user-testing study in the lab will make it a functional tool, and a long-term diary study might make it an artificial sense of people. We are not just studying different phenomena, we are studying different things, possibly with varying boundaries.

This is where the current framing of intermediary knowledge breaks down. Its ingrained representationalism means it focuses on finding first fleeting signs of patterns across situated solutions that 'work', which could inform future designs and ultimately lead to theories with predictive power. It thereby systematically starts to cut the ties of associations and destabilises what the thing was in its particular configuration (cultural artefact, tool, sense, etc.). Alternatively, we could look across enactments that have some commonalities in configuration (e.g., the presence of a designed artefact). The most valuable knowledge then lies in the ways these enactments differ, rather than are the same. Staying with Barad and her reading of Haraway [1997], the key to knowledge may not lie in reflecting, abstracting and generalising, but rather in the method of diffraction. Drawing on the optical phenomenon, Barad [2007] argues for diffraction as a knowledge production method

that is much more attuned to performativity, as it attends to the differences, relationalities and the uncertainties in the differential becoming of things. It acknowledges that producing knowledge means accounting for material-discursive practices and not reflecting on representations.

Understanding knowledge practices in this way leads us to ask different questions: it may be unproductive to ask what makes *Flow* work and much more informative to ask how *Flow* becomes different things, i.e., what are the mechanisms of differential becomings? Or in other words, what are the re-configurations that make *Flow* a tool, a sense, a nuisance, a racist and so on.

So, where does this leave HCI knowledge production? I argue that first, we have to let go of the idea that ultimate particulars and general theories are the two extremes of a spectrum of knowledge types. Knowing about a particular artefact means tracing its relations in different modes of becoming (e.g., design, evaluation, use, appropriation...) through a material-discursive engagement. Understanding these differential ways of becoming is what we learn about and informs our future material-discursive engagements in designing things. The 'sign of excellence', the rigour of our knowledge practices is given by how attentive and rigorous we are in describing the causal relationships between configurations (including our own role in asking these questions) and becomings. This is independent of the level of engagement. For example, knowing how *Flow* becomes an embodied sense for individuals with autism to how it becomes a part of societal discrimination because it may be racist in one way or the other, are two different, complementary ways of knowing about configurations that involve *Flow*. Asking questions about these causal dependencies may require different discursive engagements, e.g., one in which a single device is used by an autistic person for a long time and the other where the phenomenon is enacted by a large number of devices across society. As a result of these knowledge production processes, any of the configurations that involve *Flow* may be re-configured, which may or may not involve engaging with the material components of the actual thing.

I would argue that intermediary knowledge formats still can serve important roles in HCI, mainly, because many are oriented towards providing rich context, which is not the same as (re-)configurations for differential becoming, but may be developed into such an account. Others, such as the original concept of design patterns by Alexander [1979] explicitly include relational aspects (pattern languages). But there is also a need to evolve the concept to diffuse my two main criticisms while retaining their practical usefulness.

In summary, I propose to develop knowledge production practices in HCI further in three different ways to escape the lingering science wars: (a) by re-framing HCI knowledge as performative, i.e., focusing on knowledge production as an enacted phenomena, a material-discursive engagement that results in reliable, trustworthy and causal understandings of configurations and reality as it plays out; (b) by abandoning any notion of hierarchy in knowledge, but embracing the many ways of knowing about related phenomena; and, (c) by re-tuning our collective scrutiny on how well knowledge claims are substantiated through the careful engagement with configurations and differences.

3.3 Ethics, Responsibility and Accountability

The extent to which society is being shaped by technology, in good and bad ways, has hardly ever been so large and visible for all to see. Social media, big data, internet of things and artificial intelligence are unlike the first computers, confined to offices, they pervade our whole existence. Consequently, they have very real consequences in our everyday lives, be it getting health insurance to autonomous mobility, and the question of who is responsible for what and 'is this still what we want?' has become more prominent in the field [e.g., Light et al. 2017]. Here, I want to examine what entanglement theories can provide to help us tackle the moral and ethical challenges of creating digital technology.

Entanglement theories seek to distance themselves from an anthropocentric view on agency, and consequently also reject that ethics and morality is something that humans can possess. Introna [2009] quotes Latour 'Morality is no more human than technology' and interprets it as a radical move to disturb the liberal ethical foundations that judges responsibility under the premises of autonomy, freedom and free will. Recognising things as actors and agency as enacted within a network of associations means that 'morality is not simply a matter of our choosing' [Introna 2009], in other words we cannot assign responsibility for the results of our enacted world exclusively to humans. In the material-discursive practices that bring about our world, in our intra-actions with others and things, we are *one* actor amongst many. This does *not*, however, allow us to deflect responsibilities that come with the role we have. Barad puts it this way:

> Learning how to intra-act responsibly within and as part of the world means understanding that we are not the only active beings - though this is never justification for deflecting that responsibility onto other entities. The acknowledgement of 'nonhuman agency' does not lessen human accountability; on the contrary, it means that accountability requires that much more attentiveness to existing power asymmetries. [Barad 2007, p. 218]

In tracing the associations [Latour 2005] through the *disclosive analysis* of phenomena [Introna 2014] and by making the agential cuts visible Barad [2007], our responsibility in re-configuring the socio-technical assemblages that make up our lives becomes clear. Our choices matter, quite literally.

Returning to our running example of *Flow*, accountability stems from making visible the agential cuts that have been made and are suggested by its program of action. As we have seen in the previous section on knowledge, many such cuts are being made in the design of *Flow*. Some of these are conscious choices, others are unconscious biases or unintended consequences and yet others are produced by the configurations in the material practice with technology. Being attentive to the ways in which phenomena (e.g., *Flow*, the artefact) is enacted allows us to trace accountabilities and make them available for moral judgements. Such judgement of the designer's intent, for example, may require a nuanced understanding of their relations and boundaries within the configuration that enacted the design of *Flow*. Beyond explicit choices, the availability of cheap EEG sensors may play a role in making a particular agential cut as much as legislation that limits sharing of personal data or the designer's professional environment. In some design activities, designers shape decisions as actors in their own right, in others, they are part of the actor that was hired to solve a particular problem.

As with knowledge production, tracing accountabilities does not end with designing it, but continues in use. The way that *Flow* re-configures human encounters matters ethically as it normatively suggests successful interaction. It supports some actions while restricts others and all the while it either becomes an actor in its own right, or is being folded into the performed, ontological entity of a human peer. While it comes with a program of action, its intent may be subverted as it is configured in ways that would be morally questionable. Imagine users who take advantage of *Flow* for maximising their gain in negotiations by knowing how to make their peers feel most uncomfortable. Imagine an insurance company that siphons off data collected through *Flow* to create psychological risk profiles for their customers. Tracing accountabilities within the configurations that causally produced these phenomena allows us to move beyond a reductive blame game, but instead leads us to informed moral judgements on the basis of nuanced understandings of intra-actions.

Entanglement theories have demonstrated how our knowledge practices have direct implications on the very nature and boundaries of things, i.e., how epistemology and ontology are

fundamentally inseparable. But, it is not only the knowing and the being that is collapsed, Barad [2007] makes clear that every aspect of the discursive mattering is also inseparably an ethical practice. So, every intra-action in assemblages of human and non-human actors not only draws ontological boundaries and determines ways of knowing, it also is an ethical encounter. These links between ontology, epistemology and ethics are not arbitrary, but causally linked through an *ethico-onto-epistemology* in the Agential Realism of Barad [2007].

Saying humans and machines are ontologically inseparable continues to draw criticism for its "Menschenbild" (the idea of (wo)man). The ethical concern is rooted in the perceived danger to loose some of the most fundamental principles of humanism that we fought so hard to agree on. While I agree with the concern, I think the critique stems from a misinterpretation of what flat ontologies aim to do and I think they can be defused upon closer reading. Suchman [1998] makes this point:

> I am arguing for a certain restoration of the boundaries between humans and machines, not as the restoration of some natural order but as a historically and culturally specific act of refiguring. The point of the refiguring is twofold. First, to recover certain qualities – interactivity, intelligence – from trivialization. And second, to restore authorship and thereby accountability to our relations with artifacts.

While the mention of certain qualities—interactivity and intelligence—seem to be less fitting now in times of VR and AI, I share the underlying sentiment. To say that we ontologically intra-act with machines does not make us machines or machines human. Suchman [1998] goes on, stressing that she is not questioning the role of machines (along with other material things) as 'active actants' in making realities, that

> the price of recognizing the agency of artifacts need not be the denial of our own. Agency – and associated accountabilities – reside neither in us or nor in our artifacts, but in our intra-actions. The question, following Barad, is how to figure our differences in such a way that we can intra-act responsibly and productively with and through them.

There is another important implication in recognising non-human actors as participants in the enactment of ethics: it enables us to make it an ethical concern to care for things, the environment or our planet.

The continuous boundary making and intimate entanglement in intra-action further shifts our attention from impact to the shifting ontological nature of humans and things. Introna [2009] writes

> Ultimately the ethical/political question of the nuclear power station is not only 'Is it safe?' but also 'Is this the sort of humans that we want to be?' (p. 402)

Paraphrasing this statement, our ethical and moral deliberations in HCI should not only centre around the question what impact the technologies we create have on humans, but rather, what humans we become in the intra-actions with these technologies—and whether this is who we want to be. This resonates with the philosophy of Günther Anders discussed above and his notion of the Promethean Shame. Coming back to our example, in our moral, disclosive analysis of *Flow* it may not only be productive to ask what it is making users do, but also what kind of humans we become by having technology mediating our conversations in such a way. In other words, do we want to be what *Flow* is making us?

3.4 Designing, Making, Mattering

User-centred design has arguably been the most influential approach to designing interactive artefacts over the past decades. Coined as a term by Norman and Draper [1986], it has put the needs and requirements of the user in the centre of our efforts, however, not without recognising the importance of context [e.g., as in Contextual Design Beyer and Holtzblatt 1998]. With it, user experience (UX) has become the mantra of a whole industry. The Nielsen Norman Group, sees UX 'encompassing all aspects of the end-user's interaction with the company, its services, and its products'. and states that an exemplary UX is 'to meet the exact needs of the customer, without fuss or bother'.[3]

Despite the centrality that the field of HCI grants 'the user', a fundamental unease with this role was voiced early. Redström [2006] has formulated a critique in response of the field moving from designing an object to designing for the user. His concern is that by optimising the fit between objects and users, we may well end up designing the user to fit a system and not the other way round. More recently, Baumer and Brubaker [2017] coined the term *post-userism* and analyses instances where the classical conception of the user breaks down. They also invoke post-humanist theories to hint at a more holistic view on possible relations between humans and computers. Relatedly, non-functional use of technology as in ludic design [Gaver et al. 2004] or studies into interactions with unaware objects [Odom and Wakkary 2015] or technology non-use [Fuchsberger et al. 2014] call into question whether the classical conception of the user and her needs really should be the pivot point of interaction design.

It comes as little surprise that entanglement theories too, would seek to shift this anthropocentric view and broaden our scope of attention from the user towards the intra-action of actors and their enacted relations and associations in the world. Taking such a holistic perspective immediately makes the focus on optimising user experience seem like a cynical marketing stunt—is our own experience really what makes the world a better place? Or is this not what this is about?

Despite its honourable role in reminding technologists to think about people, I want to argue to abandon user-centred design. Not because humans do not matter, quite to the contrary: to shape who we want to be in this world, we should be designing meaningful relations, not user experiences. *Meaningful Design* encompasses the *political mattering of things through which we make sense of us in the world*, going beyond what we experience, but who we want to be. This kind of *Dasein* (being-in-the-world) could be interpreted as an ethical take on Heidegger's philosophy and fits very well with the Post-Phenomenology of Ihde and Verbeek. It also builds on the notion of post-userism [Baumer and Brubaker 2017], but goes beyond it by committing to the full ontological, epistemological and above all ethico-political implications that such a decentreing of the human brings with it. The following picks up on current discussions in design-oriented HCI that may provide effective starting points for making this sift.

Storni [2015] makes a strong case for using ANT not only in descriptive ways, but to re-assemble the social through design. Latour himself remained sceptical towards design, mainly because of design's tendencies to black-box decisions and silencing controversies. But Storni [2015] argues that this can be overcome by moving towards participatory and agonistic design practices. Feeding off controversies is one of the central methods Latour [2005] proposes to trace associations and to make things speak. So, in order to overcome user-centred design, maybe counter-intuitively, I argue we need to evolve our PD practices and think of how we can create spaces and processes that enable humans and non-humans to come together in the creative, political, controversial **Participatory Speculation** and mattering of future socio-technical configurations.

[3] https://www.nngroup.com/articles/definition-user-experience/, visited June 2019.

Various works in HCI have approached this participation of non-human things from different angles. Liu et al. [2018], for example, take a post-anthropocentric view towards designing digital tools for collaborative survival, i.e., for the wellbeing of humans *and* non-human species. Through a design research approach, they probe into human-fungi relationships and thereby position technology as part of a larger matter of concern, our being on this planet of limited resources. Wakkary et al. [2018] had philosophers live with the *tilting bowl*, an artefact designed to allow productive co-speculation on possible futures with digital things in people's everyday life. Elsden et al. [2017] offer *speculative enactments*, a method by which participants are invited to collaboratively enact meaningful relations with technologies and [Desjardins et al. 2019] use booklets as a format for situated, experiential co-speculation. Wiberg [2018] proposes a material-centred interaction design with the aim to create purposeful material configurations for human activity. I argue, we need to further develop such techniques to enquire into, understand and work with the many ways in which humans and things mutually depend on each other. A pressing open concern, for example, is how such methods could be made effective at scale, e.g., in industry contexts [Frauenberger et al. 2018].

Wakkary et al. [2015] have written about their material speculations as forms of critical inquiry in their design research practice. They build on a long tradition of critical and speculative design approaches [Dunne and Raby 2001, 2013] as well as the growing body of work that uses design fiction to open up a discourse about possible and/or desirable technological futures. All this design and speculation as well as the very configuration of participation is of course far from neutral or innocent in the political arena that is the creation of technological futures. Reflecting on their own work in Pihkala and Karasti [2018] highlight how their practices of mattering are deeply political. Bardzell [2018] eloquently articulates some of these political interactions between design, participation and the imagineering of possible futures drawing on contemporary feminist utopianism. Björgvinsson et al. [2012] look to the work of the Belgian political theorist Chantal Mouffe [Mouffe 2013] to frame PD as an activity in which different agendas are being negotiated. They coin the term *Agonistic Design* that is characterised by employing processes and creating spaces where groups of people can passionately engage in vigorous, but tolerant disputes and design that quite literally feeds off the controversies. A similar perspective is taken by DiSalvo [2012] in his book *Adversarial Design*, where he discusses a wide range of works in which designers have not sought consensus, but constructive controversy. Early work, which also focused on the making of things for the purposes of provocations, includes Mogensen [1992] and their concept of *Provotyping*. More recently, we also have explored in our own work with autistic children how controversies in co-designing can be productively used to drive design outcomes [Frauenberger et al. 2019]. I argue it is paramount to understand designing things as ethical and political encounters and we have some way to go in re-politicising our methods.

Storni [2015] also points out how a relational perspective connects to the work of Star and Ruhleder [1996] on infrastructuring and boundary objects, which has had significant impact on the understanding of socio-materiality in PD. Ehn [2008] uses the concept of infrastructuring and ANT to argue for a move away from designing objects, towards things as socio-material assemblages [see also Binder et al. 2011]. Fitting with the performative perspective of entanglement theories, such infrastructures are enacted and re-interpreted in use, i.e., become different things in their intra-activity. This leads Ehn [2008] to question the strict distinction of design and use times, pointing to concepts such meta-design (or design-after-design) [Fischer and Giaccardi 2004]. Redstrom and Wiltse [2018], too, begin with questioning the dichotomies between design and use, production and consumption, and offer a conceptual toolkit to deal with the fluidity of assemblages. I argue that we need to build on these ideas and further push our design methods to

move beyond the distinction between design and use, and embrace the *design-use* of things as a continuous process of re-defining and re-enacting our relationship to technology.

Summarising, I have argued to leave user-centred design behind us, and with it the mantra of user experience. Instead, I suggest to move towards design practices that feed off controversies, that are *participatory*, involving human and non-human actors, that are *speculative* to create spaces in which we negotiate desirable futures, that are *agonistic* to recognise the creation of technology as a political arena and that reach across *design and use*. I am suggesting to move from optimising user experience to designing *meaningful* relations that are enacted as part of our ongoing re-configuring the world.

In the context of designing collaborative cities, Laura Forlano writes:

> A deeper engagement with theories from STS (and the development of corollary methodologies) may improve the capacity of designers to play an important role in charting the ethical and political challenges posed by emerging technologies. Designers can introduce codesign and speculative design as strategic resources for collaborative citymaking to build networks, constituencies, publics, and alliances around pressing policy issues. Experiments, prototypes, and demonstrations in hybridity and liminality that defy existing categories can serve to showcase productive collaborations between human and nonhuman actors that will shape hopeful, alternative possible urban futures Forlano [2016]

4 CONCLUSION

To conclude, this article has aimed to make a humble start to sketching Entanglement HCI, on the basis of a collection of related philosophical stances, that I called entanglement theories. I argue that this effort, alongside the other works that draw on these theories in HCI already, might be the beginning of the next paradigm shift in HCI as the existing practices and theories are starting to show conceptional shortcomings in describing and conceptualising the changes we see in our relationship with digital artefacts. In particular, I argue that third paradigm HCI, with its focus on situatedness, values and embodiment, is ill equipped to deal with the increasing ontological uncertainties that technologies such as virtual reality, artificial intelligence or neuro-implants pose. Further, current knowledge production practices seem to find themselves between a hard place and a stone, an intermediary level that neither satisfies the rich contextual commitments of constructivism, nor demonstrate the expectations of external rigour of empirical positivists. Finally, in recognition of the increasing responsibility for how technology changes us and our societies, the existing representationalism proves to make it hard to assign agencies and, connected to it, to effectively trace accountabilities.

As a possible way forward, I have proposed to engage with entanglement theories. These theories have in common, that they are making the argument that humans and their things are ontologically inseparable from the start. Embracing performativity, they postulate that ontological entities, or actors, only constitute themselves through intra-action with other entities. The boundary making, the making of agential cuts, in activity is the mechanism by which agency is enacted in the network of associations. All this serves to decentre the human as the sole source of activity and to elevate the role of the non-human world from a passive backdrop to human activity, to active contributors to relational action as it unfolds.

I review a purposefully selected range of entanglement theories—ANT, Post-Phenomenology, OOO and Agential Realism—and their existing intersections with HCI literature. Building on their central ideas, commitments, concepts and vocabularies, I set out to sketch Entanglement HCI from four perspectives, ontological, epistemological, ethical and methodological, with a view to show

pathways for addressing the above shortcomings in current HCI thinking. I argue that the performativity driven notion of agential cuts and the post-phenomological notion of mediation provide effective ways to deal with the increasingly fuzzy borders between humans and machines and the distribution of agency. Further, knowledge creation practices are also conceptualised as materially discursive and performative. Configuration and the enactment of phenomena are not random, but causally connected, i.e., reality is enacted un-ambiguously by the intra-action of things and people. Thus, I propose to evolve our ways of knowing to centre around the notion of phenomena, rather than facts; to abandon knowledge hierarchies in favour of relational knowledge creation; and to carefully engage with (re-)configurations and diffraction as the basis for collective scrutiny.

Possibly the strongest case for Entanglement HCI stems from our need to address accountability, responsibility and ethics. Counter-intuitively perhaps, the acknowledgement of the contribution of our material world to enacting reality, provides a systematic way of tracing the distribution of agency and hence accountabilities. It is through non-human agency that we can create nuanced links between design intent, context of use and people intra-acting with technology. Further, Entanglement HCI recognises the mutually constitutive relationship between humans and their tools and thus re-directs our moral deliberations about desired futures from questions of impact to questions of who we want to be. Lastly, Entanglement HCI suggests an evolution of our design practices. Collapsing ontology, epistemology and ethics into one, makes clear that any making of futures is all of this at once: designing technology means creating hybrid things with ambiguous boundaries and proposed programs of actions that seek to reconfigure agency and power with moral responsibility. I suggest to leave user-centred design behind and develop agonistic, participatory speculation methods to design meaningful relations, rather than optimising user experiences.

With my sketch of what might become Entanglement HCI, I shape up the proposition of a new paradigm in HCI. It is tentative and necessarily only the starting point, but it is also radical in that it might require us to unequivocally break with previous paradigms that we so far argued could co-exist. I hope this work serves as a springboard for a theoretical and practical evolution of an HCI that contributes to bringing about desirable future realities.

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