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Beyond Human-Centred Design: Supporting a New Materiality in the Internet of Things, or How to Design When a Toaster is One of Your Users

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ABSTRACT This paper challenges the assumption that humans should *naturally* be given primacy over non-human actors in the design process. New technological capabilities are starting to give non-human actors (e.g. networked objects) decision-making ability, thereby allowing for an active form of agency. This move will only grow in sophistication in the future and has the potential to be profoundly disruptive to both the design process and wider society. Using Donald

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A. Norman's fundamental characteristics of user-centred design, ideas informing the Internet of Things, and philosophies around New Materialism, this paper argues that the fundamental assumptions that underpin the act of designing need to be reassessed.

KEYWORDS: user-centred design, design process, materialism, object-orientated ontology, internet of things

Introduction

User-Centred Design (UCD) codified a way for designers to conceive of their relationships with the people that will use their designs. This recognized that the user (or 'human') matters in design processes. Understanding the needs, abilities, and perspectives will improve the likelihood of a design being effective. From the genesis of UCD in the 1980s, the principles developed then are almost universally applied and adopted. These principles are now part of the foundation of modern design to the point that it seems obvious that the people who will use a product or service should have an input in its design. This paper seeks to go beyond and in the process challenge some of the assumptions that underpin UCD.

Increasingly, decisions are being made in the world autonomously, without human control or knowledge. In our everyday lives software will decide on the best way to get from A to B in order to avoid traffic, systems will create lists of music that we will like to listen to, more and more we will be driven around in vehicles that are making their own decisions about navigating through our road networks.

This trend of 'smart objects' which make decisions for us is likely to increase, and the decisions they make will have a steadily greater effect on us. For design, this means that the decisions 'smart objects' make will start to have a bearing on the success of design projects and how products and services function.

This paper explores the implications of having non-humans with agency or acting as 'users' in the design process. It seeks to energize a debate in this area, prompting new design theory, practice, and ultimately a new 'smart object' inclusive of the design approach.

Human-Centred Design in Context

Human-Centred Design (HCD) is a design approach that places the end users or recipients of design outcomes as a central focus in the design process. In this context, HCD is used as an umbrella term for an overlapping collection of classifications of design practices including: people-centred design, user-centred design, person-centred design, and user/client-oriented design. While there are distinctions made between these approaches (Steen et al. 2004; Zhang and Dong 2008), they all have their roots in the seminal work of Donald Norman in the 1980s. His two books, *User-Centered System Design: New Perspec-*

tives on Human-Computer Interaction (Norman and Draper 1986) and *The Psychology of Everyday Things* (Norman 1988), mapped out a new direction for good design. This message stemming from 'A philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable' (Norman 1988, 141) is a mainstay of contemporary design education and is widely recognized in professional practice (Sanders and Stappers 2008; Coleman and Clarkson 2016). Later in this paper, the design processes that go far beyond just inviting people into the designer's process will be discussed. These approaches such as open design and democratized innovation have citizens (people) leading design processes often without feeling the need to involve designers at all.

The fundamental principles for HCD remain in essence those laid out by Norman in the 1980s, and these are:

- Make it easy to determine what actions are possible at any moment.
- Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions.
- Make it easy to evaluate the current state of the system.
- Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state. (Norman 1988, 188)

Building on these, Norman proposes seven principles to enable designers to adopt a user-centred approach.

1. Use both knowledge in the world and knowledge in the head. By building conceptual models, write manuals that are easily understood and that are written before the design is implemented.
2. Simplify the structure of tasks. Make sure not to overload the long-term memory, or the long-term memory of the user. On average the user is able to remember five things at a time. Make sure the task in consistent and provide mental aids for easy retrieval of information from long-term memory. Make sure the user has control over the task.
3. Make things visible: bridge the gulfs of Execution and Evaluation. The user should be able to figure out the use of an object by seeing the right buttons or devices for executing an operation.
4. Get the mappings right. One way to make things understandable is to use graphics.
5. Exploit the power of constraints, both natural and artificial, in order to give the user the feel that there is one thing to do.
6. Design for error. Plan for any possible error that can be made, this way the user will be allowed the option of recovery from any possible error made.
7. When all else fails, standardize. Create an international standard if something cannot be designed without arbitrary mappings. (Norman 1988, 189–201)

The focus here is on Norman's early work because this paper continues to argue that thinking about users could in a way be better and more progressive than thinking about humans as things that engage with design outcomes. It is possible to regard non-humans as users, widening the scope of key stakeholders in an interesting manner. As such, Alison Black's definition of User-Centred Design from the Design Council in 2006 is helpful.

> *User-centred designers engage actively with end-users to gather insights that drive design from the earliest stages of product and service development, right through the design process*. (Black 2006)

Here the case is made for a re-evaluation of HCD seeking to challenge the assumption that humans should automatically occupy a dominant position in the design process. As part of this examination there will also be an investigation of some of Norman's later ideas, in particular his own critique of HCD in the context of Activity-Based Design (Norman 2005).

Going Beyond HCD

The aim of this paper is not to replace HCD as a rubric or heuristic for everyday design activity across the board. There are excellent reasons why HCD or some version of it has become the *de facto* approach to professional design. This paper argues here that there is a changing cultural, social, commercial, and technological landscape that will require a reassessment of the fundamental assumptions that underpin HCD. In particular, when considering the broad area of the Internet of Things, the role of humans is complicated by the agency (decision-making) of non-human actors. In his paper, 'Human-Centred Design Considered Harmful', Norman identifies some of the fundamental assumptions open to challenge in HCD, for example, know your user, adapt technology to people, and focus on the static product over the dynamic system (Norman 2005).

Partly these assumptions are grounded in the product-centred nature of the principles Norman lays out in *The Psychology of Everyday Things.* Here, design creates products (physical or virtual) that have to be understood and used by a public. The result is a focus on instructions and what cognitive load to impose on the receiver of designs in the principles above. The principles reproduced above focus on helping users live with the decisions made in the design process through, for example, including explanatory graphics or effective instructions.

There are a growing number of examples where this distinction between designer and user (or person) is not at all clear-cut (Beegan and Atkinson 2008). This has led to new types of design and innovation that exploit the interplay between use and creation, between designer and user. There are a very broad range of participatory design approaches where participants are welcomed into the heart

of the design process rather than being the subject of insight-gathering from designers, as seen in conventional HCD. Processes such as co-design aim to work in close collaboration with a range of stakeholders (Sanders and Stappers 2008). This requires a new set of skills for the design professional who is becoming closer to a facilitator rather than translating insights into designs appropriate to the relevant technologies of production; a move from 'gatekeeper to innkeeper' (Cruickshank 2014). Beyond this, in terms of not just the participation, the power of the non-professional designer or person lies in Open Design. Here there are design and innovation processes that often have no professional design input at all (Abel et al. 2011; Cruickshank 2014). These processes, and others, are complemented by innovation models such as Erik von Hippel's Democratized Innovation (von Hippel 2006) and to an extent the move towards Open Innovation in business (Chesbrough 2003). There are very well developed case studies in this area of innovation research that highlight democratized innovation in the areas of mountaineering equipment, medical devices, kite surfing, and computer chip development. In each of these cases 'lead users' have been shown that everyday users have the potential to be more successful innovators than specialist R&D professionals (von Hippel 2006). This makes a societal case for looking beyond processes that allow or even welcome people into a professional designer's creative process.

It is not just in terms of the design process that there are grounds for going beyond HCD, there are also arguments to be made in terms of social responsibility. Again, this is partially recognized by Norman but taken much further by Joaquim Lloveras. In 2009, Lloveras called for a move beyond User-Centred Design – instead calling for a Global Design movement, he says,

> in the future hybrid biological-artificial beings may exist that are a mix of biology and technology or some biological beings may be replaced by artificial ones. In the past these ideas were only expressed in science fiction. Robots will evolve and will be able to do many jobs. (Lloveras 2009, 161)

Lloveras highlights the tension between a move towards personalization and a wider community responsibility. For example, an individual may want to indulge in conspicuous consumption for personal gratification, but cumulatively this has wider societal impacts that affect us all. This tension can also be seen when people can easily make their own personal products beyond any outside regulation. While there are a growing number of people making things for themselves, there are also growing communities that are interested in sharing and profiting from their designs. This could take place through the sale of the physical products or by selling the digital models that can then be either created as they are, or modified. There are a number of platforms that facilitate this kind of exchange of products and models for products, such as Shapeways (www.shapeways.com), Thingiverse

(www.thingiverse.com), Quirky (www.Quirky.com), and Ponoko (www.ponoko.com).

To a designer's eyes some (many) of the designs available on sites such as Quirky and Shapeways are not well designed. 3D printed handcuffs are not robust enough to really act as a restraint (perhaps this is a good thing). More seriously, Shapeways has recently removed any gun components from its download database. In America this is a subject undergoing intense study, with 3D printing seen by some citizens as a way to sidestep the real or imaginary threat to their ability to purchase guns via normal means. Groups like Defense Distributed (www.defensedistributed.com) have set up an online repository of models that can be used to create gun components (www.wikiweps.org).

While Lloveras's ideas have been widely taken up in the area of sustainable design (Acosta and Romeva 2010; Lange-Morales, Thatcher, and García-Acosta 2014), the issue of 3D-printed guns puts the spotlight on the ethical implications of citizen-led design and manufacture and draws the relevance of Lloveras's call for an ethical framework out from ecological considerations into the mainstream consumption of products. The open, free creativity and optimism of the proponents of FabLab is facing a challenge by people taking openness seriously and using technology for their own agendas that are challenging to mainstream or liberal sensibilities.

This call for an ethical framework is not a new debate; it closely echoes the concerns raised in K. Eric Drexler's notable book on nanotechnology from 1986, *Engines of Creation: The Coming Era of Nanotechnology* (Drexler and Minsky 1990). Drexler's solution was to make the means of design free to all, yet to make the means of making these designs closely controlled. In contemporary society the means of self-production are already in place for anyone with a web connection, and developing quickly to maturity. In the area of Open Design, where design is undertaken by people outside the professional design/innovation ecosystem (Cruickshank 2014), ethical issues come to the fore. There is a growing realization that when these approaches are used with real people undertaking critical problem solving that will affect lives (rather than, say, looking for a new mug or T-shirt), the ethics of self or non-expert design are more problematic. In a paper 'Closing in on Open Design' Cruickshank and Atkinson (2014) look at the ethics of a group of open designers with cystic fibrosis designing furniture for themselves. These members of the general public were creating furniture specifically for their unique needs and paying a considerable amount of money for manufacturing these designs.

Escaping the Designer/User Spectrum

The above examples demonstrate a range of design activity; at one end designers have a controlling agency and welcome people into their design process, at the other end of this spectrum people have controlling agency and through activities labelled open design and democratized innovation they as non-professionals have the controlling

agency. In both cases, this paper has demonstrated that these positions can be problematic. Here this paper argues for a disruption of this spectrum where users are central either directly or spoken for by designers. We want to promote a debate by arguing that both conceptually and practically there is a good case for recognizing explicitly that non-human actors have the potential for agency. This has the potential to disrupt design approaches that are fundamentally based on humans as the pre-eminent concern. The practical and then the philosophical foundations of this position are outlined below, drawing on the potential of digital technology and networks and conceptually on theories of Object-Orientated Ontologies (OOO) and New Materialisms.

Smart Objects and the Internet of Things (IoT)

Networking and digital technologies are radically changing the way objects interact with us and critically with each other. Under the broad term Internet of Things (IoT) these capabilities are giving non-human actors agency in our environment. The means of production and ideas such as truth to materials have always had a framing or envelope-defining influence on design. Within the IoT we are moving beyond this context-setting function to more active modes of contribution by non-humans. In an age of automated Bots, IBM's Watson (Baker 2011), and the Internet of Things the bedrock of this assumption that humans are the most important actors is being eroded daily. A key question for the future of design is how to design when non-human actors in the landscape have agency, respond independently, and act as part of a wider system. This can be noted already in a tentative manner in things like search engine optimization (SEO) where websites are designed to be more 'appetizing' to the virtual robots or 'spiders' moving around the web cataloguing and understanding the connections between sites to make our web searches ever more effective.

In a key paper in this area Kortuem et al. define IoT as 'a loosely coupled, decentralized system of smart objects – that is, autonomous objects augmented with sensing, processing, and network capabilities' (Kortuem et al. 2010, 44). The influential Disruptive Civil Technologies report identified IoT as one of six technologies likely to disrupt US interests before 2025. This report identifies the ability of software to 'makes sense of' data and other information as a key indicator of IoT development (NIC 2008). In both of these descriptions autonomy (agency) is a defining feature. Kortuem et al. draw the distinction between sophisticated but 'dumb' systems that, for example, track the movement of goods through warehouses using technology such as Radio-frequency identification (RFID) and systems that use 'smart objects' that have a level of *understanding* built into them, that is to say that they are aware of their surroundings and can respond to changes. It is these 'smart objects' that characterize a move to IoT. Kortuem et al. define 'smart objects' as having the capacity to 'sense, log, and interpret what's occurring within themselves and the world, act on their own, intercom-

municate with each other, and exchange information with people' (Kortuem et al. 2010, 44).

The theory of the IoT is (finally) beginning to translate into real-world changes. For example, Dubai is currently installing a system supporting autonomously guided flying taxies where customers select a destination within a 31-km radius and they are then automatically flown to that destination through the city.

There have also been experiments with autonomous postal delivery. While the logistics company DPD are actively developing this technology,[1] the Swiss postal service already has a limited pilot of autonomous delivery robots. Developed in conjunction with the UK company Starship Technologies, these small 'rovers' can deliver parcels up to 10 kg in weight.

Currently these are isolated examples, but when such technology becomes more commonplace the issue of agency of autonomous objects will increasingly become a pressing issue. In the case of autonomous passenger vehicles the vehicle will at times have to make judgments with ethical implications, for example when taking avoiding action would lead to greater loss of life (Arkin 2008; Coeckelbergh 2013).

The argument made in this paper is that we need to design with this emerging new agency in mind, and that this necessitates a reappraisal of the assumption that humans occupy a hierarchical position in the design process. While the examples described here place this activity in a technological context, and 'smart objects' as artificially constructed artefacts, the definition above does not restrict 'smart objects' to the artificial. As a class or category, humans very much qualify as 'smart objects' here as much as, say, an autonomously driving car. Every individual can be regarded as potential objects in the IoT with the same potential for agency (no more or less) than the 'smart objects' developed in conventional innovation processes (smartphones, fitness monitors, games, and so on). Together these objects interact, communicate, and reason (have agency). This raises some profound issues for design. In this area it does not make sense to place humans in a hierarchical position, as the centre of focus. In the IoT, effectiveness comes from the whole system working together without predicating one type over another; often it will be the effective interaction of non-human actors that will determine effectiveness. When considering the implications for designing for the IoT, theories of OOO and New Materialisms can help to interrogate the role or agency of the human.

There is a rich tradition in philosophy that challenges the primacy of humans, though this has often been characterized as being abstract, difficult, and dislocated from practical concerns. In some senses this is inevitable; some of this thinking (e.g. Heidegger) investigates the fundamental characteristics of our existence. Similarly more contemporary theory (Object-Orientated Ontology) was developed to engage with 'objects' that are inherently ungraspable, for example pollution or global warming, which Timothy Morton

describes as 'hyperobjects' (Morton 2013). This paper argues that there is great value in the thinking that has been undertaken in this area over the last 20 years, but it is often presented in a form that is not at all easy for designers or design researchers to engage with. Ultimately there needs to be a new dialogue between theories of materiality and actual material design where the interchange is rigorous, robust, and sensible. To achieve this in the future though, there does need to be an engagement with the philosophy of materialism in its current form.

In one sense this can be traced back to Heidegger's *Being and Time* (Heidegger, Macquarrie, and Robinson 1962, 15th ed) through to the writings of Deleuze and Guattari (1996), who in particular have influenced many recent philosophies of New Materialism or Object-Oriented Ontologies. The wider branches of continental philosophy stemming from Alain Badiou and Francoise Laurelle (Mullarkey 2006) have also influenced current writing and thinking in this field. Closer to design, Levi R. Bryant's *Onto-Cartography, An Ontology of Machines and Media* (Bryant 2014) considers the interactions of objects.

Since 2007, there has been a proliferation of texts, conferences, lectures, and books broaching the wider topics of Object-Oriented Ontologies stemming from philosophers such as Graham Harman, and New Materialisms stemming from philosophers such as Rosi Braidotti and Jane Bennett. It is important to examine this diverse selection of philosophies and examine their ramifications in design. Despite the differences between Object-Oriented Ontologies, these philosophies propose that reality can be known without its being shaped by and/or for human comprehension. This paper will now provide a basis for the approaches designers can consider when working with these recent theories.

Supporting this, and in resonance with Lloveras's call for Global Design as a concern for ecological issues, some philosophers in this area criticize environmental thinking for purporting to be focused on the real world but in fact remaining rooted in the abstract, while other thinkers focus on materiality, thereby characterizing an object of one scale or another into a flat interconnected hierarchy (or ontology).

Rationale for Change, a Move from Hierarchies to a Flat Ontology

Describing the nuances of New Materialisms and Object-Oriented Ontologies lies outside the scope and space available within this paper, but in engaging with some of the core philosophical ideas in this area it is possible to draw out some key issues to be addressed in the reformulation of design processes for IoT. Recent Object-Oriented philosophies and New Materialist theories provide a basis for how to navigate and re-contextualize the levels of micro-politics and the personal, local engagement, and issues revolving around sustainability and the various manners in which non-humans have their own agency. Deleuze and Guattari comment on the qualities of micro-politics by focusing on

the scale of the components interacting in a network and the nature of those interactions. While the macro-scale may be more visible, it is also important to keep in mind that you can have a macro-politics of a two-person interaction, or the micro-politics of a large group (Deleuze and Guattari 1996).

Object-Oriented Ontologies follow in the philosophical lineage of Deleuze and Guattari and are closely aligned to the philosophies of Bruno Latour and Manuel De Landa. The latter, in his book, *Intensive Science and Virtual Philosophy* (De Landa 2002) writes,

> In a flat ontology of individuals, like the one I have tried to develop here, there is no room for reified totalities. In particular, there is no room for entities like 'society' or 'culture' in general. Institutional organizations, urban centres or nation states are, in this ontology, not abstract totalities but concrete social individuals, with the same ontological status as individual human beings but operating at larger spatio-temporal scales. (De Landa 2002, 147)

Recent critiques of Flat Ontologies note the tension at play with how Object-Oriented Philosophies conceive of relations and how they sit in the hierarchy of the flat ontology. Object-Oriented Ontologies place more attention on the objects themselves and less attention on their relations. In order to expand how to think about design and objects, the ground between New Materialism and Object-Oriented Philosophies can be explored further.

The philosophical lineage of New Materialists builds upon Deleuze and Guattari and engages with the question of subjectivity. Writers and philosophers such as Rosi Braidotti or Elizabeth Grosz are examples of this line of thinking. However, this subjectivity in question is a multiplicity, and it is also a post-human multiplicity. Moreover, New Materialisms at their core are about political emancipation, more sustainable becomings, and traditions that look into a human–nonhuman continuum.

A major distinction between Object-Oriented Ontologies and New Materialisms is that the latter actively works with ethical and political concepts. Jane Bennett's Vibrant Matter is 'a political ecology of things' (Bennett 2010). Similar to examples noted by Bennett, Bryant provides an example of the cycle involved in spillages in an ecosystem. He considers how a spillage enters a water supply, moving onto contaminating wildlife, and eventually reaching humans who eat contaminated wildlife. Bryant is concerned with how different systems, encompassing both human and non-human elements, are entered in various ways. Echoing Bennett and New Materialist thinking, Bryant remarks: 'A body, as it were, is sheathed in a world' (Bryant 2014, 49). Here we can start to see how Bryant is aligning culture and nature and how it interacts with the human. This can be a starting point for considering how these theories and how this line of thinking can be translated to design or the design process.

Implications for UCD

In *Vibrant Matter: A Political Ecology of Things*, Jane Bennett writes:

> I have been trying to raise the volume on the vitality of materiality per se, pursuing this task so far by focusing on nonhuman bodies, by, that is, depicting them as actants rather than as objects. But the case for matter as active needs also to readjust the status of human actants: not by denying humanity's awesome, awful powers, but by presenting these powers as evidence of our own constitution as vital materiality. In other words, human power is itself a kind of thing-power. At one level this claim in uncontroversial: it is easy to acknowledge that humans are composed of various material parts (the materiality of our bones, or the metal of our blood, or the electricity of our neurons). But it is more challenging to conceive of these materials as lively and self-organising, rather than as passive or mechanical means under the direction of something nonmaterial, that is, an active soul or mind. (Bennett 2010, 10)

Here we see Bennett bringing about various notions of the agency of the components in the body and how systems function. This is aligned with the thinking of Bryant. According to Bryant, his concept of 'Alien Phenomenology' is a component of Onto-Cartography (Bryant 2014). Bryant outlines that the ethical consideration of 'Alien Phenomenology' helps to extend the boundary of humans and non-humans and opens out the relations of human to non-human to machine; and not just what machines can do for us. Onto-Cartography is the mapping of relations or interactions between machines, the mapping of relations between machines and interactions, and how they influence each other or are modified. Bryant writes about flows and permeability in a similar way to how philosopher Nancy Tuana does. Bryant remarks: 'If we are to change and influence these machines we must interact with them in terms of how they encounter the world so as to devise strategies for getting them to respond' (Bryant 2014, 72). Bryant goes on to write: '... it is necessary to determine the flows to which these machines are open, how they operate out of these flows, and what goals or aims animate these machines' (Bryant 2014, 72).

In her paper 'Viscous Porosity: Witnessing Katrina', Nancy Tuana (2008) uses the term 'viscous porosity' to indicate how our bodies are open to various objects. Tuana places human bodies in the middle of a wide range of phenomena caused by Hurricane Katrina and demonstrates how 'cultural' things permeate 'natural' ones, a point which Bryant also contends with. These theories erase the boundary between inside and outside through these real-world examples. In this line of thinking, they move beyond traditional approaches by Object-Oriented Ontologies, which maintain that objects have a fixed interior and exterior.

Here we see multiple strands of philosophy that intersect at a number of points critical to practical design for the Internet of Things, both in terms of the things that are designed but even more so in the processes

used for the act of designing. Most important of these is the assertion that hierarchies, especially unexamined hierarchies, should be treated with suspicion. This very much applies to the assumption that the human is the 'unit of analysis' that design is built upon. It is important to reassess how we design when humans are not the sole yardstick, when non-humans need to be considered as agents in the process.

These theories focus on transformations in the ways we currently produce, reproduce, and consume our material environment. The analysis of our daily interactions with material objects and the natural environment is also core to these theories. These theories highlight that it could be useful to question the place of humans within a material world, especially in the context of design processes. Even as things, objects, actants, and the non-human engage in a wide array of pursuits, the anthropocenic perspective seems to confine humans certain to roles. Moreover, these theories could help designers think about the potential for transformation in design, which involves innovation in how we build new things, retrofit, reconcile our waste, and what materials and processes we use in the first place.

Implications and Conclusion

OOO and materialist approaches present a rich area of philosophical intervention that problematizes the human as the unit of concern in design processes, especially when designing for the IoT. This section will explore a limited number of the implications for design; really the intention here is to start a more comprehensive, far-reaching debate on this area rather than a comprehensive review or offering solutions. To help focus this discussion, this section will start by considering two of Norman's seven fundamental principles for User-Centred Design – not to criticize these principles but to use them as a catalyst for a wider discussion about the issues we need to address to reflect the new possibilities of designing for IoT. Norman has already challenged the principles of UCD. In a paper exploring where UCD could be damaging he proposes an alternative called Activity-Centred Design (ACD). Broadly ACD is a call for designers to refrain from engaging with their users. 'Sometimes what is needed is a design dictator who says "ignore what users say: I know what's best for them"' (Norman 2005, 17). This is a move to (sometimes) free designers to use their intuition instead of engaging with external actors. This is an interesting provocation that maps onto real-world design practice; in the context of this paper Norman is positioning designers in relation to users in general. This paper argues that users can be regarded as 'smart objects' (both human and non-human), and as such this could fit into an ACD approach, but it is not dependent on it.

The seven principles of User-Centred Design have become part of the DNA of contemporary design practice, education, and theory. To stimulate a wider debate two of these principles are presented alongside a series of questions for further exploration when designing for the IoT.

Principle 1. Use both knowledge in the world and knowledge in the head. By building conceptual models, write manuals that are easily understood and that are written before the design is implemented. (Norman 1988)

This presents a number of challenges:

- How can the knowledge contained within smart objects be used/accessed?
- What conceptual models are comprehensible to smart objects? How do these relate to conceptual models comprehendible to humans? How can both of these (or one common model) inform the design of complex systems?
- In a networked world, designs emerge and continually evolve rather than being completed; how does this relate to knowledge required as well as knowledge generated within actors in the system as well as cumulatively across the system?

Principle 3. Make things visible: bridge the gulfs of Execution and Evaluation. The user should be able to figure out the use of an object by seeing the right buttons or devices for executing an operation. (Norman 1988)

- Who is the thing being made visible to? How can/do smart objects experience the world, how does this inform their understanding or experience of the world, how should designers be accommodating this different view of the world?
- How can smart objects be made easy to figure out, and critically how can we design to help smart object figure out other elements in the design? This notion of affordances for and of smart objects in the IoT, the right equivalent of buttons to change things is core to the challenge of designing for the IoT; what are the affordances for human and non-human smart objects to interact with each other?

There are many questions here. While we are not in danger of 'smart objects' gaining true intelligence right now (in the next year or so), the degree of agency objects are gaining is increasing. Things such as autonomously driven vehicles are a very visible example of this type of agency. This paper offers a series of provocations and considerations, arguing that *now* is the time to get to grips with the implications of 'smart objects' with agency in the design process and to develop new fundamentals of design that can accommodate non-human agents. OOO and New Materialisms offer an interesting conceptual starting point for this discussion. Currently designers have to strike a balance between empathy for the humans that use the things that they design and drawing them into the creative process to give them their own voice. Both of these are a challenge for non-human actors; the danger is anthropomorphizing them, assigning them human senses and motivations, and the challenge is to truly understand the world they will be a part of and also to develop ways that allow them to contribute to creative processes.

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Note

1. https://postandparcel.info/76430/news/dpd-unveils-research-paper-on-autonomous-parcel-delivery-vehicles/].

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