Products as Agents: Metaphors for Designing the Products of the IoT Age

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ABSTRACT
Design-based inquiries into the networked products of the Internet of Things (IoT) lack a coherent understanding of the effect of such products on society. This paper proposes a new taxonomy for networked products, which would allow articulation on their current state and future, and provide insights to designers for creating meaningful and aesthetic products of IoT. Central to this framework is the proposition that our current product-scape should be understood as a distribution of material agencies and best analyzed through the metaphor of "agency". We identify three types of agencies, i.e., the Collector, the Actor, and the Creator, and discuss how this approach could create new design methodologies to create more meaningful networked products that would empower people in their everyday lives.

Author Keywords
Internet of Things; networked products; agency; metaphor; interaction design.

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H.5.m. Information interfaces and presentation: Miscellaneous.

INTRODUCTION
Products of the 21st century are quite different from their older brothers and sisters. Since information processing has become cheap and widespread, the capability to collect and handle information has become one of the many 'materials' from which products can be made [38]. Through gaining computational power and network connectivity, cars, thermostats, and even light bulbs have begun to communicate with their users, manufacturers, and of course one another. The speed and scale of this "Internet of Things" (IoT) provide new design opportunities to empower people and enrich their everyday life. In order to gain insights on how to create networked products that attain these aims, as design researchers, we are required to better understand not only the technical infrastructure and technological parameters of networked products (as IoT is generally tackled in engineering and computer sciences), but also the social relationships of these products with everyday practices of people [37].

For the past couple of decades, there has been a shift in the definition of designers' main task from designing "things", which are objects, to designing Things, namely socio-material assemblies [6,7]. Things have become political gatherings around shared matters of concern with a visible effect in the world. When it comes to the current product-scape of IoT, however, we fail to observe this Thing-ness. This situation is humorously demonstrated at the blog "we put a chip on it" (http://weputachipinit.tumblr.com/). Its tagline "It was just a dumb thing. Then we put a chip in it. Now it's a smart thing" accurately summarizes the current approach towards smart products. Clothespins that notify you when the laundry is dry or socks that keep track of how many times they were washed indicate how shortsightedly IoT could be executed. Being smart, however, has a lot more potential.

Networked products should be a hybrid of technological developments and cultural articulation [37]. They need to be in a form that enables users to invite these products into their lives and makes an impact on people's life quality. Design practice has been trying to invent the new IoT medium by exploring the new affordances and challenges that being connected brings [46]. Design research, therefore, should catch up with the practice by undertaking inquiries into what these products mean for design culture and society and how to create empowering networked products that go beyond simply embedding a chip in something. Coming to grips with the IoT demands new ways of seeing, understanding and asking pertinent questions about the ontological nature of smart and connected products and their impact on users' lives. Frameworks and theories in interaction design help making strategic choices about how to proceed and where to invest energy [36]. In this paper, we propose a framework that is based on the metaphor of "agency" in order to do so.

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In our understanding, IoT currently deals with four different types of products: (1) products that connect to its users to inform their status and receive orders, (2) products that connect to its users and learn from these interactions to become more intelligent, (3) products that are connected to other products to exchange status information that is used to steer rule-based behavior, and (4) products that do not connect to the user or other products via Internet, but have an internal architecture that can adapt to the behavior of the user. All these types indicate a capacity to sense and act autonomously. These products can learn and evolve. They can reveal new patterns and change our minds. In other words, they are actants with performative roles in our lives. Seeing them as agents can help us unravel the ecologies between products and users, provide guidance about analyzing and discussing the products of IoT, and eventually offer a new framework for developing methodologies to design them better.

The IoT field is no stranger to metaphors. Kuniavsky, for instance, uses the term "information shadow" to refer to the digital information that tails a product's usage [38]. Rose uses the metaphor of enchantment to describe the pleasant experiences that well-designed smart products provide [49]. As casting a magic spell to an ordinary object, the smart products gain some remarkable ability that make them more useful, engaging and delightful, than their ordinary self. Romero, Pousman and Mateas describe the potential of ubiquitous computer systems to sense and react unpredictably to the behavior of users as an "alien presence" [48]. IoT as a field is susceptible to using descriptive metaphors, because many concepts of the field are rather abstract and the effect of its outcomes are difficult to grasp, which is what metaphors are good at overcoming. Although these metaphors vividly evoke the invisible, yet powerfully present potential of IoT, they do not offer a framework in which we can systematically compare and abstract the use and impact of smart products.

In his seminal work, Schön introduces the term "generative metaphor" in order to broaden the extend of metaphor from being a frame for looking at things to a process by which new perspectives on the world come into existence [52]. We consider that the potential of smart products to change behaviors of users and their capacity to make a visible effect on society call for a generative metaphor. A metaphor of agency can provide such new way of thinking as it accounts for the ways we currently communicate and work with an ecosystem of responsive objects.

In the remainder of this paper, we will first draw selectively from the perspectives on object agency coming from various disciplines. Then, we will present a taxonomy that is based on our understanding of how agency is and will be manifested in smart products. We discuss and reinterpret products that fall under each type of agency in the taxonomy, and point out to specific issues that are raised through their material agency. Finally, we argue for a theoretical approach that follows from an understanding of product agency by discussing the benefits of this metaphor, propose design methodologies that are fitting for creating agents and discuss the design challenges that follow from the form and behavior of such agents.

THE RISE OF AGENCY

Scientific inquiry into the notion of agency is not new to the science and technology studies, humanities, feminist studies and philosophy. Over the past decades, scholarship in these disciplines has started to retire from perspectives that place human beings at its center. This non-anthropocentric understanding prompts considering human as a single knot in a system where many other nonhuman actors are also at play. Each human or nonhuman actor in the system exerts impact on others.

The most prominent account in this regard is Actor-Network Theory (ANT). ANT offers valuable insights into mapping the complex relationships between technologies and humans. Scholars in this tradition revoke the privilege of human actor and discuss the ontological symmetry of humans and nonhumans in networks of relations [40,42]. In other words, human and nonhuman are studied as equal actors in any kind of network, and their agencies can be continuously transformed into one another. This flat ontology is also at focus in materialist philosophies, e.g., [10,13,31]. In particular, "Object-oriented ontology" (OOO) represents the philosophical positions that dissociate philosophy from anthropocentrism and consider objects to live an existence that exceeds the relations with humans. Central to this proposition is considering objects "as entities in their own right without requiring recourse to human use, perception, or meaning making" [19].

As a matter of fact, this is the argument that ANT and OOO stand apart. Although both perspectives ascribe human and nonhuman equal being, in OOO the reality of objects is binary—something is either real or not regardless of the relations it enters into [14]. In ANT, on the other hand, alliances take the center stage and the reality of objects is defined through each object's relation to other actors. The more an object enters into additional alliances and extends the range of its effect on other actants, the more real it becomes [14]. Therefore, there is a constant dynamic transformation of things through coupling.

Another theory from social sciences, activity theory, also supports this claim. According to activity theory, understanding two or more actors (subject and object in activity theory terminology) is only possible through analyzing the relationship/activity between them—an understanding that cannot be achieved by focusing on the subject or object separately [36]. Agency, the ability to act for producing effects, is a fundamental attribute of both subject and object. However, not every entity can be a subject. Subjects have needs that drive them for acting in the world, which turns the agency manifested by the subject into a special character: it is the ability and also the "need"

to act. For this reason, only living things can be subjects. Nonhuman have the ability to act but not the need to act, which makes the relationship between the subject and the object asymmetrical. For this reason, activity theory rejects the symmetry granted to humans and nonhumans by ANT and OOO. In these theories nonhuman can delegate action to human, but in activity theory delegation always flows from human to all other kinds of agents (a detailed comparison of agencies between ANT and activity theory can be found in [36]). This theoretical position is also held by Ingold, who considers agency to signify intentionality [33,34]. Agency in his view is not an innate property of things but is something that emerges out of encounters with other things or human beings and actualized in specific situations.

This argument advocates for a relational, emergent form of agency as in ANT. The relational agency provides ANT to align with feminist theorizing in which there is an emphasis on the relational character of our capacities for action. Corresponding with the arguments of ANT and OOO, feminist theorist Barad also sees agency as something that occurs instead of something that one has [4]. In her view, everything is entangled with everything else. Studying any sort of situation where agency is displayed, that is any kind of knowledge practice, requires making an "agential cut" between what is included and what is excluded from the thing being studied. Barad argues that separations are temporarily enacted so one can examine something long enough to gain knowledge about it [4]. Agential cuts are a means for thinking about complex systems and cultures, and a critical framework for discussing what is brought forth or ignored when analyzing such complexities.

Regardless of their different viewpoints over the ontological symmetry between human and nonhuman or the definition of agency, all these theories coming from different disciplines have effectively challenged the traditional perspectives that restrict agency to humans. What these approaches have in common is seeing objects not solely as augmenters of human action, but as peers within a complex network [35]. In this paper, we do not adopt the arguments of any of these approaches directly as our theoretical foundation but rather aim to appropriate their main message that humans and nonhumans are both capable of action and making an impact on each other. This approach of distributed agency corresponds well with design, especially since the products have become smarter and more responsive.

The integration of (largely) autonomous set of interacting objects in everyday life has been explored from the early days of Ubiquitous Computing. In his seminal work, Weiser (1991) envisioned a world in which computing is so pervasive that everyday devices can sense their relationship to us and to each other and coordinate their actions accordingly [56]. Weiser's key objectives were ubiquity, i.e., embedding computation into the many aspects of the physical world, and invisibility, i.e., having these computers to operate autonomously [21]. Carrying the UbiComp principles one step further, the Ambient Intelligence (AmI) paradigm of the late nineties presented a vision on digital systems for the year 2010 and beyond [2]. AmI refers to the environment-embedded electronic systems that are sensitive and responsive to the presence of people, where many products cooperate seamlessly with one another to improve the user experience [1]. The word intelligence in AmI refers to having digital surroundings exhibit specific forms of social interaction, such as recognizing people, personalizing to their preferences, adapting themselves, and possible acting upon users' behalf [1]. Recently, the concept "human-computer integration" has been proposed to replace the traditional human-computer interaction [23]. Integration is defined through a codependent partnership between the user and the product—in which partners construct meaning around each other's activities, negotiate and sometimes compromise—that carries the straightforward command-and-respond way of interacting with products and systems further towards a more symbiotic relationship.

All these perspectives emphasize how products and systems have become more autonomous with the developing technologies. Yet, there are different ways that smart products could display autonomy. Below, this taxonomy will be presented.

PRODUCTS AS AGENTS TAXONOMY

Products of IoT can exhibit different behaviors as agents. We consider that the current trends in IoT point out to three roles: the Collector, the Actor, and the Creator. Each behavior sketches out different aspects of the HCI design space that need further attention and calls for a different mode of inquiry. These roles are not meant as disconnected categories, but rather envisioned as a scale. The degree of product agency increases from the Collector type towards the Creator type. Also within the same category, some products may display more agency than the others. We will be using this taxonomy to compare, abstract, and generalize the current approaches and trends in HCI research, as well as to discuss how to proceed in order to create better networked products.

The Collector

(Also known as: the data reader; Used for: understanding, making invisible patterns visible)

The first type of agency we can elicit from IoT has to do with the Collector products which sense and process information. They have the ability to aggregate data from embedded sensors or social media platforms and feed the data back to its user, to other users, or to other products. These products are sometimes referred to as smart things [38], meta-products [32], everyware [30], or hybrid products [31]. Most of the Collector products have a dual identity—a physical form and a virtual existence that is connected to online services. Well-known self-monitoring devices such as Jawbone or FitBit, for example, allow

people to collect and utilize data on everyday activities like sleep patterns or the number of steps walked, and therefore, can be considered as part of this category.

Laurel describes one of the functions of sensors as inviting nature into collaboration [41]. When a sensor gathers information about bird migrations, wind, or processes inside a living being, the invisible patterns of nature are brought into the realm of senses. Lapka personal environment monitor, in a similar vein, render the invisible radiation, electromagnetic fields, and humidity in a room into abstract shapes to be displayed on a cellphone (Figure 1). Having entered our daily lives tremendously, the Collector products are not only able to tap into environmental factors, but also reveal people's patterns of behavior and webs of practices. In this sense, they serve as "co-ethnographers" [28]. They have access to data and patterns that we as humans do not, and thus, help us see what was previously invisible. As an example, the connected baby bottle designed by Bogers and his colleagues reveals the correlations between feeding quality and environmental noise, formula temperature, teat size, and feeding location [9]. During the testing of the product, the parents welcomed these less obvious insights because they made certain patterns in their feeding practice visible, which prompted the parents to make changes in their practice to have a better experience.

Figure 1. Lapka personal environment monitor.

On a larger scale, in "smart cities" where many products and apps contribute to a pulsing cloud of urban data, the same co-ethnography is also at play. DiSalvo, Jenkins, and Lodato discuss the notion of "computed civics", i.e., the situation in which civic participation emerges from computation [18]. Examples include sensor systems that count car throughput on particular roads or cycling apps that gather data on the quality of cyclists' routes. The data collected by these systems provide detailed knowledge about the city and city life, which is utilized in the design of physical infrastructure, creation of policy, or justification of planning decisions. In such ways these systems create a new kind of civics, where it is not the citizens themselves, but instead their mobile phones or sensors are doing the civic volunteering [18]. This is a fascinating display of agency; the Collector products participate in social and political exchange.

Whether it is on personal, societal, or environmental level, the Collector products measure one or multiple parameters that are invisible to human perception, visualize this data on a screen or on the product itself, and provide handles for insight into everyday life, which has an enormous potential for molding users' behavior and social practices.

The Actor

(Also known as: the interventionist; Used for: creating dialogs)

The second type of agency involves the Actor products, which act autonomously according to the behaviors of users or other products. These products sense and interpret data like the Collector products, but also respond to it. Designers create a potential space for the product behavior. The users navigate in this space and perceive the product's behavior while the product is also engaged in autonomous interpretation of the users' behavior. Perhaps the best-known smart device, Google Nest is an Actor product in our taxonomy as it monitors users' activities throughout the day and learns to adapt itself and the environment according to their behavior patterns.

In the interactions with the Actor products, the user and the product continuously delegate action to each other. Marenko argues that this situation induces animistic responses in users [44]. The more the product seems intelligent and autonomous, the more our experience to deal with it tilts toward animism. As a matter of fact, the animistic behaviors of products can enable fluid and meaningful interactions between users and interactive systems. Van Allen and McVeigh-Schultz deliberately employed animism as a methodological framework in their design case of six interactive objects called Anithings [55]. Each Anithing has different intentions, personality, and inner life. Their exploration shows that these qualities of Actor products have a potential to trigger myth-making tendencies of people and produce pleasant user-product interactions.

A similar pleasurable interaction is also experienced through the use of the Addicted Toaster (Figure 2) [47]. As a behavior that some Actor products are prone to, the toaster exploits online social network services to mimic sentience and gain identity. It nudges its owner to consume more toast by tweeting about it. Sterling names such material objects with immaterial identities that engage in conversations with other actors as "spimes" [53]. Many of the Actor products in fact fall under the spime category.

Figure 2. Addicted Toaster by Simone Rebaudengo and Haque Design+Research (Courtesy of Simone Rebaudengo).

As in Collector products, the reach of the Actor products has started to extend beyond the home environment. With the advancement of the smart city notion, cities have become a playground to experiment with material agency as well. The Hello Lamppost project, for instance, uses pre-existing identifier codes on street furniture to enable people sending text messages to the objects like post boxes or trash bins (http://www.hellolamppost.co.uk/). The objects hold a conversation with the user by passing on the information that other residents had sent before (Figure 3). These conversations are intended as an opportunity to share memories of the city and rediscover local environments. While the Hello Lamppost had a playful aim and interaction, Bambea intends to ascribe sentience to the lampposts in order to improve health of the residents of Amsterdam (http://digitallifecentre.nl/projecten/bambea/). It is a computing system that is composed of beacons and a smartphone app. The beacons are attached onto the lampposts in Oost Park in Amsterdam, which have the lampposts send motivational messages to the smartphones of runners in order to coach their running experience.

Figure 3. Hello Lamppost by PAN Studio, Tom Armitage and Gyorgyi Galik (Courtesy of Playable City).

Regardless of being embedded at home or outside environments, using Actor products requires coordination and negotiation. They sometimes nudge the users subtly to change their behavior, as in Bambea where the lampposts mainly "suggest" a better route, speed, or additional exercises. But sometimes the Actor products make more dramatic interventions. For example, the Addicted Toaster relocates itself to a new home if neglected or the Amazon trashcan of MIT Media Lab scan the barcodes of things thrown away and have them reordered from Amazon automatically [15]. Although the intensity and limits of the intervention could vary, what is common among the Actor products is their intention to make a visible effect on everyday life and practices.

The Creator

(Also known as: the self-aware; Used for: creating futures)

The last type of agency is drawn from near future scenarios, in which the products will become the Creator of futures. Active research is being conducted on robots that can be used in daily lives [12] and a robotic future that merges with everyday products [3]. This indicates that robots and AI are breaking free from their traditional anthropometric looks and entering the daily lives of people. Then why not these everyday robots, or more aptly the everyday products with robotic qualities, start making a tangible difference on their form, the environment they are in, and the way they are used?

The ability to learn and evolve is a continuous concern in the robotics and AI fields. Bongard, Zykov and Lipson have been developing the Starfish, which is the first robot to develop some sort of "self-awareness" [11]. The robot synthesizes a predictive model of its own body through the interaction with its environment and uses this model to develop new behaviors without an internal mathematical model constructed by engineers. Carrying the self-awareness concept one step further, Samuelsen and Glette have been developing a robot system that has a connection with a 3D printer and is able to print new robots or customized robot parts instantly to tackle any situation they face [51].

As the algorithms have become this sophisticated, what kind of a future it will hold when everyday products with robotic qualities become self-aware about their form, environment, and usage? The vision of personal fabricators to expand outside of laboratories into homes has started to become a reality [27]. Connecting the self-aware everyday robots to 3D printers, as in the previous example, could open up an immense playground for displaying product agency. Since a toaster can arrange itself new host families by using the Internet (i.e., the Addicted Toaster), may be in the near future it could also order custom-made 3D printed pieces to be delivered at its owner's home for the toaster to be used more efficiently.

Such not-there-yet but feasible scenarios will not only affect the users' authority at home, but also influence the nature of the design process. Devendorf and Ryokai tackle the new configurations of humans and machines in hybrid making [17]. They invited users to mimic a 3D printer in order to elicit personal reflections on human-machine-product relationship and expose tensions between agency and control. Based on this, another configuration could be the machine taking charge of improving itself or its connected products. When the nonhumans will start to conceive such futures, designers will have to give up some authorial control and come up with concepts and forms that would prompt "free agents" to make choices and take actions that would yield to satisfying outcomes [17]. Through the new forms of product agency, new roles for designers in creation are bound to emerge.

DISCUSSION

Users' tendency for ascribing intelligence or intentionality to products has been a longstanding concern in HCI. What is recent, however, is the realization that a product is contextualized within a network of other products, users, values, and contexts, and that it gains an agency via establishing relationships with the actors in this network. This theoretical position of shared agency and the generative metaphor used for describing the situation open up new investigative opportunities for the design and study of new forms of entanglements with smart products.

First, it brings in a broader perspective to adopt when creating a nonhuman actor, i.e., a smart object, as a component of ecologies involving complex interactions and interrelations. Designing from an agency standpoint requires considering the interdependence of human and nonhuman actors, and crafting meaningful interactions between all the relevant actors in a context. Second, the symmetry between human and nonhuman advocated by this perspective enables exploring new design possibilities that may be overlooked in a typical human-centered design process. DiSalvo and Lukens argue that a non-anthropocentric approach in design, when used as a deliberate exercise, allows designers to break free from the human form, capabilities and affordances, consider the ways nonhuman may figure into action and experience, and eventually see a technology with a fresh eye [19]. Third, through the agency perspective, we can strive toward a new way of discussing and envisioning the use of the smart products. It allows for a better articulation about the impact of these products in society and discussing the ethics of such interactions. In all these means, the agency metaphor extends the theoretical and social agendas of contemporary HCI research.

In what follows we examine the considerations that play a role in the design of agent products. We start by discussing the potential design methods that are suitable for tackling each type of agency. Next, we discuss the social, aesthetic, and ethical implications of delegating control to autonomous agents. Finally, we present considerations that need to be taken into account when giving form to these products and the potential uses of their designed behaviors. We consider that these issues could offer insights into using the full potential of smart products, as opposed to being limited with just sensor embedding.

Designing agents

Interaction and product designers are faced with new forms of material affordances when creating networked products. These products are typically spread across various platforms, technologies, and infrastructures (e.g., Google Nest uses a sensor platform, an application platform, WiFi network, database, and so on). This requires a holistic approach during design, in which each component is designed with and around to produce a coherent product experience [37]. This integratedness needs to be present in addressing the ecosystem that the product is in as well. As argued by ANT and activity theory, studying multiple actors means studying the relationships in between. In the design of smart products, instead of addressing each product "vertically", i.e., being only responsible for its form and behavior, a horizontal approach is needed where the designer is also responsible for considering the multiple overlapping relationships with other products and contexts while giving form and ascribing behavior to a product.

Although a holistic and horizontal approach that works across various platforms and connects various actors applies to the design of all agents, different design methods may fit better to each type of agency. The main issue with the Collector products, for instance, is finding ways to use the collected contextual, experiential and behavioral data as creative design material in the design process—as a step going further than using them solely for optimize and validate design [9]. In the design process of the Collector products, a combination of sensor data and ethnographic methods would work best in revealing the complex architecture of practices and values surrounding the use of these products [16]. Ethnography is well equipped to position data in specific socio-cultural situations and offer in depth insights of the use context and experiences. Together, these analyses could grant the designers the relevant quantitative data coming from the algorithms interpreting the sensor data and the qualitative data that unveil the forms of practice the object partakes in. Such knowledge, when fed back into the iterative design process, help to bridge the gap between sensor data insights and real experiences, and help designers to create products that are well-fitting to the use context.

The design process of the Actor products is a viable arena for experimenting with speculative design. These products have an autonomous character, and hence, a strong potential to make an impact on the user and everyday practices in ways that are currently unknown to us. In order imagine and critically reflect on these futures, the discursive space created by the speculative design would work well [43].

While doing so, a "maker" approach is also needed. Material engagement is an important factor to care for the critical matter at hand. The behavior of the Actor products should be carefully crafted considering various use situations and interactions. Research-through-design methods could allow for exploring not only the material affordances of an Actor product, but also its effects on socio-cultural situations. Knutsen, for example, goes through a "critical making" process of a playful networked product that peaks out according to his friends' activity at Foursquare in order to discover infrastructural landscape of IoT with its material and immaterial relationships [37]. This approach, he argues, enabled him to engage with the critical matter of technologies differently than would have been the case by studying existing products. Similarly, Rozendaal suggests using animated low-fidelity mockups in order to bring autonomous "objects with intent" to life [50]. These mockups are invaluable to understand an object's expressiveness in relation to its purpose and reflect on its possible implications on user activity and behavior. Overall, these RTD experiments, address the possibilities and problems implicit in the design of the Actor products and bring about a range of procedural and conceptual insights to be articulated [25].

When it comes to the Creator type of smart products, the main question to tackle is how designers and design researchers can conceive of a vision when the products start to use the data they collect to make physical interventions on the way they look, move, or behave. A speculative design approach, but this time using "design fiction" as a method, can again be of help here. Design fiction is a prototyping technique that is particularly tailored to facilitate studying near futures and investigate where the ideal situation is located within the range of possible futures [43]. By not allowing the current technical and social mechanisms to influence the discursive space, design fictions can help to imagine how designers, users, and Creator products can work together to create new concepts or improvements in the current products and how this situation will effect the nature of the design process. By doing so, the assumptions about the role of the designer and his/her relationships with smart products are challenged. Employing design fiction methods can open up new questions and unfamiliar opportunities in this regard.

What all these proposed methods have in common is an acknowledgement of the ongoing interaction between human and nonhuman and looking for methods of design research that give both an equal voice. A thing-centered perspective can bring unique insights about the role of objects in human practices, and thus open up design opportunities that we may not be able to see with traditional user-centered design methods [28,29]. This requires a methodological re-orientation towards the concerns of objects in shaping how technologies are imagined, realized, and researched [45]. Ordinary objects should be engaged in the design process as participants to collaboratively elicit new insights. This non-anthropocentric approach does not eliminate the human agency. It is just a shift away from privileging human activities and desires over other agents in order to better understand, describe, and critique a given scenario, which eventually broadens the conditions and issues of design and design research [19].

Delegating control

Our commonsense understanding of reciprocity holds that the way we behave toward others affects the way others behave in return. But how does this human conduct apply to our interactions with smart products that display autonomous behavior? These products should know when to respond and when to delegate in order to provide pleasant experiences. Failing to engage in this proper social conduct can cause a growing tension between human and product agency. Striking examples in this regard are illustrated in the Uninvited Guests video, which is a critical depiction of the tension between an elderly man and his "smart" devices at home and how he deceives the system, as would be expected from anyone whose boundaries and routines are invaded by smart products alike [54].

As the smart products gain more autonomy, it becomes imperative to train these with the art of social grace and diplomacy. Let us take the talking shoe of Adidas and Google collaboration as an example (Figure 4). The sneakers have a microprocessor that translates the pressure sensor and accelerometer readings into audio instructions. This enables the shoes literally speak with the wearer and encourage physical movement by offering pep talk or sometimes trash talk (an Actor product). Compared to FitBit or other Collector type products that track movement and offer encouragement through a screen, the talking shoe is quite vocal and expressive for the same purpose. Although it may be easier to form an emotional bond with the latter one (and possibly, being more encouraged to move), the situation that one is in may not always be appropriate to deal with this shoe. That is why these sneakers will always be in the gadget category, rather than entering everyday lives as everyday products. To develop a meaningful interaction between users and smart products, the context in which the interaction takes place should be investigated well, together with how people in a specific situation may respond to the product.

Such conflicts may not only be between the user and the product but also among products. When each product has its own goals and agendas, who will mediate the emerging conflicts? Bihr and Thorne give the example of different home appliances fighting over the blinds being open or closed on the basis of their respective goals, such as the coffee machine wanting them closed so the milk lasts longer, the plants wants them open, the Nest wants them closed to keep the temperature low, and so on [5]. For now the users are the ones to moderate these conflicts, but when there will be a time when products are able to take on more

negotiation among them, new challenges for interaction designers will arise.

The autonomous behaviors also raise ethical challenges to consider how interaction design can be sensitive to the situation in which it intervenes. Fallman challenges the question of what is ethical design in the contexts of material objects enhanced with digital capacities [22]. He emphasizes the ethical and moral responsibility on the part of the designer rather than the user. For example, designers should consider how people might wish to overrule the autonomous actions performed by the smart product in particular contexts. Expecting that a smart product would be able to foresee and respond appropriately to any possible situation is a naïve idea in our current reality. Being teased by your shoe by it asking if you are a statue would be something funny when one is hanging out with friends at home, but it could be slightly embarrassing when waiting for the bus with strangers; and it is most probably difficult for the shoe to make a differentiation between these two situations. Rozendaal gives the responsibility here to the designers [50]. Designers should create some space of freedom for the users, which allows a product to display an autonomous action but this action could always be tempered or overridden by the user depending on the situation they s/he is in.

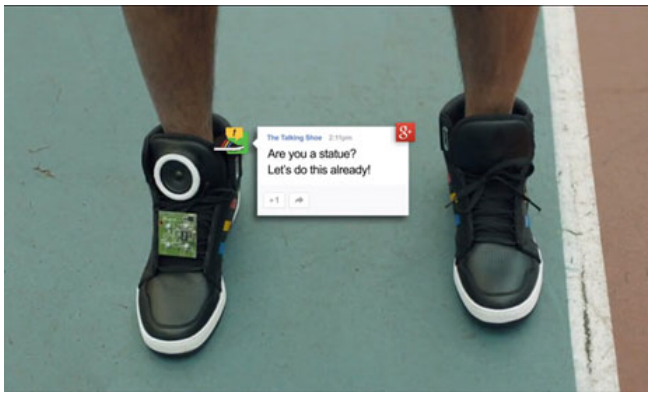

Figure 4. Talking shoe by 72andSunny, Google, and YesYesNo (Courtesy of 72andSunny and YesYesNo).

In the design of the smart products to know when to respond and when to delegate, guiding visions must be developed, which provide the means for analyzing and discussing the social, cultural, ethical, moral, ecological, and political implications of these experiences and how they foster particular relationships between users, designers, artifacts, and contexts [22]. The same ethical considerations surely also apply to the design of the Collector type of products, whose promise of easier and healthier lives, and more efficient and greener cities is hinged on getting hold of more data, or to the Creator type products which will change the relationship between designer and user and the nature of the design process. As in any kind of design process, here the core values of moral epistemic standing, i.e., human welfare, privacy, universal usability, and informed consent, should be followed [24].

Form and behavior of agents

An understandable trap to fall when giving form to agents is to be (unintentionally) affected by the "ultimate agent" of our times—a robot. Currently the form of robots is more commonly influenced by their historical and fictional representations, based on the assumption that it is more natural for humans to interact with humanoid than abstract forms [3]. However, considering that the use context of most smart products is home environment and everyday life, following a normative product design methodology is a better route to shape these products. The "robotification" of products should be by incorporating a clear functional purpose and adapting them to the domestic landscape using established modes of interaction, rather than simulating the human form and capacities [3].

A good and classic example in this regard is the Technological Dreams Series (Figure 5). This project is an exploration of the near future where robots become cohabitants in daily life and the ways they could relate with us [20]. The beauty of these robots, or Actor type products in our taxonomy, comes from the abstraction: their form is adapted to accommodate brand new technologies, but still appearing familiar. A similar approach can also be seen in the aforementioned examples of the smart baby bottle or Amazon trash can: They appear as autonomous everyday products, instead of robots.

Figure 5. Technological Dreams Series: No. 1, Robots by Dunne & Raby (Courtesy of Fiona Raby).

We judge sentience through actions, intentions, and personality. Smart products display behaviors that evoke the perception of sentience. These kinetic behaviors provoke action from the user. The Caterpillar extension cable, for example, initiates a dialogue with the user about

his/her energy consumption by twisting and turning as if in pain when the TV is left on stand-by (Figure 6) [39]. The product could have exhibited other agent behaviors to communicate the same message, such as Tweeting about it or automatically turning off the TV, yet the Caterpillar employs a powerful means—by relying on the user's empathy to act upon the artificial pain s/he causes on the product. Such animistic behaviors are significant for creating an emotive connection between the user and the product.

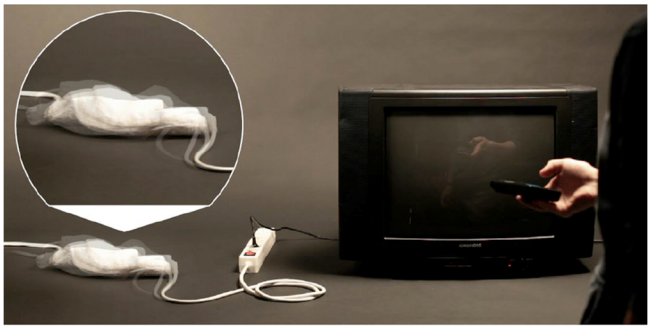

Figure 6. The Never Hungry caterpillar by Matthias Laschke, Marc Hassenzahl and Sarah Diefenbach (Courtesy of Matthias Laschke).

Instead of targeting a specific goal or solving a task, the physical behaviors of the products can also be designed for stimulating thinking and reflection. In the previously mentioned Anithings project, for example, the Actor type products are designed to have a life of their own, where they display unique behaviors depending on their assigned personality and knowledge [55]. Their behavior is expressed through a combination of visual display and sound, as well as how they influence each other. This makes the interaction with them unexpected, which is intended to "foreground the meaning making role of people as they interact with an ecology of heterogeneous, tangible, networked objects that behave in the world and acquire narrative, mythic qualities in people's lives."

The same approach is also sometimes experimented in relation to the Collector type of products. The agency of these products comes to an end after the communication of the gathered data. The reflection over the data and the decision to change behaviors and practices are left for the consideration of the users. HCI field has been exploring with other means of data communication than the aggregated numbers and stats. For example, the home health horoscope of Gaver and his colleagues communicates sensor data through the language and form of daily horoscopes [26]. The system embraces the ambiguity of data interpretation by shifting the responsibility for interpretation from the system to the user. Similarly, Romero, Pousman and Mateas's Tableau Machine is a system that deliberately avoids one-to-one mappings between data and display in order to engage the user in co-interpretation [48]. These examples demonstrate how users and products can work together for making sense of patterns, and the Collector products can be used as provocateurs for reflection.

CONCLUSION

In this paper we have argued that IoT design and research could benefit from a generative metaphor of product agency to describe the new affordances, challenges, and opportunities of smart and networked products. That is, these products are active agents in shaping the network of relationships they are in together with other human and nonhuman actors. They collect data, act on data, and make visible interventions in the contexts they are in based on data, which are all powerful displays of agency. We called out three types of behaviors that smart products exhibit as agents, i.e., the Collector, the Actor, and the Creator, and described some projects that employ that sort of agency in attempt to discuss the current and potential socio-cultural impact of such products.

The notion of agency, we propose, is valuable to come up with new opportunities and experiences of designing for IoT. While agency is a concept that has started to appear in the discussions in HCI to offer a pluralistic approach to meaningful interactions between all the actors involved in a context without merely focusing on human [19, 28, 35, 36, 45], we also need inquiries into the design process of such agents with regard to the relevant design methods to be used, the extent of the negotiation and delegation between the agent and the user, and the forms and behaviors that are suitable for them, which is the discussion this paper intended to start. The agency metaphor and its related taxonomy we offer hope to suggest new theoretical, methodological and practical directions for HCI research.

HCI is considered to be in its "third wave" presently, that is a shift from a narrow task-orientation to a broader concern of improving the quality of everyday experiences [8]. Smart products should have this mission as well. They already influence the rhythms and routines of our lives, which will potentially change our cultures, beliefs and preferences in the near future. An extended discussion of these behaviors and effects would facilitate enrichment and deepening of the current discussion on creating user experiences with smart products, and how to provide empowerment and behavior change through these agents.

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