6 CASTING THINGS AS PARTNERS IN DESIGN: TOWARD A MORE-THAN-HUMAN DESIGN PRACTICE

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Introduction

Understanding how we live with things, and in turn, how things come to live with us calls for methodologies that go beyond a focus on humans. As scholars, from material culture studies to object-oriented philosophies, we have come to appreciate the agency and social life of the things we make. Yet as designers, we fail to move past the blind spots of our intentions and give things a voice in doing design work. We still believe that the relationship between humans and things is unidirectional: only humans make things.[1]

In the face of such negligence, design is rapidly being widened and disrupted by the flood of data technologies under the name of Internet of Things, machine learning, and artificial intelligence. These technologies have a profound effect on the nature of products and services, enabling things to "make" things too through the exchange and processing of data (e.g., generating playlists, delegating assistance requests, arranging smart contracts). This raises urgent and fundamental questions about the way designers will participate in this expanded world of design next to the things enabled and made autonomous by data technology.

The work presented in this chapter suggests that things—as they begin to be artificially enabled to sense and perform autonomously by means of software, sensors, and actuators—may have access to perspectives and fields that we as humans do not. My argument is that casting such things as partners in design may in turn enable designers to explore new spaces and objects of design. More precisely, bringing a thing perspective to design provides a different point of view that can help us see what is not immediately apparent to human observation (because on a different perceptual scale) but also what may fall outside of our sense of relevance (because not yet accounted for). This can help problematize what we

take for granted and offer different ways of understanding what we know and what we do, humans and nonhumans alike.

So the question addressed in this chapter is not so much whether things have their own intentionality, ontologically speaking, and whether this is manifest or opaque. The question is methodological. It concerns the co-ability of things to make things next to us in ways that are uniquely artificial, and the role they can play in the work of doing design.

But designers need to creatively and extensively exercise and practice the principles of a new approach, and to take the underpinning technology seriously, before they can actually design with it (Giaccardi, Speed, and Netten 2016). And so this chapter unpacks, by means of case studies and concrete examples extending over an arch of three years, how designers and things worked together as partners and the trade-offs of more-than-human design practices.

Data Technologies and the Agency of Things

Before moving to the case studies, though, it is important to clarify what is meant by "thing" in this chapter, and what is unique about data technologies from a thing perspective.

As argued in design research after Heidegger[2] (Tonkinwise 2005) and Latour[3] (Ehn 2008; De Michelis et al. 2011), designers make things. A "thing" is not the artifact in its straight materiality but a nexus of relations that has the ability to shape ways of doing and open up new futures. In simple terms, we could think of a "thing" as the design artifact(s) plus the people (or other artifacts) that relate to it plus how they relate to it. In design, we often think of this relation as one of use, though of course "use" is a simplification of the more entangled relation we have with things, and things with us (or with other things) (Redström and Wiltse 2018).

Today autonomous vehicles; assistants such as Alexa, Google Home, and Cortana; drones that deliver purchases within minutes of placing an order; Ethereum tokens; and smart contracts are new kind of things that increasingly do business with humans and with each other (Iqbal 2018). As things become enabled through the exchange of data to see, make judgments, and perform actions that create new connections to and shape new relations with both humans and other things, we must acknowledge that increasingly also things make things.[4]

This problematizes how things take part in design next to us, professional designers and everyday designers alike, and how their uniquely artificial competence and skills, their point of view, can be brought to bear on design work in ways that broaden and balance both human and nonhuman perspectives. In a world where the complexity and scale of design problems have grown, and where distinctions between design and use, subject and object, producer and produced have blurred, the challenge of design is not a matter of getting rid of the emergent

and placing the human more firmly at the center. It is rather a matter of how to partner with things in doing design and make it an opportunity for more creative and hopefully more appropriate solutions.

Attributing agency to things is not a new concept (Brown 2001). Actor network theorists discuss the ontological symmetry of humans and nonhumans, in which material forms take on the characteristics of humans: they judge, form networks, speak, and work performatively (Engeström and Blackler 2005). Similarly, anthropologists concerned with materiality have suggested that objects are dynamic and emergent entities that contain their own life forces, energies, and histories (Appadurai 1986; Miller 2009; Hodder 2012; Gatt and Ingold 2013). More recently, object-oriented philosophy posits that things do not exist just for us (Bogost 2012); they can be many and various (Bryant 2011), but no matter their size, scale, or order, they enjoy equal being (Harman 2009). Though criticized by object-oriented philosophy for disavowing any reality external to human experience, postphenomenology too considers things' agency (or more precisely mediation) as potentially withdrawing from human understanding and perception, hiding, receding into the background of human awareness even when in use (Ihde 1993; Verbeek 2005).[5] In design, the gap between things and us is often addressed through the speculative exploration of the new forms of attachments people may develop toward things despite the gap (Di Salvo and Lukens 2011; Wakkary, Houser, and Oogjes, this volume). As shown in development psychology (Piaget 1959) and the psychodynamic tradition in psychoanalysis (Turkle 2007), this often leads to people ascribing intentionality and consciousness to inanimate objects (McVeigh-Schultz, Stein, Watson, and Fisher 2012; Marenko 2014; Rozendaal 2016), seeking similarities between the animate and the inanimate (Giaccardi, Speed, Grossen, and van Allen 2014).

This ontological gap and the design implications of the perceived intentionality of things for user experience are not the concern of this chapter. As argued in a previous publication (Giaccardi 2019), data technologies challenge design practice to respond to three emerging shifts: the *agential shift* toward the inclusion of things in design as partners, the *temporal shift* toward always-available opportunities for co-creation, and the *material shift* toward more infrastructural and fluid forms of generating and sustaining value. According to Tonkinwise (2015), this move in technology development toward platforms that bring people closer to the production and distribution of products and services had already been anticipated by metadesign (Giaccardi 2005; Busbea 2009) and postindustrial design (Cross 1981; Hunt 2005).

In the attempt to further unpack the agential shift brought about by data technologies and its implications for design practice, this chapter suggests that a useful perspective to position things in design is to consider agency in terms of their capability to co-perform, to carry out artificial performances next to people (Kuijer and Giaccardi 2018). Over the course of repeated performances, and alongside newly developed artifacts with unprecedented capabilities such as

machine learning algorithms, human and artificial minds and bodies change and learn to take on different roles in co-performance. The idea that data technologies enable things to perform according to skills different than humans had already been suggested in an earlier work (Giaccardi, Speed, Cila, and Caldwell 2016). The elaboration of this idea as a modification of theories of practice, in terms of co-performance, resonates with feminist reconceptualization of performativity, according to which agency is not something that people or artifacts have; it is the emergent result of how the world actively and continuously configures and reconfigures itself (Barad 2003; Bennett and Joyce 2013).

Considering data-enabled, algorithmic things as capable of performing practices next to people challenges and offsets the idea of humans and nonhumans as independent from each other and autonomous. Even further, considering things as capable—as I argue in this chapter—of actually "making" things next to people (because of their ability to co-perform) shifts the locus of doing design toward a fundamentally participative relation, one that is informed by capabilities and doings uniquely human and uniquely artificial.

Things as Design Partners

In unfolding a future in which algorithms and autonomous devices increasingly make things together with humans, it is imperative to move past the blind spots and unilateral arrangements of human-centered design. The idea of things as partners in design, as presented in this chapter and further elaborated through the case studies, builds on the conceptualization of the co-ability of things to make things next to us in ways that are uniquely artificial. As argued before, things make things too.

Bringing a thing perspective to design offers an alternative that harbors different ideas about human and artificial expertise and skills, and their relation. The patterns revealed through a thing perspective emerge at the intersection of the data and trajectories that things give access to and the inquiry that humans bring to it. This is not done simply to provide different and unique information about people or to offer out-of-the-box inspiration for original solutions. The aim of a thing perspective is fundamentally to problematize and enable the exploration of spaces and objects of design that are not constituted yet but emerge in response to nonhuman perspectives. As beautifully captured by Tim Ingold: "It is not, then, that things have agency; rather they are actively present in their doing… And as things carry on together, and answer to one another, they do not so much interact as correspond. Interaction is the dynamic of the assemblage, where things are joined up. But correspondence is a joining with; it is not additive but contrapuntal, not 'and … and … and' but 'with … with … with'" (2017, 13).

Considering this co-performative relation as design partnership—as the co-dependent ability to make things—moves us past the limitations of using the notion of co-performance to examine and predict analytically the practices performed by

autonomous devices after design (Kuijer 2018)[6]. And it allows us to conceive of the artificial performances of things as taking part in a fluid and unstable more-than-human design practice, which is not separate from professional or everyday design practices but entangled with them in the looping and blurring of design time and use time.

But what are these more-than-human design partnerships for? By exerting the ability to access trajectories unattainable to human observation and make design proposals, potentially contesting our worldview, things contribute a different perspective and unique insights that enhance, complicate, and even challenge those of humans (Giaccardi, Speed, Cila, and Caldwell 2016). Considering things as design partners is different from looking at them as collaborators in achieving human originating purposes (Kaptelinin and Nardi 2006; Rozendaal 2016; Grudin 2017). But a partnership with things requires engagement, and practice. It assumes to "spend time" with things and "work together with" them. It requires sustaining collaborative processes with things and among things that offer different ways of understanding what we know and what we do (Gunn and Donovan 2012).

Different ways of understanding allow for reframing and reconfiguring social and material relations, and are inherently performative and transformative. Engaging with things for an extended period of time and reflecting on what we usually take for granted open up and articulate spaces and objects of design that were previously unattainable. It troubles distinctions between subjects and objects, producers and produced, and in so doing supports ways of understanding and designing that take place *after* design (at use time), but also *with* and *beyond* the design work at project time.

Three Cases of More-than-Human Design Partnership

In this section, I describe three cases in which designers and things have worked together as partners and examine the emergent character of their partnership. A final reflection on what such partnerships may add to human-centered design practices will be offered at the end. The cases are based on projects conducted at the Connected Everyday Lab, Delft University of Technology between 2015 and 2018. The projects employed different techniques to include a thing perspective in the process of doing design, from life logging to bespoke sensors and open libraries for data visualization to expert machine learning.

Each case is unpacked along two axes. First, I examine what things "have seen": what trajectories and data worlds the things enlisted as partners in the project enabled the designer(s) to access through artificial sensing and data analytics. As introduced in earlier work (Giaccardi, Cila, Speed, and Caldwell 2016), the expression "data worlds" is used here instead of "data" to consider the arrangements among people and things, and things and things, and thus the ecosystems in which

these are imbricated. It is access to these horizontal relations and arrangements, and the unique insights generated about such ecosystems, which things bring to bear on the design partnership through what we have referred to in other work as "thing ethnography" (Giaccardi, Cila, Speed, and Caldwell 2016). Then, I examine how a thing perspective may have "problematized" the design space: whether things unsettled the designer's assumptions; demonstrated the problem to be more uncertain, more nuanced, or more complex than originally assumed or regarded; and how a more-than-human partnership configured within the process of sensemaking and framing. "Framing" is used here to refer in design terms to the result of "sensemaking," that is, to the outcome of the "constant process of acquisition, reflection, and action," which is fundamentally based on the perspective or point of view of those participating in doing design (Kolko 2010). In design research, framing is conceptualized as the hypothetical way of looking at the problem (Dorst 2015a, 25), the talking into existence of "assumed-to-be-real facts" or "facets of things" that do not exist yet (Kolko 2010). As such, framing configures the scope of design work (Kolko 2010) and can mutate what was initially envisioned as a desired outcome (Dorst 2015a), helping to think of problems (and thus solutions) in always new ways. Ideally, in a world of increasing complexity and blurring of the design disciplines, the creation of frames should painstakingly embrace the "unknown nature of the outcome" (Dorst 2015a). Attributed conventionally to expert design practice, sensemaking and framing are opened up in this chapter to the perspective of things and their performances. It is through more-than-human sensemaking and framing that design achieves its intention.

Lastly, I will briefly mention the objects of design that emerged out of the partnership with things within each project, ranging from speculative demonstrators to product concepts.

Envisioning Culturally Sensitive Innovation for Taiwanese Smart Mobility

Taiwanese use scooters to carry out many of their daily activities, especially in highly populated urban environments. It is a complex relationship that Taiwanese have with their scooter in everyday life (Lin 1998; Lai 2010). Scooters are not just a means of transport but intimate companions of daily practices, from shopping at the street market to transporting goods and picking up children. Scooters impact how Taiwanese perceive and imagine the world.[7] Blind to this reality, smart mobility has so far mostly focused on energy consumption and efficiency optimization.[8] In the thing ethnography that we conducted on the use of scooters in Taipei as part of a project in collaboration with the National Taiwan University of Science and Technology,[9] we focused instead on revealing the imbricated web of relations that develop around scooters in Taiwanese everyday life. Our goal was to envision culturally sensitive forms of smart mobility for the Taiwanese context.

Trajectories and Data Worlds Accessed through Artificial Sensing and Data Analytics

Six scooters were equipped with intelligent cameras and sensors and enlisted as partners to collect data in the field and help generate insights from a thing perspective. By enabling scooters to artificially "sense" and "see," we hoped to gain insight into their social life, and specifically into the cultural idiosyncrasies of the relationship that develops between scooters and Taiwanese in everyday life. In order to access this data world, we instrumented scooters for artificial sensing with a time-lapse camera and a repurposed smartphone for recording GPS tracks, for a data collection period of three days. The time-lapse camera was attached to the scooter's handle, facing the scooterists, and was set to take a photo every ten seconds. Without the shutter button being controlled by a human, as shown in early studies (Giaccardi, Cila, Speed, and Caldwell 2016), the time-lapse camera would have captured both recognizable and hidden social practices around the scooter and the broader systems of relations of the scooter with other things. The smartphone with the app for recording GPS tracks was used instead to collect data on the scooter's daily trajectories and other geographical data such as location and acceleration. As opposed to the domestic objects instrumented in earlier work (Giaccardi, Cila, Speed, and Caldwell 2016), the scooter is highly mobile and may reach a speed that hinders the efficacy of lifelogging techniques. Finding the right placement for the camera was tricky on a scooter. But by complementing lifelogging with geographical data, we enabled the scooter to "see" and "sense" also the more dynamic and eluding elements of its relationship with Taiwanese everyday life.

Knowing that scooters in Taiwan are used very differently depending on the lifestyle of their owners (Lin, 1998; Lai 2010), we then invited six people with different jobs and different lifestyles to take part in the thing ethnography with their own scooter (Figure 6.1). Human participants included: a student, an office worker, a motorcycle enthusiast, a housewife, an insurance agent, and a plumber. Nonhuman participants included: Pudding, Jog100, Moon, Fighter125, Breeze125, Vino50.

Once data were collected, they were organized and presented in a format conducive to role-playing. The goal was to limit the efforts needed to approach data as an analyst and facilitate instead immersion into the social life of the scooter. Six well-trained professional actors were invited to engage with the data, role-play one of the six scooters, and "speak" on its behalf when interviewed by the designer. The rationale for this choice was to develop a technique that would help the human designer empathize with the always-withdrawing inner life of things. The assumption was that professional actors are well positioned to speak for the nonhuman, as they are trained to bring people and things to "life" in a highly relatable way. The technique we invented is called Interview with Things (Chang, Giaccardi, Chen, and Liang 2016).

Pudding and Mrs. Cheng.

Jog100, Mr. Lin and Mrs. Wu.

Moon and Mr. Chen.

Fighter125 and Mr. Liu.

FIGURE 6.1 Portrait photos of participating scooters and scooterists. Photos by Wen-Wei Chang.

Videos edited from the same perspective as the time-lapse photos were one of the formats in which data were presented to professional actors. These videos, recorded from the point of view of the scooter, were particularly useful to help actors immerse themselves in the dynamic experience of being a scooter. Actors showed great potential to decenter human perspective. During the interviews, the actors not only "felt what the scooter felt" but "thought and reflected in a scooter's way." For example, one actor implied her difficulty understanding some "too human" words. Another actor also mentioned that, for her as a scooter, all things can be categorized into things that don't move (e.g., buildings), things that move by themselves (e.g., humans and street dogs), and things moved by other things (e.g., scooters and cars). In all these cases, the actors skillfully immersed themselves into being a thing, bracketing their human-oriented way of thinking. By thinking and reacting as scooters, actors helped broaden our understanding and imagination about the scooter as a thing.

One of the insights generated from a thing perspective, for example, was that the function of the scooter is dependent on the speed of the scooter. Depending on their speed, scooters in Taipei become carts for grocery shopping at the street market, temporary addresses to which to deliver flowers, or benches for chatting with your friends in the parking lot. In the ideation phase this contributed to the speculative concept where the scooter's tailpipe, when used at full speed, is used as a heater for a variety of improvised uses on the road, from ironing to warming up foods and drinks, which work and make sense within the social and cultural norms of Taiwanese everyday life.

More-than-Human Sensemaking and Framing

Scooters are notoriously low cost and easy to modify. As described in studies of material culture (Lin 1998; Hebdige 2001; Lai 2010), scooters are often subject to creative appropriation along their material and functional dimension. The handles can be arranged as a rack to hold drinks, and the backseat can be used as storage to contain goods. Designers have learned from this and incorporated some of these elements in the scooter as product features. However, the thing perspective brought to bear on the exploration of a possible design space for smart mobility has revealed that there is more to the arrangements between Taiwanese, scooters, and environments than material and functional factors. The unique social relations and meanings that develop between scooter and scooterist are an equally important element in Taiwanese everyday life. In other words, Taiwanese value scooters not only because of their usefulness for commuting and delivering goods but also because of the diverse and dynamic meanings the scooter acquires in the way it helps build and maintain social connections. The tension between the intent and expectations of the designer (focused on material and functional features) and those of the user (concerned instead with the social quality of the scooter) was expressed several times by scooters during the interviews. For example, the

small scooter revealed that while the "double (sometimes triple) carries" is not considered proper use by its designer, the social quality of physical proximity expressed by this misuse is instead highly valued by lovers and family members.

As social qualities and material affordances of a product (including its functionalities) go hand-in-hand, making sense of the collected data together with things in the interviews helped understand that the dynamic and unique relationship that develops between scooter and scooterist according to different usages and in different situations should be considered an important element of the socio-material arrangements that constitute Taiwanese's everyday life.[10] The importance of a scooter's social qualities and how these translate into usage, how social qualities, material affordances, and creative misuse are imbricated in the Taiwanese context through everyday practice, is ignored instead by mainstream smart mobility as currently framed.

Interviewing scooters was not only valuable to make sense of the collected data. It was also an inspiring intervention for the designer to speculate what is like to be a thing within specific socio-material arrangements. By encountering and empathizing with a convincing nonhuman actor, the designer gained rich and novel inspiration. The interview was not just a solo performance by the actor but a cooperative speculation by the designer and the "thing" (as enacted by the actor's performances). To help the actor understand the thing and decenter momentarily from a human perspective, the interviewer also needed to decenter his human-centered logic. For example, instead of using terms such as "personal relationship" in the interviews, he used the term "scooteral relationship" to help consider the scooter as a thing and not just a product. Through the interviews, the designer was able to defamiliarize and engage in an imaginative design partnership with the always-withdrawing nonhuman. By making sense and speculating through role-playing, the design technique used in this project was a sincere invitation for both humans and nonhumans to engage and understand each other and explore together culturally sensitive forms of smart mobility for the Taiwanese context.

Emergent Objects of Design

The outcomes of this project included a series of speculative scooter portraits and a speculative set of accessories for smart scooters. The scooter portraits were commissioned to an illustrator and directly based on the transcripts of the interviews with things conducted with the actors (Figure 6.2). These portraits served the designer as an intermediate object to organize insights and move toward his final concepts.

The final concepts were prototyped and exhibited in Taipei in 2017 as a speculative set of three accessories for smart scooters aimed to foreground scooter's social qualities in a playful manner: pipe heater, sound generator, and red light pointer & atmosphere meter.

FIGURE 6.2 Scooter portraits based on the transcripts of the "interview with things" conducted with professional actors. Image courtesy of Wen-Wei Chang.

Pipe heater (Figure 6.3) is an open-ended device for scooterists to reuse the heat produced during a ride, for example, preparing a warm lunch during a working commute. As a concept, the pipe heater broadens the margins of resourcefulness of the Taiwanese scooter in everyday life by inviting creative appropriations around one's own lifestyle and daily social interactions.

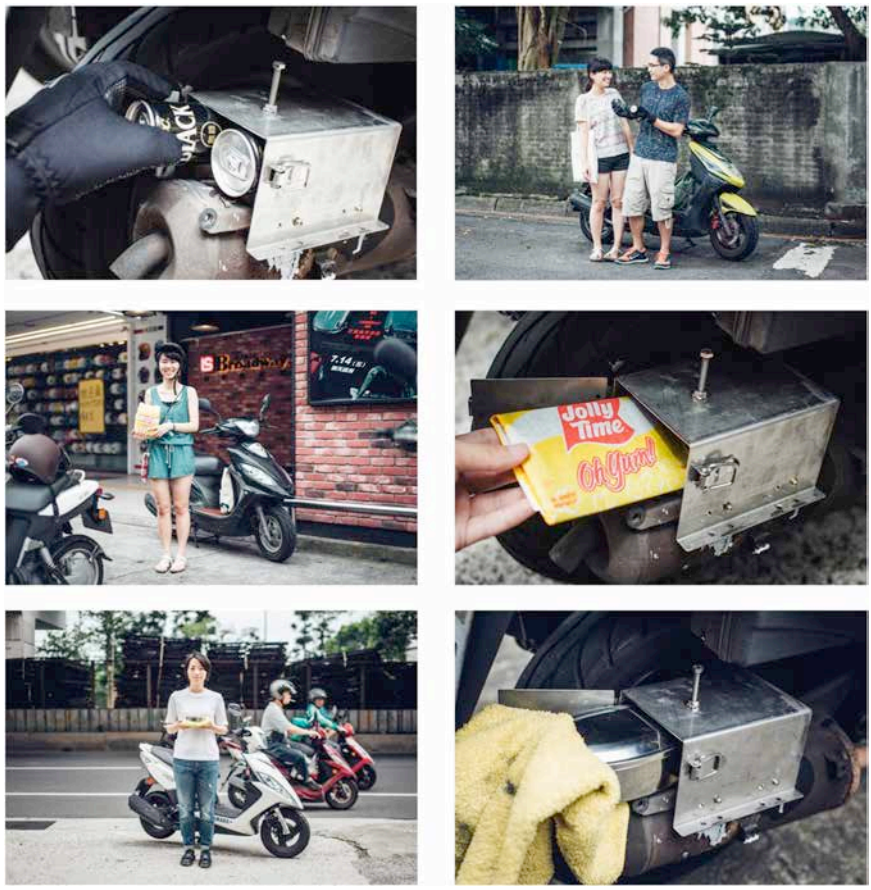

FIGURE 6.3 Pipe heater is the speculative concept for an open-ended device that reuses the heat produced during a ride for personally and socially meaningful activities (e.g., warming up food, sharing a hot drink). Photos by Wen-Wei Chang.

Sound generator (Figure 6.4) is a smart audio component producing a sound out of a scooter's engine that is personalized according to a scooterist's riding patterns, for example, an aggressive and high-pitched sound for a racer and a prim and proper sound for a gentle scooter rider. This concept enriches people's ability to express themselves through the scooter. In the final exhibition, five sound artists were invited to create unique sounds for the six scooters in the scooter interviews, to help the audience imagine how the generated sounds might sound like.

Red light pointer and *atmosphere meter* (Figure 6.5) are smart dashboard components designed to bring people physically closer. The red-light pointer is attached below the original speed meter pointer. Rather than telling the current speed, the red-light pointer indicates the "recommended" speed to encounter more traffic lights, and more opportunities of hard braking and physical contact. The atmosphere meter is a pointer attached below the original fuel meter pointer.

FIGURE 6.4 Sound generator is the speculative concept of a smart audio component for a scooter's engine that is personalized according to one's riding patterns and needs for social expression. Photos by Wen-Wei Chang.

FIGURE 6.5 Red light pointer and atmosphere meter are speculative concepts of smart dashboard components designed to bring people physically closer and create intimacy. Photos by Wen-Wei Chang.

This pointer does not indicate the amount of fuel in the tank but visualizes the current social atmosphere on the scooter. As a concept, these smart dashboard pointers aim to encourage and facilitate social and intimate interactions on the scooter.

Stimulating Creative Dialogues in Democratized Manufacturing

Over the past decade, technologies for computer-aided technical drawing (CAD) and rapid prototyping and manufacturing (CAM), in combination with online platforms for the distribution of creative projects such as Etsy and Instructables, have revived interest in self-made, do-it-yourself (DIY) products. The phenomenon referred to as the Maker Movement has promoted a further step towards a democratization of design, as technology effectively puts control over geometry, materiality, and assembly into the hands of a new pool of makers. However, design encompasses more than control over the object itself; it also involves an understanding of the object in its context. This type of appropriateness between an object and its context cannot always be engineered, because it varies in different situations of use and under different circumstances. Production tools alone are not sufficient for the democratization of design. The potential of modern-day DIY lies far beyond hundreds of differently styled iPhone cases to choose from. In this project,[11] we focused on how rapidly spreading Internet of Things systems for the home might help makers discover new applications of their crafting and making skills. Our goal was to understand how to introduce a thing perspective in the creative process of the DIY practitioner and help them open up their design space.

Trajectories and Data Worlds Accessed through Artificial Sensing and Data Analytics

The project enabled seven makers to deploy Wi-Fi-enabled sensor modules and conduct thing ethnographies of their homes, with the intent to learn more about their context and open up the design space for home improvement. Compared to the previous case, the challenge of this project was to work with nondesigners, unfamiliar with the general principles of contextual inquiry and primarily driven by the need to express themselves and learn new skills (Atkinson 2006; Kuznetsov and Paulos 2010). A total of seven makers took part in the project. In this chapter, I will discuss the second study of this project, which used bespoke sensors and open data visualization libraries.[12] In this study, we asked four makers to think of what they wanted to make, and in what ecology of other artifacts and practices their object would have ended up. Then, in discussion with participants, we hacked some of the artifacts in this ecology by enabling them to collect sensor data from a thing perspective and access their domestic data world. The assumption was that this would have revealed additional design opportunities. The study concluded

with a creative session, in which the makers first discussed their process and findings and then were asked to swap their data and design for each other.

In a couple of cases, makers were able to come up with a good sensor placement, discover something they did not know, and generate solutions for preventing cooking smells or reminding partners to take their shoes off when working late at home. However, in trying to address nondesigners unfamiliar with sensors, the project failed to help makers partner with things to generate unexpected insights that could open up novel design spaces for home improvement. Relating graphed sensor data to real-life phenomena was problematic for our participants. Anticipating what kind of data they would receive from the sensors, and owning the process of which sensors to use and where to place them, was even more problematic. Equally complicated for the makers was to move past (or through) the sensitivity and sampling rate of the sensor. It was notable that most participants came up with design ideas that revolved around automation. Examples are curtains that open automatically when the sun rises, based on the light sensor, or an alarm that would sound when housemates would start cooking without opening the window. Instead of using things to access previously unattainable trajectories, the makers seemed eager to incorporate the sensors in their solutions, expressing a tendency to what Amram (2016) describes as "automation fixation." Makers experienced fixation also in relation to what to expect from the sensor data, which Amram (2016) refers to as "phenomenon fixation." For example, once the constant relation between room temperature and one of the maker's shoe cabinet was interpreted as signifying the presence of people in the room, the maker became blinded to every other possible meaning of the data.

However, in the concluding session in which makers were asked to swap data and design for each other, a different kind of sensemaking emerged. Whereas makers had a difficult time making sense of their own data and accessing the broader data world in which the domestic object under examination was (or could be) imbricated, swapping data and designing for each other took away these barriers by removing expectations and fixations. For example, in the case of the shoe cabinet, the constant temperature was not considered a failed measurement by the others. Instead, it gave way to the out-of-the-box idea of a terrarium where to farm reptiles for leather.

More-than-Human Sensemaking and Framing

While there is something to be said about the importance of technological literacy for being able to capitalize on artificial sensing and data analytics in a creative process, this project suggests that even in the case of nondesigners, it may be possible to find ways to partner with things. The project involved participants who varied in terms of their involvement and interest with the sensors, and our findings made clear that the more engaged and knowledgeable the maker was, the more he could engage a "creative dialogue" with things. However, it is in the concluding

session during which makers collaborated to make sense of the data that they were able to use the results of their thing ethnographies to enhance communication and creativity within the convened DIY community and problematize the original scope of their projects. Questions like "Why did you put that sensor there?" proved to be excellent sensemaking starters.

In speaking of their placement, and making otherwise tacit design considerations explicit, things counteracted makers' fixations and frames of reference and revealed new design opportunities.

Emergent Objects of Design

MakeDo (Figure 6.6) is a speculative design concept for fostering creative dialogues between makers and things in democratized manufacturing created by Amram (2016) that embodies the findings of this research and promotes a distributed type of the design partnership with things. Elements of the design address recurring issues observed in makers' thing ethnographies. The main difficulty in casting things as partners in makers' workflow was that ethnography (and contextual inquiry more in general) is an unfamiliar component of the DIY practice. The observable consequences of this unfamiliarity are a fixation on automation projects and phenomenon fixation.

MakeDo can be shortly described as a platform for DIY recipes where data collected from things are an integral part of the making process. On the *MakeDo*

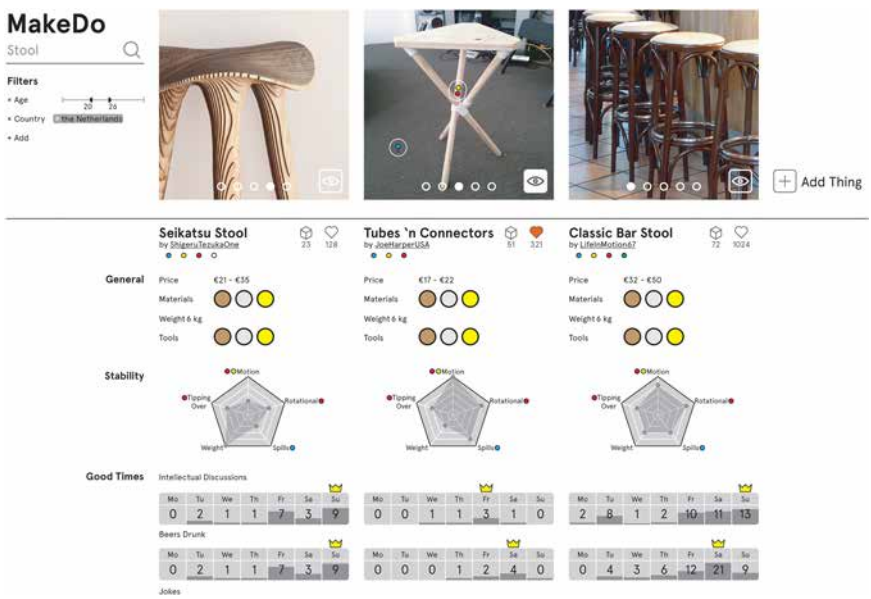

FIGURE 6.6 MakeDo is a speculative platform for DIY recipes where data collected from things are an integral part of the making process with the goal to foster creative dialogues between makers and things in democratized manufacturing. Image by Tal Amram.

platform, community members do not only share the "making" of an object (its DIY recipe) but also its "doing" (its data). Instead of a linear process from author to platform via the DIY recipe, recipes that are shared on *MakeDo* also include sensor data about the use of the thing generated and collected by its multiple physical instances. Conventionally, DIY recipes are created, published online, downloaded, made into a physical artifact, and eventually used. *MakeDo* closes this loop by feeding use data back into the recipe.

For data sharing to be so intimately interwoven into the making process, the design concept envisions radically compact and simple sensors called "knots" (Figure 6.7), which could be bought in the hardware store or ordered online to the exact specifications and quantities of the project the maker may be

FIGURE 6.7 Example of the executed DIY recipe of a stool with sensing knots from the MakeDo community. Photos by Tal Amram.

undertaking. As single knots are inserted into a physical artifact, they begin to form a small local network of cooperative sensors and exchange their data with the *MakeDo* platform.

Community members can then publish and share not only the blueprint of the DIY recipe, including placement of the knots, but also a plugin for data aggregation and visualization. Using different plugins, a maker could then compare several DIY recipes of stools based on requirements such as the measured stability or the amount of jokes inferred through data.

The feedback that the thing can now send to inform its own blueprint blurs the traditional dichotomy between design time and use time. This poses interesting opportunities for parametrically designed objects or procedurally generated designs. Collaborating algorithms from several plugins could map what design decision has what effect on the use of an artifact, and the resulting information will give makers new source of inspiration. This is the very essence of *MakeDo*: combining design time and use time into a cyclic process. There is no fixed optimum to strive toward (at least not enforced by the platform), but an endless string of discoveries to be made.

Empowering Older People to Age Resourcefully in the Connected Home

In products designed especially for older people, the inventiveness and resourcefulness of elderly are often underestimated in favor of designs mistakenly assuming older people to be helpless and frail (Giaccardi, Kuijer, and Neven 2016). In the Resourceful Ageing[13] project, we focused instead on what older people can still do and the strategies they put in place to creatively cope with their ageing skills. Our goal was to find out how to design connected products for elderly people that can improvise in use and thus remain appropriate to a large variety of situations.

A collaboration between industrial design, computer science, social sciences, and industry partners,[14] this project used a combination of machine learning and ethnographic fieldwork to research and prototype designs that can support the everyday practices of resourcefulness of elderly people.

Trajectories and Data Worlds Accessed through Artificial Sensing and Data Analytics

Because resourcefulness is a dispersed practice that is difficult for the human eye to observe and capture (Kuijer, Nicenboim, and Giaccardi 2017), we invited five households of people in between sixty-five and seventy-eight years of age as well as their domestic objects to take part in the thing ethnography. Human participants included four females and one male living independently at home, two of which with their spouses. Nonhuman participants included doors, fridges, chairs, and remote controls as well as unique "things," such as spider stick and rope on stairs.[15]

These were selected together with human participants through a combination of sensitization techniques and ethnographic fieldwork[16] (Figure 6.8).

We deployed a bespoke wireless sensor network infrastructure and instrumented with artificial sensing capabilities eight objects per household, for a total of thirty-two domestic objects. Over a period of two months, we collected 133 MB of sensor data from three of the participating households. Sensors sampled when objects moved in space as well as environmental data.[17] We then used unsupervised machine learning techniques to discover structure from data and assign meaning to it. The intention was to ask our nonhuman partners about routines developed within temporal patterns of day and night, weekday and weekend, which might suggest practices of resourcefulness too dispersed for a human observer (including our human participants) to discern.

The resourcefulness witnessed by objects in elderly homes and captured by human observation looked like the magnet in Figure 6.9: a thing, a very mundane entanglement, central to the resourcefulness of one of our elderly—who uses the magnet to keep together small objects she would not be able to grab when flat on the table.[18] But what the algorithms that we developed for this project were able to see is the probability of a thing being handled at a particular time of day and the clusters of things being handled at the same time: a hint to the possibility that these things may be used together often as part of a dispersed yet established practice of resourcefulness, which escapes human observation or normative sense of relevance. By moving from the analysis of raw temporal events (Figure 6.10) to the interpretation of their clustering at an abstract level (Figure 6.11), we did

FIGURE 6.8 Resourceful Ageing: Selecting nonhuman participants via a combination of sensitization techniques and ethnographic fieldwork. Photo by Iohanna Nicenboim.

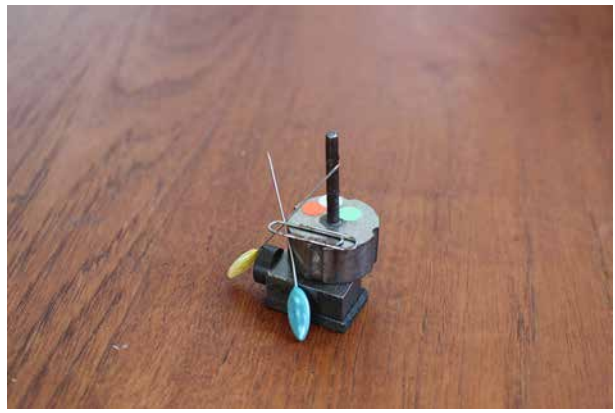

FIGURE 6.9 Resourceful Ageing: Participating magnet, central to the resourcefulness of one of the human participants. Photo by Iohanna Nicenboim.

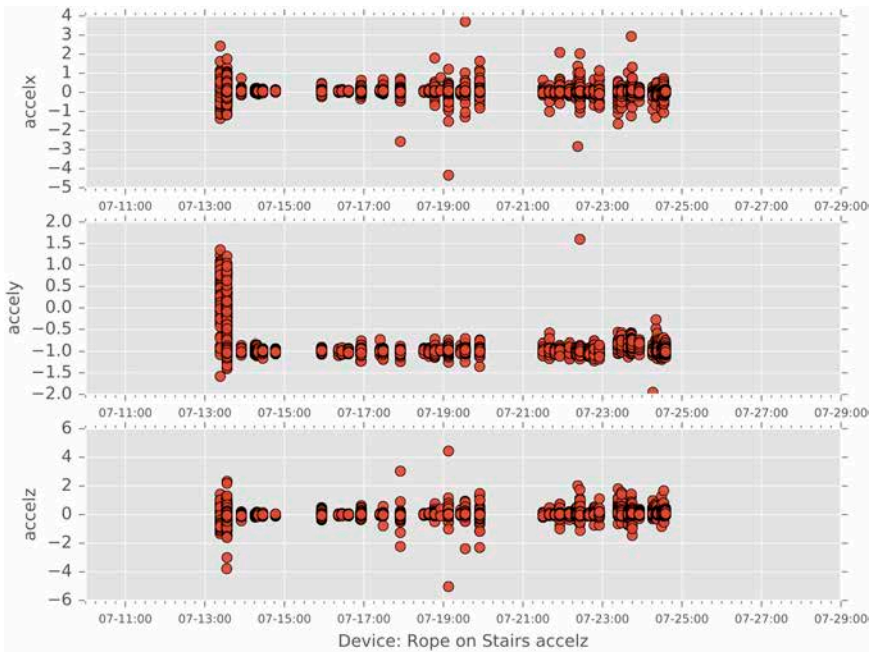

FIGURE 6.10 Resourceful Ageing: Analysis of raw temporal events concerning co-usage of instrumented objects (i.e., relations among nonhuman participants). Data visualization by Yanxia Zhang.

not expect our nonhuman partners to be able to reveal practices of everyday improvisation that are inherently human. Our original hypothesis concerned whether the collected data were able to reveal unusual usage of things, and whether the clusters identified through machine learning analysis were consistent with the

FIGURE 6.11 Resourceful Ageing: Visualization of machine learning interpretation of the co-usage of objects, from high to low probability of occurrence. Data visualization by Philips Design.

strategies observed by humans in the field or actually suggesting new strategies. The expectation was that, through sensors and algorithms, things could give us access to previously unattainable trajectories of use and reveal patterns that could help us ask interesting questions to our human participants.

When nearly a year after data collection we managed to take the patterns generated by machine learning back to our human participants, we indeed obtained new insights about resourcefulness that would have been difficult to obtain otherwise. One of the strategies of resourcefulness that we identified as most prominent in older people was finding your own, unique solutions to challenges: doing things your own way, for your own reasons. These unique solutions deviate from commonly agreed ways of doing. For our participants, they included, for example, eating dinner at their daughter's home or microwaving a meal (both revealed by the absence in the patterns of the fridge around dinner time) or having breakfast in front of the TV with the grandchildren (revealed by the simultaneous use of remote control and fridge in the morning).[19] Identifying these forms of resourcefulness is tricky, because there is no one commonly agreed way of doing that applies in all situations. There is also some form of embarrassment that goes with solutions that participants enact and yet perceive as "uncommon," "strange," or somehow "out of the norm." With this evidence on the table, participants were nudged to reveal a little more information about their everyday lives that might be considered slightly deviant from what is "normal" or expected.

There were also new examples of resourcefulness that came up in the follow-up interviews and not in the data at all. Just talking about resourcefulness—whether triggered by the machine learning patterns or something else—will bring out more examples and knowledge about it. For example, we learned how strategies of resourcefulness—in this case a clever way of getting the coin out of the shopping cart with reduced force in fingers—are eagerly shared among age peers.

More-than-Human Sensemaking and Framing

In this project, the configuring of a more-than-human sensemaking and framing was meant to be the result of a continuous feedback loop between what humans can see and what things can see, where "seeing" here is understood in terms of both what can be observed and how this is interpreted. As speculated in Cila, Giaccardi, Caldwell, Rubens et al. (2015), ethnographic research and machine learning can be complementary. It is difficult for a human ethnographer to see patterns at large scales, whereas a machine (and the computer scientist writing the code) cannot see which patterns are meaningful. This is essentially a question of what inputs matter and why, in a certain situation. We assumed that by looping qualitative data (from human ethnographers in the field) and quantitative data (from thing ethnographers via machine learning), we would have learned something new about how older people use things in everyday life. Unexpected patterns of use would have emerged within the data that was streamed through the interaction between people and things, and things and things, and these would have helped designers identify opportunities for resourcefulness. Though useful insights were eventually generated in the follow-up interviews conducted at the end of the project, the design partnership that configured throughout the project took on a different character.

Confronted with technological limitations and misalignments in the collaborative process,[20] we came to realize that a much more interesting role for our artificial partners in this project was not so much about expanding the processing of the data beyond human capacity and skills and identifying unusual usage patterns within the data. It was instead a more generative role: to suggest probabilities that might constitute openings for different kinds of strategies (and values and norms) to be generated and exchanged. Rather than revealing patterns as "assumed-to-be-real facts" that designers could use for inspiration (like in the first case study), the probabilistic model used for the machine learning analysis was opening up patterns as "possibilities" for objects of design that those taking part in the design process could all contribute to construct, from professional designers and older people to algorithms.

This understanding began to shape in the first phase of the project, when a thing perspective was casted upon the ethnographic fieldwork in elderly homes, in the attempt to identify everyday objects to instrument with sensing capabilities. In this process, driven by human ethnographers but decentered in perspective, we observed that everyday objects become relevant to dispersed practices of resourcefulness when configured in fluid and dynamic arrangements, which

change according to the situation of use. These arrangements are constituted not only by spatial proximity (as by positioning in relation to each other, and location within the home) but also by temporal proximity (as in sequences, and when they are used together).[21] We could then observe links between different practices and how resourcefulness is constructed at the overlap of these practices, as objects move across arrangements and become some-thing else. A broom with a piece of tape attached to the stick becomes a handy spider killer, a newspaper moved to a daughter's mailbox becomes a message to communicate well-being, and a metal bar arranged under the bed at night becomes a defense tool to feel safe. Not only materials are reconfigured, but also skills, meanings, and the links between them.

Because taking a thing perspective helps minimize human judgments about what situations may be relevant, memorable, or representative, artificial partners are well suited to reveal misuse, variation, and deviations from norms.[22] Including the perspective of domestic objects in the preliminary ethnographic fieldwork and workshop sessions with older people invited us as humans to explore how an idea of variation could be materialized. We began to conceptualize connected technologies as resources themselves, capable to adapt to changing circumstances in a variety of ways and complement aging competences dynamically. This helped us step away from a focus on the intended use of the technology to be designed and challenged us to explore design as an ongoing process that does not end when the product is released to the market.

These considerations informed the choice of techniques used in the design of the algorithms as well as the way in which machine learning was performed. From both domestic objects and people, we learned during fieldwork and sessions that in order to shift from designing assistive products to designing for resourceful aging, we had to fundamentally step away from solving older people's problems to supporting their improvisational strategies.

For a design partnership to work, machine learning similarly had to step away from its ethnographic role in support of design and embrace the more interventionist and transformative role of future-oriented processes (Smith and Otto 2016). By modeling probabilities and opening up possibilities for new strategies to be experimented, and new values and norms to be established, we realized that machine learning could enable and encourage older people to improvise new strategies. The partnership that this project configured was not so much about identifying design opportunities or alternatives; it was instead about creating possibilities for actualizing always new resources.

Emergent Objects of Design

We decided to pursue these possibilities for empowering older people to be as resourceful with connected technologies as we have observed them to be with their physical domestic objects at home. *Connected Resources* (Figure 6.12) is a series of small, connected devices and an online service that adds digital capabilities to

older people's everyday strategies of resourcefulness. Conceptualized as resources (Nicenboim, Giaccardi, and Kuijer 2018), these devices are designed as a family of recombinant sensors and actuators, meant to emulate in physical form and digital functionality the material affordance of the mundane things used by older people in their everyday strategies of resourcefulness. Sensors and actuators can be used alone or together. Once in use, they begin to learn from the way in which they are combined and deployed (Figure 6.13). Via the service (a mobile app) older people

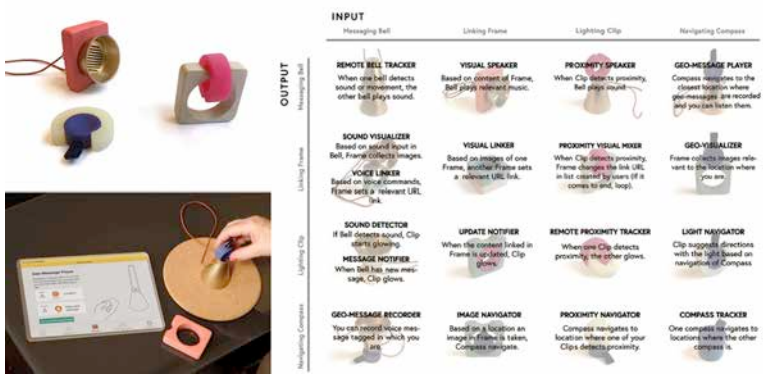

FIGURE 6.12 Resourceful Ageing: *Connected Resources* is a family of sensors and actuators and an online service for adding digital capabilities to older people's everyday strategies of resourcefulness and empowering them in their relation with care technology. Images by Masako Kitazaki.

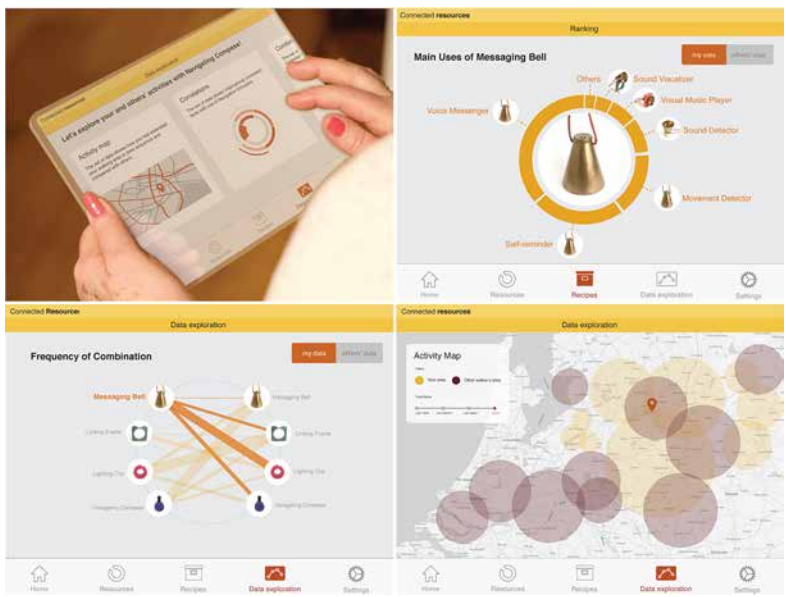

FIGURE 6.13 Resourceful Ageing: Once in use, *Connected Resources* learn from the way in which they are combined and deployed.

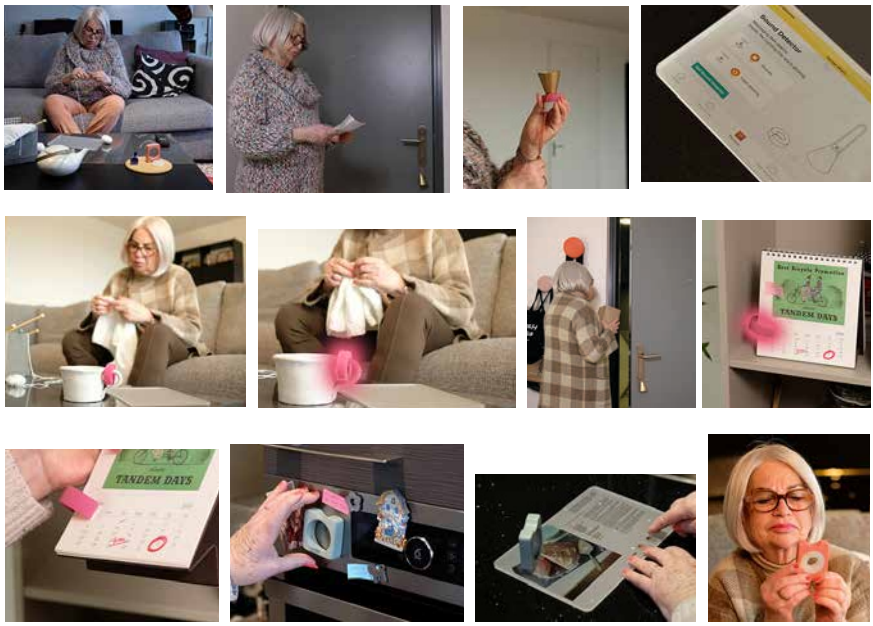

FIGURE 6.14 Resourceful Ageing: Scenario of a resourceful arrangement created by an older woman waiting for a delivery and with a mild hearing impairment, where one object visibly lights up when another remote object detects sound. Movie by Andreas D'Hollandere.

can establish connections between the devices, reflect upon their own strategies, and share their solutions with others. Figure 6.14 is the scenario of a resourceful arrangement created by an older woman waiting for a delivery and with a mild hearing impairment, where one object visibly lights up when another remote object detects sound.

In *Connected Resources*, the design work is not done by the designer alone. Machine learning algorithms are at work too. Possible affordances and performances of the technology are surfaced and arranged into resources, as algorithms work together with older people to empower them in their strategies. Casting things in design meant here for the designer to envision what dimensions of the artifact should stay open, and which instead should be closed so to enable the algorithm to continue the design work at use time.[23] This focus on resourcefulness opened up a design space for interactions between people and things, and all the relations in between (things and things, people and people), which steps away from the prescriptive frameworks of care technology for older people and invites instead creative engagement with both materiality and social norms (in this case, norms concerning what are personally meaningful and socially acceptable ways of complementing one's aging skills; what in the project our human participants often referred to as "normal").

Toward a More-than-Human Design Practice

Experimenting with how we can engage with things, and balance both human and artificial perspectives, is vital to shape future design practices. But what happens when things stop working for us and start working next to us?

As suggested by the cases examined in this chapter, designers can certainly partner with things to expand their capabilities and use "the richness of the artificially broadened context" (Dorst 2015a, 26) to understand the deeper issues that are at play in a situation. Fueled by current developments in the field of artificial intelligence (from increasingly widespread task-specific machine learning algorithms to neural networks), present data-driven design practices emphasize an idea of human augmentation that traces back to Engelbart's 1962 foundational paper "Augmenting Human Intellect." The idea of "a human-machine hybrid built to do more than any person or computer could accomplish alone" is underpinning statements among practitioners of a coming to an end of the era of human-centered design (cf. Milan 2017).[24]

In this chapter, I instead suggest that the partnership between designers and data-enabled, algorithmically powered things should be understood as more than just chasing hard data for making critical decisions in sensitive domains or than working together toward a human-originated, fixed common goal. Fully understanding the assets and benefits of such a partnership requires acknowledging that the uniquely artificial capabilities of things may question our goals by enabling us to access data worlds we have never accessed before, see what we could not see, and call attention to what we thought was marginal or irrelevant. This calls us to stay open to be challenged and surprised. It also requires acknowledging that the design work of contributing a nonhuman point of view does not end with a descriptive account.[25] As suggested programmatically in Giaccardi, Speed, Cila, and Caldwell (2016), *the implications of a thing perspective for design concern fundamentally new alliances for making sense, framing and bringing into existence "things" that do not exist yet—which is at the essence of design work*. It is therefore the hypothetical way of looking at the world in which both humans and nonhumans participate, which configures the scope of design work and generates futures. This was the case when writing social futures for Taiwanese smart mobility or rewriting assistive technology as resource, not aid for our aging future.

As highlighted by the cases, identifying, articulating, and assessing trade-offs represent a unique challenge in pursuing desirable more-than-human design practices. For example, balancing how to set up instrumentation for artificial sensing and analytics in a way that enables you to find out what you did not already know, and yet is carefully crafted to gain access to supposedly relevant data worlds, is a common trade-off we have encountered in our own practice. Trade-offs are the most basic characteristics in design (Simon 1996). As argued

in Fischer 2018, trade-offs are often characterized and conceptualized as binary choices. However, exploring the middle ground between these endpoints may help future designers gain a deeper understanding of what balance to strive for when there are no decontextualized sweet spots. Rather than an exclusive focus on human perspectives only, the value of examining trade-offs in more-than-human design practices is grounded in the key objectives this chapter had grappled with. We briefly summarize them here for convenience.

1. Take time and effort to engage with things despite their withdrawing from human perception and understanding

At the beginning of the chapter, I discuss the agency of things and the role they may play in design. At the core of my argument is the idea that things make things too. Enabled by data technologies, things not only perform social practices next to people; they make things. Compared to approaches in design pointing to the ontological gap between things and us, this feminist reconceptualization of performativity as "making" emphasizes engagement over withdrawal. In so doing, it shifts the locus of doing design toward a fundamentally participative relation. This new partnership assumes to spend time with things and painstakingly work together with them to offer different ways of understanding what we know and what we do, humans and nonhumans alike, and ultimately reframe and reconfigure our social and material relations.

2. Balance perspectives informed by capabilities and doings uniquely human and uniquely artificial

I use three case studies to show how balancing uniquely human and uniquely artificial capabilities and doings is of the essence for a more-than-human design partnership. My argument is that this act requires casting things as partners in design, in their being performatively imbricated in how the world actively and continuously configures and reconfigures itself. Ideas of human augmentation or humans and things as independent of each other do not find place in this proposal. As illustrated in the case studies, human and artificial partners have different capabilities and doings (e.g., in unveiling mobility ecosystems, supporting democratized manufacturing, or empowering older people's resourcefulness). These different capabilities and doings enable them to participate in the work doing design with different perspectives, configuring the scope of design work, and embracing the unknown nature of the outcome from different points of view. In a more-than-human design practice, human and artificial partners both participate in sensemaking as well as framing.

3. Account for how things may take on different roles before, during, and after project time

The three different case studies in this chapter also illustrate the spectrum of possible roles things may take in the work of doing design. As implied by the idea of

things making things, the central argument here is that the artificial performance of things is not separate from professional design practice. As partners in a more-than-human design practice, things can perform and do design work next to professional designers before, during, and after project time. In the case study about Taiwanese smart mobility, things helped generate insights; they played an explicit role until the designer began to produce design ideas.[26] In the case of the Resourceful Ageing project, things instead both helped generate insights and were conceptualized in the final design as capable of sustaining older people's resourcefulness over time.

4. Problematize the design space in ways that productively enhance, complicate and even challenge what we know and what we do (or how we do it)

Considering things as design partners is different than looking at them as collaborators in achieving human originating purposes. By exerting the ability to access trajectories unattainable to human observation and potentially contesting our worldview, things contribute a different perspective and unique insights that enhance, complicate, and even challenge those of humans. Instead of reinforcing existing blind spots and dominant biases, a thing perspective should instead problematize the design space: unsettle a designer's assumptions, demonstrate the problem to be more uncertain, more nuanced or more complex than originally assumed or regarded. All case studies well illustrate this point, showing for example how social relations and meanings in Taiwanese smart mobility are as important as material and functional factors, or how being resourceful with technology means to older people being independent from technology too.

5. Enable the exploration of practices and objects of design that are not constituted yet but emerge as appropriate and desirable

Considering things as partners can help us see what is not immediately apparent or may fall outside of our sense of relevance. By problematizing and potentially contesting what we take for granted, a thing perspective opens up a perspective on the emergent that goes beyond the descriptive and emerges at the intersection of the trajectories that things give access to and the analysis that humans bring to it. In a more-than-human design practice, the aim of a thing perspective is fundamentally to enable the exploration of practices and objects of design that are not constituted yet but emerge as appropriate and desirable in response to more-than-human sensemaking and framing.

Conclusion

In a world in which we come to live with things, and things with us in ways that blur distinctions between producer and produced, subject and object, us and them, design must go beyond a narrow focus on humans.

> *Things become, as does our knowledge of them. It follows that our primary focus should not be on the ontologies of things but on their ontogenies, not on philosophies but on generations of being. This shift of focus has important political ramifications. For it suggests that things are far from closed to one another, each wrapped up in its own, ultimately impenetrable world of being. On the contrary, they are fundamentally open, and all are participants in one indivisible world of becoming. Multiple ontologies signify multiple worlds, but multiple ontogenies signify one world. And since, in their growth or movement, the things of this world answer to one another, or correspond, they are also responsible. All responsibility depends on responsiveness.* (Ingold 2017)

Casting things as partners in design, bringing their artificial capabilities and nonhuman perspectives to bear on how problems are framed and addressed, shifts the emphasis in design research concerned with data technologies from the functionality of the designed artifact to the intentionality of design work and its trade-offs. This more-than-human turn offers designers an avenue to reshape human-technology relations in the widening world of design practice. Intrinsically vibrant and transformative, the more-than-human design practice proposed and experimented here is fundamentally defined by the characteristics of its process and the responsiveness of those engaged in the process.

Acknowledgments

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Notes

1. Anne-Marie Willis (2006) has made a strong argument that things also make humans in her work on ontological designing, and similarly Tony Fry (2012). This perspective, however, is not typical of "ordinary" designers.
2. Heidegger (1967).
3. Latour and Weibel (2005).
4. A connected health device, for example, is not only a product service that helps people track and monitor their diet. It is also part of broader processes of preventive care, and it may find itself in a new industry, such as the insurance industry, connected horizontally to products that could never have been connected before (Neese 2015).
5. To clarify the philosophical distinction between post phenomenology and object-oriented ontology on matters of "withdrawal," it is important to note that

in post-phenomenology, the idea of withdrawal is understood "as only one of many potential ways that technological mediation shapes the contours of a user's overall experience" (Rosenberger and Verbeek 2015, 23). Post phenomenologists also investigate "what stands forward in addition to what withdraws, what demands attention, what remains on the fringes" (ibid.) within a given human-technology relation. On the contrary, object-oriented ontology assumes things (more precisely "objects") to exist independently of human experience, and ontologically not exhausted by their relations with humans or other objects (Harman 2002).

6 Co-performance as elaborated in Kuijer (2018) confines artificial agency at use time.

7 As argued by James J. Gibson (1979), mobility is one of the cornerstones of humanity. From crawling to walking, from the saddle to the hover board, means of movement and transport change the ways we live and the relationship among people, things, and environments.

8 The Taiwan-based company Gogoro's Smartscooter™, for example, uses over eighty sensors to continuously learn people's riding patterns and suggest customized ways to save energy.

9 *Interview with Scooters* is a graduation project by Wen-wei Chang conducted at National Taiwan University of Science and Technology under the joint supervision of the author, Lin-Lin Chen and Rung-Huei Liang (cf. Chang 2016).

10 For additional examples and further insights on the dynamic, situated nature of the relationship between Taiwanese scooters and scooterists, and associated meanings, see Chang et al. (2016).

11 *Stimulating Creative Dialogues Between Humans and Things* is a graduation project by Tal Amram conducted at Delft University of Technology under the supervision of the author and Jan Willem Hoftijzer (cf. Amram 2016).

12 For details about the different studies and a complete report of their findings, see Amram (2016).

13 *Resourceful Ageing* is a project funded by STW under the Research Through Design program (2015/16734/STW), http://www.resourcefulageing.nl/. The project ran from June 2016 to June 2018, and it involved four senior researchers, three postdocs, and a range of technical assistants and master students.

14 Project partners included Delft University of Technology (coordination), Eindhoven University of Technology, Avans University of Applied Sciences, and Philips.

15 This list is nonexhaustive. For a complete list, cf. Hung and Zhang (2018).

16 For more details about the design research techniques used in this phase of the project, cf. Nicenboim et al. (2018).

17 For technical details about sensor data collection and machine learning analysis, cf. Hung and Zhang (2018).

18 For additional examples of resourcefulness captured through ethnographic fieldwork, cf. Giaccardi and Nicenboim (2018).

19 For more details about the results of the "closing-the-loop" interviews, cf. Giaccardi and Nicenboim (2018).

20 For a discussion about the limitations and challenges of interdisciplinary research projects in the space of data-enabled design, cf. Giaccardi and Nicenboim (2018).

21 For an in-depth discussion of spatial and temporal arrangements in elderly homes and additional examples, cf. Giaccardi and Nicenboim 2018.

22 Please be noted that misuse is used here provocatively, from the perspective of the professional designer's original intention (Brandes, Stich, and Wender 2008). At use time, there are no misuses, only variety of use (Hui 2017).

23 For more details on the dimensions of openness and closure in the design of Connected Resources, and how these are necessary to support both "variety of use" and "variety in use," refer to Kitazaki (2018).

24 In the field of design for healthcare and social well-being, where entire populations are targeted, the use of AI is seen as going hand in hand with the chasing of hard data for making critical, evidence-based design decisions.

25 Contemporary anthropological approaches engaged with design work clearly posit that the potential of anthropology is not in presenting a solution to a design context, as not all problems have simple answers (Dourish 2006). Greater impact is achieved in shaping the way that a phenomenon is understood in the design process, with those involved in the design process. The field of design anthropology brings this further and concerns itself with collaborative future making, with a strong commitment to intervention and transformation of social realities (Smith and Otto 2016). Our work in thing-centered design approaches has always been aligned with these positions.

26 We could argue that the designed accessories for smart scooters do turn the scooter into a thing capable to continue playing a role in design work, for example, by enabling the scooter to tune its performance in order to shape a distinct relation to users. But the designer in his conceptualization of a more-than-human design practice did not explicitly intend this.

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