The Data Hungry Home

Defining, Populating, Feeding, and Beyond

Matthew Lee-Smith, Tracy Ross, Martin Maguire

Loughborough Design School, Loughborough University, Loughborough, Leicestershire, United Kingdom, M.L.Smith@lboro.ac.uk, T.Ross@lboro.ac.uk, M.C.Maguire@lboro.ac.uk

Fung Po Tso

Department of Computer Science, Loughborough University, Loughborough, Leicestershire, United Kingdom, P.Tso@lboro.ac.uk

Jeremy Morley, Stephano Cavazzi

Ordnance Survey, Southampton, Hampshire, United Kingdom, Jeremy.Morley@os.uk, Stefano.Cavazzi@os.uk

ABSTRACT

It's said that the pleasure is in the giving, not the receiving. This belief is validated by how humans interact with their family, friends and society as well as their gardens, homes, and pets. Yet for ubiquitous devices, this dynamic is reversed with devices as the donors and owners as the recipients. This paper explores an alternative paradigm where these devices are elevated, becoming members of Data Hungry Homes, allowing us to build relationships with them using the principles that we apply to family, pets or houseplants. These devices are developed to fit into a new concept of the home, can symbiotically interact with us and possess needs and traits that yield unexpected positive or negative outcomes from interacting with them. Such relationships could enrich our lives through our endeavours to "feed" our Data Hungry Homes, possibly leading us to explore new avenues and interactions outside and inside the home.

CCS CONCEPTS

• Human-centered computing~Interaction paradigms • Human-centered computing~Interaction devices

KEYWORDS

Human Computer Interaction, Human Data Interaction, Smart Homes, Internet of Things, Interaction Design Theory

1 Introduction

> "Digital products – especially those for the home – do not have to reproduce our culture's preoccupation with work, consumption and entertainment. Instead, technology can encourage more exploratory engagements with life, providing evocative resources with which to discover new perspectives on ourselves and the world around us." [28:5]

As in-home devices approach true ubiquity and are decreasingly seen as objects that should simply fulfil utilitarian or efficiency related needs and aspirations, there is an opportunity to explore alternative and experimental manifestations of, and interactions with, these devices. Three core theoretical pillars currently inform in-home ubiquitous computing (UbiComp), calm computing, engaging experiences, and sustainable homes [47]. The inceptive work of creating engaging experiences in UbiComp emerged as a critique and furcation of Weiser and Brown's vision of calm UbiComp [94] by Rogers [75]. Rogers calls for a proactive form of UbiComp that augments human intellect and enables them to "perform ever greater feats, extending their ability to learn, make decisions, reason, create, solve complex problems and generate innovative ideas" instead of diminishing the number of tasks required by humans to perform [75:411]. Rogers also argues for reviving the "excitement of interaction" that had been suppressed by the notions of calm technology [75:418]. This paper presents a theorisation and conceptual exploration of various in-home technologies that can be understood as existing within, or constituting, a home that requires data as a form of sustenance, the Data Hungry Home (DHH). The DHH draws upon both the calming and engaging pillars with a focus on creating engaging interactions that forge relationships between people, the data they (can) generate, the home, and its contents. In doing so, the DHH seeks to gain a foothold in the nurture or care driven aspects of the human condition currently occupied by animate objects, such as house plants and cats. The DHH seeks to form symbiotic relationships with humans by providing personality-imbued data-driven interactions through the consumption of varied data from the outside world. This paper represents the first step towards describing and creating a theoretical foundation for the DHH with the hope that, as the ideas develop, further design research contributions will help expand and refine our understandings of the nature of in-home UbiComp. It does so by creating and exploring a narrative and lexicon of collecting metaphorical "food" in the form of data, feeding it to the DHH, and eliciting an output/interaction, in four sections. The first provides an initial definition of the DHH. The second investigates ways in which the DHH can be populated by looking at the possibilities for buildings and devices. The third delves into possible "food" data for the home as well as ways of collecting it. Finally, potential needs, traits and outcomes that could be attributed to members of the DHH are explored. Together these sections seek to enrich the interaction and experience with the DHH and its contents enabling people to form bonds and relationships with the technology.

2 Defining

The archetype of the DHH fundamentally describes a classification for certain homes, or their contents, that do not simply collect, create, use or transmit data but are hungry for it and require routine feeding for them to function. The hunger can be a need, craving, desire, dependency, reliance, even an addiction or simply seeking enough sustenance to plod along. The concept of the DHH alters the paradigm and shifts the hierarchy in the human-machine (or even machine-machine) relationship as it requires one component to maintain the other with regular feeding with curated and specific data in order to receive the desired outputs/interactions (Figure 1). It also sees the "members" of the DHH instilled with a certain amount of personality and agency that permits them to respond to their environment, communicate feelings and, quite macabrely, the ability to "die". The term "Data Hungry Home" emerged initially as a grouping of concepts generated through a critical practice process in the preliminary stages of a research through design process by Lee-Smith et al. [55]. Currently, "smart" homes/devices unflinchingly procure, communicate or store data for use, are accessible at a moment's notice and fulfil our every request (if they can). Members of the DHH, on the other hand, will require a more symbiotic form of relationship. You scratch my back (with data/knowledge) and I will scratch your back (with an interaction), so to speak. This definition lends itself to prevailing technology phenomena, such as the Internet of Things (IoT) as the interconnectivity with other technologies (e.g. wearables and other in-home devices) which could facilitate activities such as conversations, trading and feeding. As with any framework that has the potential to create and handle (personal) data, anonymity and security must be considered. However, the data in this scenario need not follow the conventions we have come to expect with the near-permanent internet or mnemonist self-tracking tools. For example, the data can exist locally (i.e. only within the connected devices), be collected in a low-resolution manner, and/or be ephemeral in nature as it is *consumed* by the DHH, erasing it from existence. Aspects of the DHH, in many ways, already exist. The base concepts are an advance on various in-home projects such as the work undertaken and compiled by the Interaction Research Studio and others coined as "The Curious Home" [13,30]. Their work describes a variety of pieces of furniture [30] and "threshold devices" [32] that use various forms of data (from within and outside the home) to provide ludic interactions and situate and enrichen the understanding of the home and what surrounds it. However other "smart home" approaches have also been drawn upon. Jensen et al. [47] present three different smart home personas based on the desired characteristics identified by households. These are "the helper", "the optimiser", and "the hedonist" [47:4]. In the context of the DHH, the hedonist is the most relevant, described as creating a living space that is desirable to be in. They argue to achieve this the hedonist smart home must be nourishing, beautiful, unique and playful. Jansen et al.'s discussion of the hedonist home also ties in strongly with their exploration of *Hygge* in the house, which promotes cosiness and companionship, amongst other concepts [48].

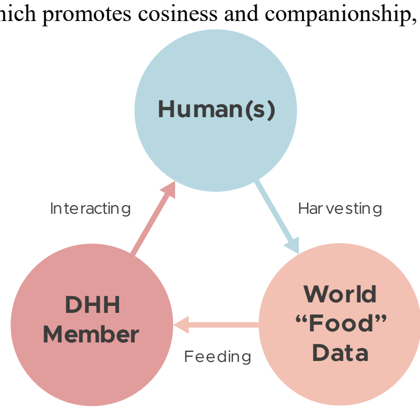

Figure 1 The human, data, member interaction loop of the DHH.

3 Populating

In order to make a home hungry for data, it must be designed and built to be able to receive and consume data or filled with artefacts (furniture, products, etc.) that are able to do the same. This section delves into populating the DHH with buildings and devices and examines informative theories and examples relevant to each. There are a plethora of design approaches, stances and theories that can be used to inspire the population of all parts of the DHH. These include design for slowness and reflection [21,33,34,36,63,68,69,81], ludic design [22,27,90], uncomfortable interactions [14], rich interactions [26,66], animism [3,58,59], tangible user interfaces [41,42,54] as well as many others.

3.1 Buildings

There are many elements in an architectural structure that we interact with regularly, whether it is opening a window, shutting a door or switching on a light. Extending the reach and interactivity of space with technology has been explored and considered for decades. Some of the early and pivotal work in the realm of tangible interaction and the “tangible bits” movement [42] featured considerations of rooms (and therefore, logically, houses) that could interact with and display data [43,95]. The work considers how data could be communicated in a subtle or ambient manner that enabled the viewer to subconsciously pick up on and be aware of the it. Here, data is displayed through “ambient media” such as sounds, airflow and shadows. This is considered to be one of the early cases of ambient displays [71], however, the approach was more focused on the architectural elements than dedicated ambient display devices, referred to at the time as “ambient fixtures” [95]. These dedicated devices will be discussed further at a later point in this section. As research has progressed, ambient technology has been integrated into building architecture and used in behaviour change [76,83]. Others look at the culmination of the overlap of interaction design, UbiComp, architecture, urban design and the building industry and economy, known as human-building interaction [65]. More experimental forms of architecture look at how data, in this case, physiological data, can impact their size and form [44,79] or vice versa [45]. In the context of the DHH there are two main areas for consideration, the first being how can the structure of the home be designed to integrate the required technology, and the second being in what ways can the main elements of a building (walls, windows, doors, etc.) interact with people without creating safety or control issues (such as doors or windows leaving themselves open because of a lack of food/data).

3.2 Devices

Members of the DHH can also take the form of devices, artefacts or products. These are perhaps the most suitable for widespread application as they are easily installed into any household, effectively retrofitting a DHH, and perhaps have the largest scope of conceptual and design flexibility as they are not constricted by as many requirements as a house. There are several different classifications and concepts for or relating to, devices that are used in the home. Peripheral [10,11] and ambient displays [71], for example, communicate information primarily through the peripheries of our attention instead of the centre. Whilst the initial concept of the peripheral display (of which the ambient display is considered a subset [71]) is linked to calm computing it can be used to actively engage with people. For example, the Physikit project [39] demonstrates how users can interact and change the data displayed by ambient display devices. Alternately, the Ambient Birdhouse uses an ambient display to help its users learn about common birds in their area [84]. Devices are also able to take advantage of data physicalisation [38,46], which involves converting data into physical/tangible outputs. Bookly, for example, is a device that communicates to its user their relation to the completion of their reading goals by changing its height, rotation and light output [50]. Outside of these larger areas of research, other forms of devices have been explored. For example, Berger et al. recently discussed their exploration of idiosyncratic smart objects for the home including an inflatable cat that fills itself when its real cat counterpart is meowing at the door [16]. In addition to smaller devices, furniture can be another medium to explore interactions (with data) [30,37,40,52,61,90]. Furniture is also a natural location to explore tangible interaction as we naturally touch or sit on them. Considering these and other data-dependent artefacts, devices of the DHH should seek to display data and interact with people in a varied and engaging manner.

3.2.1 Himilco

With these devices in mind, we posit a classification of an in-home artefact, *periplus*, that we are currently exploring as part of our research. Periplus as a term relates to navigation, voyaging, and sailing and can be used to describe a documented list of ports, a voyage or journey (notably around a coast) or an account of a circumnavigation or journey. It is in the third part of the definition that is of particular interest as a potential metaphor for an in-home device that is an account, repository or archive of adventures beyond the home (perhaps to collect food for the DHH). Currently, a periplus named Himilco (after the Carthaginian navigator), that uses approaches such as data physicalisation and ambient displays to physicalise data, is being investigated. Himilco is a reconfigurable “data object” [85] and will use an approach known as composite physicalisation [35] where it will have multiple “dimensions” which it can use to display data, such as changing its height, colour or orientation. This device could be used to communicate or playback food/data in a direct or ambiguous manner, potentially prompting self-reflection [91].

Similar approaches have been taken to the physicalisation of activity that stimulates reflection on past activities and consideration on the execution of future ones [6,78,88,89]. Stusak's work on 3D printed activity sculptures, for example, demonstrates the potential for reflection on running activities as well as considering how the next activity might be different in order to manifest alternatively shaped sculptures [88:171]. In this case, the use of the term periplus would be attributed to the machine and system (i.e. the 3D printer and PC) that generated the sculptures, not the sculptures themselves. Non-3D printed approaches have also been used with concepts such as Loop which uses a set of rings to communicate an individual's daily step count relative to a goal [78]. In this case, the Loop artefact is a periplus. Of the examples of peripli found, there is a notable focus on activity data perhaps due to the increasing popularity and ease of access to data through products such as Fitbits. Himilco, on the other hand, will use data such as temperature, humidity, altitude and colour collected by its human companion to feed itself and produce its physicalisation.

4 Feeding

A hungry house (of hungry artefacts) needs food in the form of data. How, and with what, do you feed it/them? In this section, we unpack the nature of the possible interactions around the concept of feeding and harvesting data for the DHH. We do so by first taking a brief look at the types of "foodata", a term that combines *food* and *data* as well as referencing the term and concept of "desiderata", something that is needed or desired. Foodata encompasses a diverse range or groups of available (data) sustenance, similar to how humans eat a varied diet. Following on from this, ways in which foodata can be passively harvested for the home will be discussed. Finally, active forms of harvesting will be suggested. It is within this discussion of active harvesting that the concept of Carver, a wearable device specifically designed to harvest bundles of foodata is presented. It is through these devices that the members of the DHH are able to connect with, and be fed by, the outside world.

4.1 Foodata Groups

It would be easy to plainly state that "the DHH will feed on various types of data" and move on. However, we will briefly describe the data that has been considered. In the paper thus far, activity data, such as heart rate, blood pressure and step count, weather data, such as temperature, atmospheric pressure and humidity and luminosity have been alluded to as possible foodata sources. Further inspiration can be taken from sources such as the data collected in geographic information systems (GIS) such as in the work of See et al. [80]. In the discussion of the sources of volunteered geographic information (VGI), they suggest biodiversity, crime, environmental (air quality, noise, etc.) and feature mapping amongst others. In addition to this, data such as WIFI/Mobile strength, surface textures, colour, electromagnetic wave strength and transcripts are all also viable foodata. With such a variety of data available, it is possible to imagine different groups of foodata (much like the food groups) that can sustain devices in different ways, i.e. a healthy diet of data.

4.2 Passive Harvesting

Passively collecting food for the DHH could function in a number of different ways. For example, connecting to certain types of online data, such as Twitter data or smart city data streams through application programming interfaces (API's). However, this would require little maintenance and, as such, is somewhat outside the main purpose of the DHH. On the other hand, other quasi-passive formats can be explored, such as sensors or devices that are placed outside the home and used to generate data for individuals and communities. Sethu-Jones et al., for example, discuss a project that involves the placing of four devices in a community garden [82]. The devices were equipped with luminosity sensors, cameras and a means to connect the devices to a tablet to access a "situated" or "overview" perspective of the devices and collect/view the generated data. Alternatively, the My Naturewatch project employs small camera devices that, when placed outside, can capture pictures of animals [29]. These devices can be accessed via WIFI to collect the photos or from an SD card that can be extracted. These projects demonstrate devices that passively store data but require some form of human interaction to collect, view or harvest those data. They are effectively "planted" in an outdoor context, allowed to "grow" with data and later "harvested" when they are ripe with data. This concept could be expanded to suggest an almost agricultural relationship with data. Devices (e.g. "data tomatoes") could be designed to be planted out in the wild, tended and grown, harvested and fed to the DHH. The difference in value here, from actively harvesting the foodata is the prolonged engagement with, and nurturing of, foodata for the home.

4.3 Active Harvesting

Active harvesting of data is a much more engaged undertaking. This form of harvesting will require the user to seek out data in an involved interaction with the outside world. This would entail the user taking some form of collection device, such as a wearable or smartphone, with them on the excursions. Unlike the connotation of planting, growing and harvesting suggested in passive harvesting, active harvesting evokes thoughts of a form of data foraging/hunting or data botany/conchology. On the one hand, data can be sought out in a simple pragmatic or primal sense in order to collect a certain quantity, at any point, for the purpose of bringing it back to the DHH. This is the foraging or hunting approach. On the other hand, data can be carefully curated and selected to create a refined collection. This collection can form a creative expression through how the DHH responds to the data or a meticulous catalogue of unique foodata. Finally, as was briefly eluded to previously, the harvesting and feeding, as well as other, relationships in the DHH do not need to be exclusively human-machine in nature. In fact, they can take on an entire machine to machine structure with the human acting as overseer or maintenance provider. In this context, devices can be designed to venture out into the wider world and collect foodata. A similar interaction can be seen in projects such as PotPet which features a small four-wheeled robot that is able to drive itself and its plant outside for sun and water as well as communicating to a human that the plant requires watering [51]. The ability to view the interaction of machines collecting data for one another whilst maintaining the overall operation of the system could prove as pleasant and mesmerising as keeping fish.

4.3.1 Carver

In this vein of thinking, we propose the use of the term *vasculum* as a possible class of wearables that can be used for active harvesting. In botany, a vasculum is a container used to collect botany samples. This type of wearable/carriable has existed for centuries and has appeared in many shapes, sizes and materials [2,12]. The variability in its design, connotations of sampling, collecting and storing and the relation to the explorative and informative practice of botany is why the term piqued our interest. We use the term to refer to the type of wearable that represents a counterpart to our periplus. The vasculum we designed, called Carver (after George Washington Carver, an avid botanist), combines a GPS and climate sensor with a colour sensor to create a wearable that collects passively and actively. The GPS and climate sensor will collect constantly whilst the colour sensor must be manually activated when an interesting colour is encountered. Carver, as a concept, has its origins in explorative navigation, specifically ways in which wearable/carriable devices can help us explore, and therefore potentially collect data from, space without the exact prescription of where one is going and/or how to get there. Specific inspiration can be found in projects such as Wandertroper [64], which uses a microphone and synthesising app to facilitate exploration by sampling sounds from the outside world, altering them with the synthesiser settings, and playing it back to the user through headphones. Another example, which isn't technically recognised as a navigation device, is the Datacatcher [31]. The Datacatcher concept was initially a carriable device to present and bring focus to matters such as socio-political issues and the power and breadth of big data. However, due to the location-based nature of the information, the device inadvertently prompts its users to explore their local space. What ties these two devices together is their ability to "augment" their user's capacity to engage with contextual data (in these cases sound and demographic data). Carver takes a similar approach and whereas with the other devices, one may alter their paths through space with thoughts such as "that sounds interesting" or "I wonder what life is like over there?", Carver could lead to thoughts including "I like that colour" and "today is unseasonably cold, better get outside". Whilst we consider the entire device to be a vasculum, the various sensors can be metaphorically seen as harvesting tools such as sickles or secateurs and the case, specific circuitry and code that deals with collecting, processing and storing the data to be the "true" vasculum. Both the Himilco and the Carver are members of the DHH, although they serve different purposes. However, peripli and vasculums are not exclusive to the DHH, they can exist as other devices with alternative objectives (Figure 2).

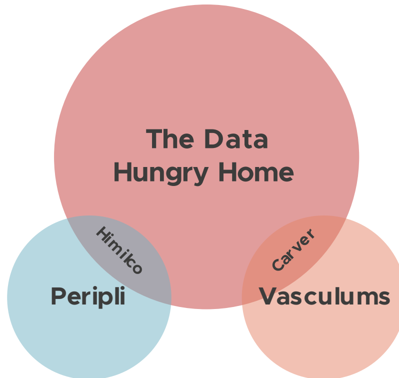

Figure 2 The relation of the DHH to peripli, vasculums, Himilco and Carver.

5 and Beyond

By defining the DHH, populating it with various forms of buildings or devices and conceiving ways in which these members can be fed, the fundamental basis of the DHH has been established. To further develop these concepts and to embody the interactions between users and the DHH with weight and consequence, the addition of certain needs, traits and outcomes have been considered. It is the implementation of these factors into the functionality of members of the DHH that will permit them to appear more responsive, individual and alive (Figure 3). These enriched and nuanced interactions could lead to the formation of long-lasting relationships and bonds [7,93] as each member will effectively be "push[ing] our Darwinian buttons" [92:3]. This section attempts to create a semantical categorisation of various concepts considered within the context of the DHH. The first relates to various possible needs, as in what inputs or statuses each member could require to continue functioning. The second pertains to various traits the members could possess. These traits will impact how the entities will respond and consider inputs in terms of (dis)satisfying the needs. The third describes possible outcomes relating to the (dis)satisfaction of these needs in relation to the needs and personality of the entities. If certain internal criteria are met, different outputs or interactions are manifested. At this juncture, it is not vital to accurately distinguish between the three categories but to simply begin the discussion of what could be either a need, trait or outcome.

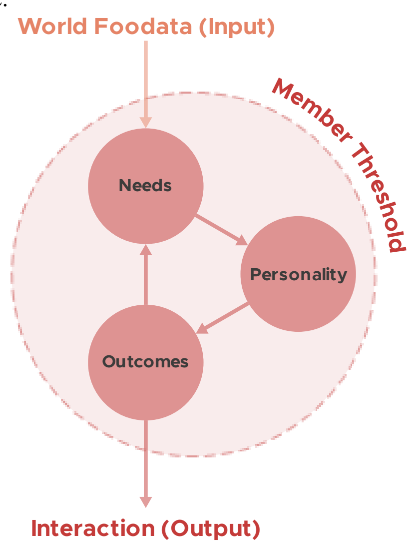

Figure 3 How a member of the DHH responds to inputs and generates outputs.

5.1 Needs

At the core of the DHH paradigm is catering to, and the satisfaction of, needs manifested by each member. The preliminary need of members of the DHH is the supply of enough foodata but other needs are possible. This section briefly probes and describes some of the possible needs of the DHH.

5.1.1 Foodata - Feeding Routines and Balance

As previously described, elements of the DHH require foodata. However, depending on the nature of the member, it may be able to sustain itself on a modicum of foodata for weeks/months (such as an alligator or cactus) or require several feedings a day (such as a human baby). As such, a great diversity in the interaction frequency with the DHH can be explored by experimentation. However, members should be fed with a given regularity and if a member is able to consume various types of data (see the omnivorous trait) then the member may also require a balanced diet.

5.1.2 Sleep - Timing and Duration

Humans, other animals, and even plants (to some extent) sleep. This is a vital state, as it allows us to process what has happened during the day. The concept of sleep isn't unheard of in HCI, computers for examples can sleep or hibernate, however the closest approximation to a machine sleeping is the digital downtime process (such as that of the smart assistant) which effectively locks the user out of the devices between certain times of the day. In these situations, the devices aren't engaging in a different activity, such as dreaming or recovering. Sleep could be one of many other needs designed into members of the DHH. While sleeping, the member enters an alternate state where functionality is limited, and new activities can emerge (such as dreaming) and disturbing this state (i.e. waking it up) can have consequences. The time of day and duration of required sleep will vary from member to member.

5.2 (Personality) Traits

With the diversification of artificial intelligence, internet of technology (IoT) devices and interaction concepts and theories, the existence of objects with personalities is ever increasing. However, what personalities can, or should, devices have? Personality, and similar social concepts such as anthropomorphism or behaviour, are a large focus in robotics (e.g. [25,49,56,60,62,73,74,96]). However, the idea of other devices, notably IoT devices, having personalities, and how that is undertaken, has also begun to gain interest. Pieroni et al. [70] propose "Affective IoT" as a framework that endows IoT products with feelings or personalities which impact how they behave in response to external and/or networked data-stimuli. Their preliminary work explores four personality types: explorer, researcher, celebrity and politician, each having their own formula and weighting for dealing with what they experience. Each personality generates different valence (positivity/negativity of an emotion) and arousal (intensity of the emotion) values based on the stimuli. The end result is a numerical fluctuating emotional state of the devices, although, in the context of their study, it doesn't impact what the devices do. Spadafora [86] and Spadafora et al. [87] suggest personality as a design method by employing metaphors of stereotypical personality traits (such as social, sombre, suspicious and calm) in the design of interactive product behaviours. This approach has been used to imbue drones with different personalities such as "the big boss" (a brave drone) or "the detached philosophers" (a grumpy drone) [19]. The various personalities, in this case, affect aspects of the drone's behaviour such as how it flies, what altitude it flies at and which specific actions it can execute. Annett et al. explore imbuing devices with more "paranormal" traits in their work [8]. They present several concepts of haunted devices that subtly (and spookily) interact with the humans in the room as well as offering a "haunted design framework" [8:1335]. In this context, we discuss various personality traits the members of DHH could embody as well as the concept of personality seeds. The type, variety and complexity of these, and other, traits will further render members of the DHH more individual and personal to each household.

5.2.1 Degrees of Neediness - Baby, House Plant, Pet Rock

A simple way of understanding how members of the DHH can have degrees of neediness is to imagine a hypothetical "spectrum of neediness of things in the home" (see Figure 4) having at one end a human baby (which is very needy) and at the other a pet rock (that requires no attention at all). There are, of course, several different examples between these two extremes, such as house plants (ranging from the delicate orchid to the hardy cactus) and animal pets (including dogs, cats, fish, snails, etc.). Neediness or being needy as a concept and term aren't alien to the world of robotics [17,20] and design [3,9]. However, in the context of traits, neediness can be seen as a governing trait that affects the presence and strength of other traits. For example, if a DHH device has a high degree of neediness, it could require a very specific diet, require more than one feeding a day or gain traits such as neophobia.

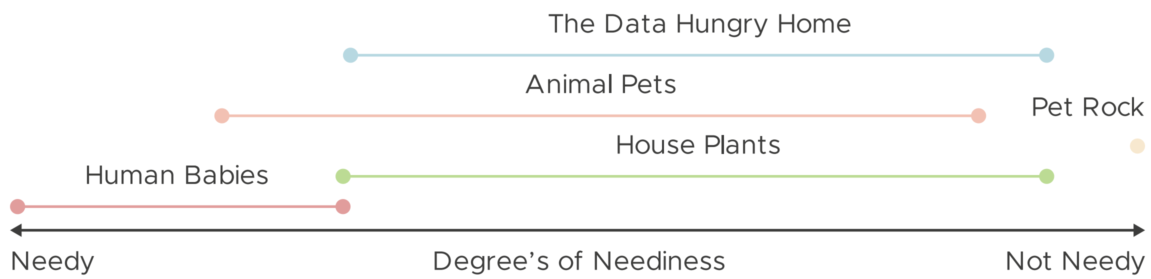

Figure 4 The spectrum of neediness of things in the home.

5.2.2 Consumption - Omnivorousness, Pickiness, Neophobia, Abstemiousness and Greediness

Our plants, pets, babies and selves all require specific types of food. The more complex and/or personality-imbued the entity we are feeding, the more specific the diet might be. We can simply water a plant, but humans require a diverse diet. Humans are omnivores, surviving by consuming a variety of foodstuffs. If this trait was integrated into a member of the DHH it would be able to be sustained on multiple data sources. Himilco, for example, is an omnivorous device, consuming various foodata sources in bundles. However, devices could also exist that survive on a single type of data. Building upon this, we all have personal tastes and occasional "pickiness" towards certain foods. Some don't like vegetables and others, fish. How might we reimagine concepts such as a picky eater or getting bored with the same meal every day? In this context, members of the DHH might be provided with the ability to reject certain types of foodata either because they don't like it (type/taste) or because the data provided to them have become boring or dull (e.g. if you take the same route to work every day). At the other end of the spectrum, DHH members could start with or gain foodata neophobia, a reluctance to or fear of new foodata. This would mean that the members in question would need a very specific set of data fed to them. These first three traits are related to how a member might respond to the quality or type of foodata. In terms of quantity, traits such as abstemiousness (abstaining from foodata or consuming in moderation) and greediness could be used.

5.2.3 Sleep - Early Bird, Night Owl, Dysania and Insomnia

The terms "early bird" and "night owl" refer to whether a person prefers to get up early in the morning or stay up late at night. These are typically neutral, factual traits used to describe an individual and could be integrated into members of the DHH, potentially leading to devices waking up or going to bed before, after or with individuals, depending on sleep patterns. On the other hand, many people struggle with some or many of the stages of sleep. Dysania is a term used to describe a difficulty when waking up and getting out of bed whereas insomnia conveys a sleeplessness or an inability to get to sleep. Whereas an early bird is able to get up in the morning or a night owl can stay up late, members with dysania or insomnia will be more tired and have greater reduced functionality at certain points of the day.

5.2.4 Personality Seeds

In computer science, a "seed" is a number given to a computer that it uses to generate random numbers. There are two basic types, a fixed seed (which generates pseudorandom or predictable random numbers) and a fluctuating seed (that can generate "truly" random numbers). This seed approach is used in videogames such as Minecraft to procedurally generate maps by passing the seed number through an algorithm [4:22]. In Minecraft, if one player finds a seed number that generates a world they enjoy, they can share it with others to generate the same world. What if this concept was transplanted and reimagined in the context of the DHH? Imagine if the personality traits described above had a certain amount of randomness or ambiguity governed by a unique seed for each individual device. This would give each device a quasi-unique personality and a further semblance of agency that begins to approach that of a pet (e.g. dog, cat, etc.), whilst also allowing people to share seeds between devices (as if you could reprogram your cat to match a friend's). Advancing this further, the seeds could be "truly" randomised by using fluctuating factors such exact times of day, phases of the moon, weather and so on. This could give the home/devices traits, such as mood swings or unpredictability. However, the opportunity to explore personalities that are neither typical machine nor human-like should also be considered. If a plant evolved a personality what would that be like? Are there traits that can be embodied by a device that cannot be anthropomorphised?

5.3 Outcomes

In this context, the term outcome refers to the result of the evaluation of the (dis)satisfaction of needs against the influence of personality traits. Fulfilling needs will lead to positive or desirable outcomes and neglecting them results in negative outcomes. Furthermore, certain outcomes must occur in order for the output or interaction between the DHH member and the user, or other members, to occur. This subsection will discuss some of the possible outcomes relating to needs from the previous subsection.

5.3.1 Foodata - Satisfaction, Lipogenesis and Starvation

The optimum outcome of feeding a member of the DHH is satisfaction. This occurs when all of the needs relating to foodata are met, however other outcomes can occur depending on the amount of foodata and other factors. The metabolic processes lipogenesis can be understood as the process of storing energy/nutrients in fat. Fat is a useful medium to store energy when there is an abundance of food, releasing that energy when there is not. From the perspective of the DHH, this process can be reimagined in two parts, virtually and physically. The virtual aspect would take the form of internal memory used as "fat stores". These stores would hold unconsumed foodata collected over time for ingesting during a period when no foodata is being provided. The physical effect of this data lipogenesis could take multiple forms. For example, by employing the techniques and possibilities seen in shape changing interfaces/devices [1,24,53,67,72] a device in the DHH could literally become "fat" with data and then lose it when it is consumed. Furthermore, if a device were to become "obese" with data, it could exhibit a lack of fitness or health through a sluggishness in executing outputs. In the most extreme circumstances, the device could be fed so much it could die. On the other end of the spectrum, but with an equal outcome, members could also be starved of food meaning that they can represent becoming emaciated, lose their strength to perform interactions and, ultimately, die.

5.3.2 Sleep - Well-rested-ness, Dreams, Tiredness and Nightmares

When someone has a good night's sleep, they "slept like a log" whereas a person of poor temperament "got out of the wrong side of the bed". In other words, the quality of sleep is deeply integrated into our language, and outcomes of sleep can have positive and negative results. For members of the DHH, sleep can equally play an important role. When a member sleeps it will enter an alternate state than when it is awake and will have access to otherwise unreachable functionalities. This state, however, can be interrupted or not last long enough, leading to consequences. If a member has a good night/day's sleep it will be able to dream, manifest specific movements (similar to twitching and eye movements in human sleep) and undergo dedicated actions (such as sorting data), emerging well-rested and able to function normally. However, if the member does not get a good night's sleep, it will be tired and sluggish. Under certain circumstances, the device may experience nightmares. These can be brought about by external and internal factors, such as what is going on in the home or perhaps diet, e.g. "cheese" foodata before bed.

6 Conclusion

We, as a species, gather and care for various companions in our homes, providing them with a safe and well-maintained existence, sometimes for little or no recompense. In return for our efforts, plants may filter our air, flower or produce fruit, a cat may sit on our laps or keep us company, however, they may not, and yet we continue providing for them. Equally, the acquisition, preparation and provision of food is a key part of relationship building across all facets of human life and culture. Devices have come to play an integral part in our daily lives and, as a result of current (and future) technology, have the potential to occupy an interesting middle ground between the truly animate and the truly inanimate. This paper explores the theoretical concept of the Data Hungry Home, a place in which the role and position of devices in our lives is elevated to something akin to pets, houseplants or even acquaintances. It does so by positing an initial definition of the DHH, exploring ways in which a DHH could be constructed and populated with technology. From this theoretical foundation we critically explore and question the forms that interactive technology might take (e.g. Carver and Himilco) and challenge the relationship between, and roles adopted by, devices and their owners suggesting a much more symbiotic relationship where the varying needs of the device and the wider DHH, in terms of foodata, are anticipated, met and, indeed, rewarded potentially through the act of acquisition as well as in response to the feeding. To achieve this outcome, we anticipate that members of the DHH would be imbued with traits akin to personalities, needs including a varied (or specific) diet and periods of sleep as well as behaviours. This concept identifies an interesting niche within which there is the potential for interactive devices to evolve into a role based on mutual fulfilment and satisfaction, not simply information. Through the exploration of these ideas, we will be able to explore and expand upon our expectation and presumptions of what interactions and relationships can be built with a home and its contents. Furthermore, pursuing the DHH and similar avenues can contribute to the realm of HCI as well as research that looks at the lifelikeness [18,77], individuation [5] and agency of artefacts [23], human-computer relationships or companionships [15], and the quantified self [57]. Finally, the next steps this work should look to create and trial members, explore more needs, traits and outcomes and flip the lens to look at a data hungry street, neighbourhood and city.

ACKNOWLEDGMENTS

This research is being conducted with the funding and support of the EPSRC Centre for Doctoral Training in Embedded Intelligence (under grant reference EP/L014998/1), Loughborough University and Ordnance Survey. The authors would like to extend their thanks to the reviewers for their helpful feedback and advice.

REFERENCES

<bib id="bib1"><number>[1]</number>Jason Alexander, Anne Roudaut, Jürgen Steimle, Kasper Hornbæk, Miguel Bruns Alonso, Sean Follmer, and Timothy Merritt. 2018. Grand Challenges in Shape-Changing Interface Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–14. DOI: https://doi.org/10.1145/3173574.3173873</bib>

<bib id="bib2"><number>[2]</number>D E Allen. 1959. The History of the Vasculum. In *Proceedings of the Botanical Society of the British Isles*, 135–150.</bib>

<bib id="bib3"><number>[3]</number>Philip van Allen, Joshua McVeigh-Schultz, Brooklyn Brown, Hye Mi Kim, and Daniel Lara. 2013. AniThings: Animism and Heterogeneous Multiplicity. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*, 2247. DOI: https://doi.org/10.1145/2468356.2468746</bib>

<bib id="bib4"><number>[4]</number>Alba Amato. 2017. Procedural Content Generation in the Game Industry. In *Game Dynamics*, Oliver Korn and Newton Lee (eds.). Springer International Publishing, Cham, 15–25. DOI: https://doi.org/10.1007/978-3-319-53088-8_2</bib>

<bib id="bib5"><number>[5]</number>Aloha Hufana Ambe, Margot Brereton, Alessandro Soro, and Paul Roe. 2017. Technology Individuation: The Foibles of Augmented Everyday Objects. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, 6632–6644. DOI: https://doi.org/10.1145/3025453.3025770</bib>

<bib id="bib6"><number>[6]</number>Zann Benjamin Anderson. 2017. "I Can Physically Feel the Difference": Exploring Physicalizations of Running Data. Brigham Young University.</bib>

<bib id="bib7"><number>[7]</number>Leonardo Angelini, Nadine Couture, Omar Abou Khaled, and Elena Mugellini. 2017. Internet of Tangible Things (IoTT): Challenges and Opportunities for Tangible Interaction with IoT. (2017), 1–34. DOI: https://doi.org/10.3390/informatics5010007</bib>

<bib id="bib8"><number>[8]</number>Michelle Annett, Matthew Lakier, Franklin Li, Daniel Wigdor, Tovi Grossman, and George Fitzmaurice. 2016. The Living Room: Exploring the Haunted and Paranormal to Transform Design and Interaction. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16*, 1328–1340. DOI: https://doi.org/10.1145/2901790.2901819</bib>

<bib id="bib9"><number>[9]</number>James Henry Auger. 2014. Living With Robots: A Speculative Design Approach. *J. Human-Robot Interact.*3, 1 (2014), 20. DOI: https://doi.org/10.5898/JHRI.3.1.Auger</bib>

<bib id="bib10"><number>[10]</number>Saskia Bakker, Elise van den Hoven, and Berry Eggen. 2015. Peripheral interaction: characteristics and considerations. *Pers. Ubiquitous Comput.*19, 1 (2015), 239–254. DOI: https://doi.org/10.1007/s00779-014-0775-2</bib>

<bib id="bib11"><number>[11]</number>Saskia Bakker, Elise van den Hoven, and Berry Eggen. 2015. Evaluating Peripheral Interaction Design. *Human–Computer Interact.*30, 6 (November 2015), 473–506. DOI: https://doi.org/10.1080/07370024.2014.921531</bib>

<bib id="bib12"><number>[12]</number>H G Barker. 1958. Origin of the Vasculum. In *Proceedings of the Botanical Society of the British Isles*, 41–43.</bib>

<bib id="bib13"><number>[13]</number>Jacob Beaver, Andy Boucher, and Sarah Pennington. 2007. *The Curious Home*. Goldsmiths University of London, London.</bib>

<bib id="bib14"><number>[14]</number>Steve Benford, Chris Greenhalgh, Gabriella Giannachi, Brendan Walker, Joe Marshall, and Tom Rodden. 2012. Uncomfortable Interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI'12*, 2005. DOI: https://doi.org/10.1145/2207676.2208347</bib>

<bib id="bib15"><number>[15]</number>David Benyon and Oli Mival. 2010. From human-computer interactions to human-companion relationships. In *Proceedings of the First International Conference on Intelligent Interactive Technologies and Multimedia - IITM '10*, 1–9. DOI: https://doi.org/10.1145/1963564.1963565</bib>

<bib id="bib16"><number>[16]</number>Arne Berger, William Odom, Michael Storz, Andreas Bischof, Albrecht Kurze, and Eva Hornecker. 2019. The Inflatable Cat: Idiosyncratic Ideation Of Smart Objects For The Home. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–12. DOI: https://doi.org/10.1145/3290605.3300631</bib>

<bib id="bib17"><number>[17]</number>Vanessa Budde, Nils Backhaus, Patricia H. Rosen, and Sascha Wischniewski. 2018. Needy Robots - Designing Requests for Help Using Insights from Social Psychology. In*2018 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, 48–53. DOI: https://doi.org/10.1109/ARSO.2018.8625724</bib>

<bib id="bib18"><number>[18]</number>Irem Cakiroglu and Cigdem Kaya Pazarbasi. 2019. Critical Design in Daily Life: Lifelike Products. *Des. J.*22, sup1 (April 2019), 1227–1234. DOI: https://doi.org/10.1080/14606925.2019.1594987</bib>

<bib id="bib19"><number>[19]</number>Jessica R. Cauchard, Kevin Y. Zhai, Marco Spadafora, and James A. Landay. 2016. Emotion encoding in human-drone interaction. *ACM/IEEE Int. Conf. Human-Robot Interact.*2016-April, (2016), 263–270. DOI: https://doi.org/10.1109/HRI.2016.7451761</bib>

<bib id="bib20"><number>[20]</number>Catherine Caudwell and Cherie Lacey. 2019. What do home robots want? The ambivalent power of cuteness in robotic relationships. *Convergence* (2019), 1–13. DOI: https://doi.org/10.1177/1354856519837792</bib>

<bib id="bib21"><number>[21]</number>Justin Cheng, Akshay Bapat, Gregory Thomas, Kevin Tse, Nikhil Nawathe, Jeremy Crockett, and Gilly Leshed. 2011. GoSlow: Designing for Slowness, Reflection and Solitude. In *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems - CHI EA '11*, 429. DOI: https://doi.org/10.1145/1979742.1979622</bib>

<bib id="bib22"><number>[22]</number>Padma Chirumamilla and Joyojeet Pal. 2013. Play and Power: a Ludic Design Proposal for ICTD. In *Proceedings of the Sixth International Conference on Information and Communication Technologies and Development Full Papers - ICTD '13 - volume 1*, 25–33. DOI: https://doi.org/10.1145/2516604.2516628</bib>

<bib id="bib23"><number>[23]</number>Nazli Cila, Iskander Smit, Elisa Giaccardi, and Ben Kröse. 2017. Products as Agents: Metaphors for Designing the Products of the IoT Age. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, 448–459. DOI: https://doi.org/10.1145/3025453.3025797</bib>

<bib id="bib24"><number>[24]</number>Marcelo Coelho and Jamie Zigelbaum. 2011. Shape-changing interfaces. *Pers. Ubiquitous Comput.*15, 2 (February 2011), 161–173. DOI: https://doi.org/10.1007/s00779-010-0311-y</bib>

<bib id="bib25"><number>[25]</number>Brian R. Duffy. 2003. Anthropomorphism and the social robot. *Rob. Auton. Syst.*42, 3–4 (March 2003), 177–190. DOI: https://doi.org/10.1016/S0921-8890(02)00374-3</bib>

<bib id="bib26"><number>[26]</number>Joep Frens. 2017. Designing for Embodied and Rich Interaction in Home IoT. In *Proceedings of the Conference on Design and Semantics of Form and Movement - Sense and Sensitivity, DeSForM 2017*. InTech, 64. DOI: https://doi.org/10.5772/intechopen.71130</bib>

<bib id="bib27"><number>[27]</number>Bill Gaver. 2002. Designing for Homo Ludens, Still. *I3 Mag.*12 (2002), 2–6.</bib>

<bib id="bib28"><number>[28]</number>Bill Gaver. 2007. Conclusion: The Anatomy of a Wave. In *The Curious Home*, Jacob Beaver, Andy Boucher and Sarah Pennington (eds.). Goldsmiths University of London, London, 5–10.</bib>

<bib id="bib29"><number>[29]</number>William Gaver, Andy Boucher, Michail Vanis, Andy Sheen, Dean Brown, Liliana Ovalle, Naho Matsuda, Amina Abbas-Nazari, and Robert Phillips. 2019. My Naturewatch Camera: Disseminating Practice Research with a Cheap and Easy DIY Design. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–13. DOI: https://doi.org/10.1145/3290605.3300532</bib>

<bib id="bib30"><number>[30]</number>William Gaver, John Bowers, Andrew Boucher, Andy Law, Sarah Pennington, and Brendan Walker. 2007. Electronic Furniture for the Curious Home: Assessing Ludic Designs in the Field. *Int. J. Hum. Comput. Interact.*22, 1–2 (April 2007), 119–152. DOI: https://doi.org/10.1080/10447310709336958</bib>

<bib id="bib31"><number>[31]</number>William Gaver, Liliana Ovalle, Andy Boucher, Nadine Jarvis, David Cameron, Mark Hauenstein, Sarah Pennington, John Bowers, James Pike, and Robin Beitra. 2016. The Datacatcher: Batch Deployment and Documentation of 130 Location-Aware, Mobile Devices That Put Sociopolitically-Relevant Big Data in People's Hands: Polyphonic Interpretation at Scale. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 1597–1607. DOI: https://doi.org/10.1145/2858036.2858472</bib>

<bib id="bib32"><number>[32]</number>William Gaver, Alex Wilkie, Andy Boucher, Andy Law, Sarah Pennington, John Bowers, Jacob Beaver, Jan Humble, Tobie Kerridge, and Nicholas Villar. 2008. Threshold Devices: Looking Out From The Home. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, 1429–1438. DOI: https://doi.org/10.1145/1357054.1357278</bib>

<bib id="bib33"><number>[33]</number>Maliheh Ghajargar and Mikael Wiberg. 2018. Thinking with Interactive Artifacts: Reflection as a Concept in Design Outcomes. *Des. Issues* 34, 2 (April 2018), 48–63. DOI: https://doi.org/10.1162/DESI_a_00485</bib>

<bib id="bib34"><number>[34]</number>Maliheh Ghajargar, Mikael Wiberg, and Erik Stolterman. 2018. Designing IoT Systems that Support Reflective Thinking: A Relational Approach. *Int. J. Des.*12, (2018), 21–35.</bib>

<bib id="bib35"><number>[35]</number>Mathieu Le Goc, Charles Perin, Sean Follmer, Jean-daniel Fekete, and Pierre Dragicevic. 2019. Dynamic Composite Data Physicalization Using Wheeled Micro-Robots. *IEEE Trans. Vis. Comput. Graph.*25, 1 (January 2019), 737–747. DOI: https://doi.org/10.1109/TVCG.2018.2865159</bib>

<bib id="bib36"><number>[36]</number>Lars Hallnäs and Johan Redström. 2001. Slow Technology – Designing for Reflection. *Pers. Ubiquitous Comput.*5, 3 (August 2001), 201–212. DOI: https://doi.org/10.1007/PL00000019</bib>

<bib id="bib37"><number>[37]</number>Sabrina Hauser, Ron Wakkary, William Odom, Peter-Paul Verbeek, Audrey Desjardins, Henry Lin, Matthew Dalton, Markus Schilling, and Gijs de Boer. 2018. Deployments of the table-non-table: A Reflection on the Relation Between Theory and Things in the Practice of Design Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–13. DOI: https://doi.org/10.1145/3173574.3173775</bib>

<bib id="bib38"><number>[38]</number>Trevor Hogan, Eva Hornecker, Simon Stusak, Yvonne Jansen, Jason Alexander, Andrew Vande Moere, Uta Hinrichs, and Kieran Nolan. 2016. Tangible Data, explorations in data physicalization. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '16*, 753–756. DOI: https://doi.org/10.1145/2839462.2854112</bib>

<bib id="bib39"><number>[39]</number>Steven Houben, Connie Golsteijn, Sarah Gallacher, Rose Johnson, Saskia Bakker, Nicolai Marquardt, Licia Capra, and Yvonne Rogers. 2016. Physikit: Data Engagement Through Physical Ambient Visualizations in the Home. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 1608–1619. DOI: https://doi.org/10.1145/2858036.2858059</bib>

<bib id="bib40"><number>[40]</number>Noura Howell, Greg Niemeyer, and Kimiko Ryokai. 2019. Life-Afirming Biosensing in Public: Sounding Heartbeats on a Red Bench. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–16. DOI: https://doi.org/10.1145/3290605.3300910</bib>

<bib id="bib41"><number>[41]</number>Hiroshi Ishii. 2008. Tangible Bits: Beyond Pixels. In *Proceedings of the 2nd international conference on Tangible and embedded interaction - TEI '08*, xv. DOI: https://doi.org/10.1145/1347390.1347392</bib>

<bib id="bib42"><number>[42]</number>Hiroshi Ishii and Brygg Ullmer. 1997. Tangible bits. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '97*, 234–241. DOI: https://doi.org/10.1145/258549.258715</bib>

<bib id="bib43"><number>[43]</number>Hiroshi Ishii, Craig Wisneski, Scott Brave, Andrew Dahley, Matt Gorbet, Brygg Ullmer, and Paul Yarin. 1998. ambientROOM: Integrating Ambient media with Architectural Space. In *CHI 98 conference summary on Human factors in computing systems - CHI '98*, 173–174. DOI: https://doi.org/10.1145/286498.286652</bib>

<bib id="bib44"><number>[44]</number>Nils Jäger. 2017. Interacting with adaptive architecture. *interactions* 24, 6 (October 2017), 62–65. DOI: https://doi.org/10.1145/3137113</bib>

<bib id="bib45"><number>[45]</number>Nils Jäger, Holger Schnädelbach, Jonathan Hale, David Kirk, and Kevin Glover. 2017. Reciprocal Control in Adaptive Environments. *Interact. Comput.*29, 4 (January 2017), 512–529. DOI: https://doi.org/10.1093/iwc/iww037</bib>

<bib id="bib46"><number>[46]</number>Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. 2015. Opportunities and Challenges for Data Physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, 3227–3236. DOI: https://doi.org/10.1145/2702123.2702180</bib>

<bib id="bib47"><number>[47]</number>Rikke Hagensby Jensen, Yolande Strengers, Jesper Kjeldskov, Larissa Nicholls, and Mikael B. Skov. 2018. Designing the Desirable Smart Home: A Study of Household Experiences and Energy Consumption Impacts. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–14. DOI: https://doi.org/10.1145/3173574.3173578</bib>

<bib id="bib48"><number>[48]</number>Rikke Hagensby Jensen, Yolande Strengers, Dimitrios Raptis, Larissa Nicholls, Jesper Kjeldskov, and Mikael B. Skov. 2018. Exploring Hygge as a Desirable Design Vision for the Sustainable Smart Home. In *Proceedings of the 2018 Designing Interactive Systems Conference - DIS '18*, 355–360. DOI: https://doi.org/10.1145/3196709.3196804</bib>

<bib id="bib49"><number>[49]</number>Michiel Joosse, Manja Lohse, Jorge Gallego Perez, and Vanessa Evers. 2013. What you do is who you are: The role of task context in perceived social robot personality. In*2013 IEEE International Conference on Robotics and Automation*, 2134–2139. DOI: https://doi.org/10.1109/ICRA.2013.6630863</bib>

<bib id="bib50"><number>[50]</number>Somi Ju, Kyung-Ryong Lee, Subin Kim, and Young-Woo Park. 2019. Bookly: An Interactive Everyday Artifact Showing the Time of Physically Accumulated Reading Activity. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–8. DOI: https://doi.org/10.1145/3290605.3300614</bib>

<bib id="bib51"><number>[51]</number>Ayumi Kawakami, Koji Tsukada, Keisuke Kambara, and Itiro Siio. 2011. PotPet: Pet-like Flowerpot Robot. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction - TEI '11*, 263. DOI: https://doi.org/10.1145/1935701.1935755</bib>

<bib id="bib52"><number>[52]</number>Annakaisa Kultima, Timo Nummenmaa, Heikki Tyni, Kati Alha, Jaakko Stenros, Ville Kankainen, Jussi Holopainen, and Frans Mäyrä. 2018. Playful Furniture: Breaching a Serious Setting With Interactive Seats. *Games Cult.*13, 3 (2018), 301–321. DOI: https://doi.org/10.1177/1555412017718749</bib>

<bib id="bib53"><number>[53]</number>Matthijs Kwak, Kasper Hornbæk, Panos Markopoulos, and Miguel Bruns Alonso. 2014. The Design Space of Shape-changing Interfaces: A Repertory Grid Study. In *Proceedings of the 2014 conference on Designing interactive systems - DIS '14*, 181–190. DOI: https://doi.org/10.1145/2598510.2598573</bib>

<bib id="bib54"><number>[54]</number>David Lakatos and Hiroshi Ishii. 2012. Towards Radical Atoms – Form-giving to Transformable Materials. In*2012 IEEE 3rd International Conference on Cognitive Infocommunications (CogInfoCom)*, 37–40. DOI: https://doi.org/10.1109/CogInfoCom.2012.6422023</bib>

<bib id="bib55"><number>[55]</number>Matthew Lee-Smith, Tracy Ross, Martin Maguire, Fung Po Tso, Jeremy Morley, and Stefano Cavazzi. 2019. What Can We Expect from Navigating? Exploring Navigation, Wearables and Data Through Critical Design Concepts. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion - DIS '19 Companion*, 237–244. DOI: https://doi.org/10.1145/3301019.3323889</bib>

<bib id="bib56"><number>[56]</number>Kwan Min Lee, Wei Peng, Seung-A Jin, and Chang Yan. 2006. Can Robots Manifest Personality?: An Empirical Test of Personality Recognition, Social Responses, and Social Presence in Human–Robot Interaction. *J. Commun.*56, 4 (December 2006), 754–772. DOI: https://doi.org/10.1111/j.1460-2466.2006.00318.x</bib>
<bib id="bib57"><number>[57]</number>Deborah Lupton. 2016. *The Quantified Self* (1st ed.). Polity Press.</bib>
<bib id="bib58"><number>[58]</number>Betti Marenko. 2014. Neo-Animism and Design. *Des. Cult.*6, 2 (2014), 219–241. DOI: https://doi.org/10.2752/175470814X14031924627185</bib>
<bib id="bib59"><number>[59]</number>Betti Marenko and Philip van Allen. 2016. Animistic design: how to reimagine digital interaction between the human and the nonhuman. *Digit. Creat.*27, 1 (2016), 52–70. DOI: https://doi.org/10.1080/14626268.2016.1145127</bib>
<bib id="bib60"><number>[60]</number>Bernt Meerbeek, Martin Saerbeck, and Christoph Bartneck. 2009. Iterative Design Process for Robots With Personality. In *Proceedings of the AISB2009 Symposium on New Frontiers in Human-Robot Interaction*, 94–101.</bib>
<bib id="bib61"><number>[61]</number>Sarah Mennicken, James Scott, A. J. Bernheim Brush, and Asta Roseway. 2014. Finding roles for interactive furniture in homes with EmotoCouch. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing Adjunct Publication - UbiComp '14 Adjunct*, 923–930. DOI: https://doi.org/10.1145/2638728.2641547</bib>
<bib id="bib62"><number>[62]</number>Alexandros Mileounis, Raymond H. Cuijpers, and Emilia I. Barakova. 2015. Creating Robots with Personality: The Effect of Personality on Social Intelligence. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. 119–132. DOI: https://doi.org/10.1007/978-3-319-18914-7_13</bib>
<bib id="bib63"><number>[63]</number>Ine Mols, Elise van den Hoven, and Berry Eggen. 2016. Technologies for Everyday Life Reflection: Illustrating a Design Space. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '16*, 53–61. DOI: https://doi.org/10.1145/2839462.2839466</bib>
<bib id="bib64"><number>[64]</number>Beatrice Monastero, David McGookin, and Giuseppe Torre. 2016. Wandertroper: Supporting Aesthetic Engagement with Everyday Surroundings through Soundscape Augmentation. In *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia - MUM '16*, 129–140. DOI: https://doi.org/10.1145/3012709.3012725</bib>
<bib id="bib65"><number>[65]</number>Julien Nembrini and Denis Lalanne. 2017. Human-Building Interaction: When the Machine Becomes a Building. In *Human-Computer Interaction INTERACT '97*, Regina Bernhaupt, Girish Dalvi, Anirudha Joshi, Devanuj K. Balkrishan, Jacki O'Neill and Marco Winckler (eds.). Springer International Publishing, Cham, 348–369. DOI: https://doi.org/10.1007/978-3-319-67684-5_21</bib>
<bib id="bib66"><number>[66]</number>Rachel S. Ng, Raghavendra Kandala, Sarah Marie-Foley, Dixon Lo, Molly Wright Steenson, and Austin S. Lee. 2016. Expressing Intent: An Exploration of Rich Interactions. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '16*, 524–531. DOI: https://doi.org/10.1145/2839462.2856526</bib>
<bib id="bib67"><number>[67]</number>Mie Nørgaard, Tim Merritt, Majken Kirkegaard Rasmussen, and Marianne Graves Petersen. 2013. Exploring the Design Space of Shape-Changing Objects: Imagined Physics. In *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces - DPPI '13*, 251–260. DOI: https://doi.org/10.1145/2513506.2513533</bib>
<bib id="bib68"><number>[68]</number>William Odom, Abigail Sellen, Richard Banks, David Kirk, Tim Regan, Mark Selby, Jodi L. Forlizzi, and John Zimmerman. 2014. Designing for Slowness, Anticipation and Re-visitation: A Long Term Field Study of the Photobox. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, 1961–1970. DOI: https://doi.org/10.1145/2556288.2557178</bib>
<bib id="bib69"><number>[69]</number>William Odom, Ron Wakkary, Jeroen Hol, Bram Naus, Pepijn Verburg, Tal Amram, and Amy Yo Sue Chen. 2019. Investigating Slowness as a Frame to Design Longer-Term Experiences with Personal Data: A Field Study of Olly. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–16. DOI: https://doi.org/10.1145/3290605.3300264</bib>
<bib id="bib70"><number>[70]</number>Michael Pieroni, Lorenzo Rizzello, Niccolo Rosini, Gualtiero Fantoni, Danilo De Rossi, and Daniele Mazzei. 2015. Affective Internet of Things: Mimicking human-like personality in designing smart-objects. In*2015 IEEE 2nd World Forum on Internet of Things (WF-IoT)*, 400–405. DOI: https://doi.org/10.1109/WF-IoT.2015.7389088</bib>
<bib id="bib71"><number>[71]</number>Zachary Pousman and John Stasko. 2006. A Taxonomy of Ambient Information Systems: Four Patterns of Design. In *Proceedings of the working conference on Advanced visual interfaces - AVI '06*, 67. DOI: https://doi.org/10.1145/1133265.1133277</bib>
<bib id="bib72"><number>[72]</number>Majken K. Rasmussen, Esben W. Pedersen, Marianne G. Petersen, and Kasper Hornbæk. 2012. Shape-Changing Interfaces: A Review of the Design Space and Open Research Questions. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, 735. DOI: https://doi.org/10.1145/2207676.2207781</bib>
<bib id="bib73"><number>[73]</number>Hannes Ritschel and Elisabeth André. 2017. Real-Time Robot Personality Adaptation based on Reinforcement Learning and Social Signals. In *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17*, 265–266. DOI: https://doi.org/10.1145/3029798.3038381</bib>
<bib id="bib74"><number>[74]</number>Hannes Ritschel, Ilhan Aslan, David Sedlbauer, and Elisabeth André. 2019. Irony Man : Augmenting a Social Robot with the Ability to Use Irony in Multimodal Communication with Humans Socially Interactive Agents Track. In *Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS '19)*, 86–94.</bib>
<bib id="bib75"><number>[75]</number>Yvonne Rogers. 2006. Moving on from Weiser's Vision of Calm Computing: Engaging UbiComp Experiences. In *Proceedings of the 8th international conference on Ubiquitous Computing - UbiComp'06*, 404–421. DOI: https://doi.org/10.1007/11853565_24</bib>
<bib id="bib76"><number>[76]</number>Yvonne Rogers, William R. Hazlewood, Paul Marshall, Nick Dalton, and Susanna Hertrich. 2010. Ambient Influence: Can Twinkly Lights Lure and Abstract Representations Trigger Behavioral Change? In *Proceedings of the 12th ACM international conference on Ubiquitous computing - Ubicomp '10*, 261. DOI: https://doi.org/10.1145/1864349.1864372</bib>
<bib id="bib77"><number>[77]</number>Yea-Kyung Row and Tek-Jin Nam. 2016. Understanding Lifelike Characteristics in Interactive Product Design. *Arch. Des. Res.*29, 3 (August 2016), 25. DOI: https://doi.org/10.15187/adr.2016.08.29.3.25</bib>
<bib id="bib78"><number>[78]</number>Kim Sauvé, Steven Houben, Nicolai Marquardt, Saskia Bakker, Bart Hengeveld, Sarah Gallacher, and Yvonne Rogers. 2017. LOOP: A Physical Artifact to Facilitate Seamless Interaction with Personal Data in Everyday Life. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems - DIS '17 Companion*, 285–288. DOI: https://doi.org/10.1145/3064857.3079175</bib>
<bib id="bib79"><number>[79]</number>Holger Schnädelbach, Ainojie Irune, David Kirk, Kevin Glover, and Patrick Brundell. 2012. ExoBuilding: Physiologically driven adaptive architecture. *ACM Trans. Comput. Interact.*19, 4 (2012), 1–22. DOI: https://doi.org/10.1145/2395131.2395132</bib>
<bib id="bib80"><number>[80]</number>Linda See, Jacinto Estima, Andrea Pődör, Jamal Jokar Arsanjani, Juan-Carlos Laso Bayas, and Rumiana Vatseva. 2017. Sources of VGI for Mapping. In *Mapping and the Citizen Sensor*, Giles Foody, Linda See, Steffen Fritz, Peter Mooney, Ana-Maria Olteanu-Raimond, Cidália Costa Fonte and Vyron Antoniou (eds.). Ubiquity Press, 13–35. DOI: https://doi.org/10.5334/bbf.b</bib>
<bib id="bib81"><number>[81]</number>Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph "Jofish" Kaye. 2005. Reflective design. In *Proceedings of the 4th decennial conference on Critical computing between sense and sensibility - CC '05*, 49. DOI: https://doi.org/10.1145/1094562.1094569</bib>
<bib id="bib82"><number>[82]</number>Geraint Rhys Sethu-Jones, Yvonne Rogers, and Nicolai Marquardt. 2017. Data in the Garden: A Framework For Exploring Provocative Prototypes as Part of Research In The Wild. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction - OZCHI '17*, 318–327. DOI: https://doi.org/10.1145/3152771.3152805</bib>
<bib id="bib83"><number>[83]</number>Jaime Snyder, Mark Matthews, Jacqueline Chien, Pamara F. Chang, Emily Sun, Saeed Abdullah, and Geri Gay. 2015. MoodLight: Exploring Personal and Social Implications of Ambient Display of Biosensor Data. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*, 143–153. DOI: https://doi.org/10.1145/2675133.2675191</bib>
<bib id="bib84"><number>[84]</number>Alessandro Soro, Margot Brereton, Tshering Dema, Jessica L Oliver, Min Zhen Chai, and Aloha May Hufana Ambe. 2018. The Ambient Birdhouse: An IoT device to Discover Birds and Engage with Nature. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–13. DOI: https://doi.org/10.1145/3173574.3173971</bib>

<bib id="bib85"><number>[85]</number>Ricardo Sosa, Victoria Gerrard, Antonio Esparza, Rebeca Torres, and Robbie Napper. 2018. DATA OBJECTS: DESIGN PRINCIPLES FOR DATA PHYSICALISATION. In *Proceedings of International Design Conference, DESIGN*, 1685–1696. DOI: https://doi.org/10.21278/idc.2018.0125</bib>
<bib id="bib86"><number>[86]</number>Marco Spadafora. 2015. Object's Personality, a Tool to Chase an Aesthetic Approach in the Design of Smart Objects. In *Design and semantics of form and movement (DeSForM 2015): Aesthetics of interaction: Dynamic, Multisensory, Wise*.</bib>
<bib id="bib87"><number>[87]</number>Marco Spadafora, Victor Chahuneau, Nikolas Martelaro, David Sirkin, and Wendy Ju. 2016. Designing the Behavior of Interactive Objects. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '16*, 70–77. DOI: https://doi.org/10.1145/2839462.2839502</bib>
<bib id="bib88"><number>[88]</number>Simon Stusak. 2016. Exploring the potential of physical visualizations. Ludwig Maximilian University of Munich.</bib>
<bib id="bib89"><number>[89]</number>Simon Stusak, Aurelien Tabard, Franziska Sauka, Rohit Ashok Khot, and Andreas Butz. 2014. Activity Sculptures: Exploring the Impact of Physical Visualizations on Running Activity. *IEEE Trans. Vis. Comput. Graph.*20, 12 (December 2014), 2201–2210. DOI: https://doi.org/10.1109/TVCG.2014.2352953</bib>
<bib id="bib90"><number>[90]</number>Nam Tek-Jin and Kim Changwon. 2011. Design by Tangible Stories: Enriching Interactive Everyday Products with Ludic Value. *Int. J. Des.*5:1, 1 (2011), 1–16.</bib>
<bib id="bib91"><number>[91]</number>Alice Thudt, Uta Hinrichs, Samuel Huron, and Sheelagh Carpendale. 2018. Self-Reflection and Personal Physicalization Construction. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–13. DOI: https://doi.org/10.1145/3173574.3173728</bib>
<bib id="bib92"><number>[92]</number>Sherry Turkle. 2010. In good company? On the threshold of robotic companions. In *Close Engagements with Artificial Companions: Key social, psychological, ethical and design issues*, Yorick Wilks (ed.). John Benjamins Publishing Company, 3–10. DOI: https://doi.org/10.1075/nlp.8</bib>
<bib id="bib93"><number>[93]</number>Kate Vaisutis, Margot Brereton, Toni Robertson, Frank Vetere, Jeannette Durick, Bjorn Nansen, and Laurie Buys. 2014. Invisible Connections: Investigating Older People's Emotions and Social Relations Around Objects. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, 1937–1940. DOI: https://doi.org/10.1145/2556288.2557314</bib>
<bib id="bib94"><number>[94]</number>Mark Weiser and John Seely Brown. 1997. The Coming Age of Calm Technology. In *Beyond Calculation*, Peter J. Denning and Robert M. Metcalfe (eds.). Springer New York, New York, NY, 75–85. DOI: https://doi.org/10.1007/978-1-4612-0685-9_6</bib>
<bib id="bib95"><number>[95]</number>Craig Wisneski, Hiroshi Ishii, Andrew Dahley, Matt Gorbet, Scott Brave, Brygg Ullmer, and Paul Yarin. 1998. Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information. In *Cooperative Buildings: Integrating Information, Organization, and Architecture*. 22–32. DOI: https://doi.org/10.1007/3-540-69706-3_4</bib>
<bib id="bib96"><number>[96]</number>Sarah Woods, Kerstin Dautenhahn, Christina Kaouri, R. Boekhorst, and Kheng Lee Koay. 2005. Is This Robot Like Me? Links Between Human and Robot Personality Traits. In*5th IEEE-RAS International Conference on Humanoid Robots, 2005.*, 375–380. DOI: https://doi.org/10.1109/ICHR.2005.1573596</bib>