

IoT Data in the Home: Observing Entanglements and Drawing New Encounters

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ABSTRACT

Internet of Things (IoT) technologies for the home are gaining in popularity, generating exponential data byproducts. Yet, everyday relationships between home dwellers and domestic IoT data often remain secondary interactions, preventing deeper understanding and awareness of data tracked in the home. Our paper offers a design ethnography and design inquiry which examine these human-data entanglements. Findings from working with 10 inhabitants who interact with their IoT data illustrate five characteristics of current data encounters: manifesting, inquiring, exposing, repositioning, and broadening. In response, we used speculative sketches to refine, refract and complicate these encounters. We argue that data do not have to be laborious, tidy or the byproduct of a service, but rather lively and affecting. We further suggest new modes of engagement with data which expand or step away from self-improvement and reflection: through diverse acts of noticing, by allowing data to remain invisible, and by embracing imaginative practices.

Author Keywords

Internet of things; data; home; design ethnography; research-through-design; speculative.

CSS Concepts

• Human-centered computing~Interaction design

INTRODUCTION

The promise of convenience and productivity associated with connected devices in the home (otherwise known as Internet of Things (IoT)) is inevitably entangled with large and complex datasets. The ‘magic’ that happens when smart lights turn on, or when a system detects a security breach in the home is powered by algorithms, data baselines, and live machine learning processes. As home dwellers, we might imagine these data are only in the home, but in reality, data

flow out to IoT service providers, are stored in the cloud, are sold, reworked and become the central currency of a data economy. Data are undeniably central to how IoT works, yet these data often remain unseen, hidden, or ignored by the people who are living amongst that data: home dwellers. While there are interfaces which curate home dwellers’ data, these tools are often oriented towards reflection, self-knowledge, control, or pure curiosity about the home. However, we question what other values and practices are obfuscated when we only discuss these *designed* ways of engaging with data from IoT. Furthermore, we question how looking at emergent engagements outside of this limited set might inform more diverse design approaches.

We argue that, to achieve an IoT that is more fair, open, and healthy (as proposed in recent manifestos [12,21]), it is crucial that we understand better current practices around data and acknowledge that interactions with data require attention and intention in their design. Specifically, we question how people might encounter, make meaning of, and search the seemingly mundane but extensive logs of daily routines captured by, for instance, the changing temperature in their home, or the opening and closing of doors and windows. The work we present aims to reveal the complex tensions and contradictions that exist in the multiple forms of arrangements and entanglements between home dwellers and their home data. We ask: How do home dwellers encounter IoT domestic data? and How else might data entanglements in the home be imagined and shaped?

To investigate these questions, we take a dual approach: we combine a design ethnography with a research-through-design (RtD) series of speculative sketches (inspired by [1,49]). While design ethnography allows us to investigate how people currently live with IoT domestic data, RtD opens a space for us to further synthesize but also complicate our findings. We conducted in-home semi-structured interviews, tours, and two creative activities with 10 participants living with at least one IoT device at home (participants had between 1 and 60 devices). Through thematic analysis, we developed five themes regarding how our interlocutors are entangled with the data generated by their IoT devices. From those themes, we then created five speculative concepts, taking an authorial stance to attend to data through design.

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Our contributions include: (1) a broadening of the roles IoT data already play in their entanglements with inhabitants and their homes, from their sheer manifestations, to how they reframe everyday experiences, to how they travel beyond the home, and (2) generative and creative openings that shift data’s existing and residual interactions to primary ones and an exploration of data’s modes of engagement in addition to self-improvement and reflection.

RELATED WORKS

While data has been extensively described in design, science and technology studies (STS) and human-computer interaction (HCI) as heterogeneous, local, not smooth, incomplete, lively, and part of assemblages, these observations are seldom applied to the personal encounters people have with data from their IoT devices and services in their homes. Below, we highlight lines of research that contextualize our work, and which represent current discourses we wish to broaden by opening up other ways people might live with data including and beyond self-knowledge or self-improvement.

Smooth data, plural data, local data

Similar to the long traditions of pervasive computing and home automation, IoT relies on adding a layer of data to the physical world, and, as a result, radically transforming our relationships to things. Philosopher and cultural theorist Byung-Chul Han [26] remarks on this transformation by characterizing objects as conduits for information. The aesthetics of data passing through these objects is often understood and imagined as smooth, frictionless and non-resistant. Han explains how data are part of a larger aesthetic fixation with smoothness—a removal of resistance and negativity—claiming “*the smooth object deletes its* Against” [27:1]. He further explains how, when data are thought of as smooth, data “*are not ambiguous. Data and information deliver themselves to total visibility and they make everything visible*” [27:9]. The apparent smoothness of data (offering no resistance, posing as unambiguous) is problematic—if not dangerous—as it obscures how actually complex, messy and dynamic data really are.

Han offers an evocative account of current perceptions of data, and in commenting on the aesthetics of data, raises a red flag. We turn to STS scholar Loukissas [35] to further describe the many ways that data are not smooth, rather they are inherently heterogeneous, plural, and local. Loukissas [35] argues that when referring to data as a plural term, as opposed to a mass singular noun (such as water, air or oil), we can reinforce a multifaceted perspective, highlighting that data are heterogeneous, and that they can be taken apart. In addition to emphasizing the plurality of data, Loukissas also brings attention to the locality of data. He articulates: “*the widely used term data set implies something discrete, complete, and readily portable*” [35:2], and suggests that we must analyze *data settings* rather than *data sets* to situate and ground insights that might develop from those data. Dourish and Gómez Cruz further argue that data “*do not speak for*

themselves” [17:1] and that narratives are necessary to contextualize in order to give them meaning and shape. In HCI, the fields of data visualization [50] and data physicalization [29,30] have a long history in presenting *legible* data, showing trends, outliers, and stories about data (e.g. [43,47]), by staying more or less close to the data settings, and only seldomly acknowledging the heterogeneous nature of data.

Data and smart objects as assemblages

The locality of data and the emphasis on data settings position data as active actors in larger socio-technical systems (as also articulated in new materialism and posthumanism [3,5,16,33]). Once part of a heterogenous assemblage, and on equal footing with, for example, everyday objects, sensors, electric grids, pets, and spaces, we can examine how data transform, and how “*those elements acquire or maintain individual identity as they are assembled, disassembled, and reassembled as sociotechnical settings develop, evolve, and reconfigure*” [16:41], as stated by Dourish. This perspective highlights the important role data can have directly in the home (as they are assembled and reassembled with other everyday things), a role beyond a simple conduit for passing information between the home and services offered by corporations.

Sociologist Deborah Lupton’s work also points to the dynamic nature of these relations and assemblages. Using the term ‘lively,’ she emphasizes the co-shaping of data, homes, and humans over time: “*Just as we might reflect on how our lively companion devices live alongside us, we might also think about our lively personal digital data assemblages co-habit with us. As we co-habit with our devices and our data, we co-evolve with them*” [36:1603]. Remembering that IoT devices and data are part of a lively and dynamic assemblage is important in our inquiry as we aim to understand the diverse and potentially contradictory encounters people have with IoT data at home, and that these encounters might manifest themselves physically or digitally.

Data for self-knowledge

People have long used data as a way to better know ‘the self’ (as illustrated, for example, by Crawford et al. in their historical study of the weight scale [11]). Both in the Quantified Self movement [18,52], and with other personal data practices such as IoT, people “*are encouraged to take the opportunity to view and reflect on this information and use it to optimize their lives, improve their health and well-being, contribute to their memories or achieve Self-knowledge*” [36:1600]. From this perspective, data is often seen as objective or ‘true’ and in direct opposition to imprecise feelings or impressions from the body. Even further, there is a fine line between presenting data as a self-knowledge tool, and seeing data as part of larger systems of monetized surveillance. Researchers have shown how quickly these systems can generate undesirable and dangerous situations where data and surveillance are the underlining structure that supports the reproduction of

certain forms of violence, of power inequalities, and of body normativity [38,45]. While the relationship between notions of objectivity, truth, and data around personal data and quantified self is central to current discussions in HCI and STS, those relations in the context of smart home data are currently underexplored in HCI.

Data as design material in connected homes

HCI and design researchers have turned their attention to data as a design material when creating experiences for connected devices in the home or home automation systems. For instance, environmental factors in the home have been tracked and leveraged, such as monitoring and annotating air quality [37], receiving feedback for water consumption and conservation in the shower [31] and understanding domestic energy consumption [8]. Data have also been gathered with the intention of offering family memories in the form of video, audio, or motion (e.g. [28,44]). Even if the promise of data can lead to more eco-friendly homes or can support deeper family self-knowledge, data analysis and inference processes have raised concerns of privacy and surveillance [9]. In response, Gaver et al. designed the Health Horoscope [24] to critique inference systems: this system presents patterns of behavior in the home in an ambiguous manner, emphasizing the need for human interpretation. Other projects allow people to directly reclaim, use, and visualize data in their own homes, such as DIY IoT toolkits [53], the ListeningCups which questions the narratives told by IoT data [14], and Domestic Widgets [51] which materialize data sets. While these projects clearly use data as an integral part of systems in the home, they rarely address the complex qualities presented above: how these data are also incomplete, local, heterogeneous, and how they might be prescriptive or authoritative.

OUR STUDY

To inquire about IoT data practices in the home, we chose a design anthropology approach [4,34,41] where we combined home visits (including home tours [46], drawing activities, and imaginary data interactions activity) with speculative sketching (postcards). Like Khovanskaya et al. [32] who revealed synergies between design and ethnography, our work also benefited from using design alongside fieldwork. For example, we relied on iterating through speculative sketches—sketches that weren't quite right—to “*provide productive resistance*” [32:5381] to help our research group hone in on what mattered to us from our fieldwork.

Participants

We recruited participants in Seattle who own and use at least one IoT device kept within their home. We recruited participants through our personal networks, via Craigslist and Reddit, and through our university's networks. Participants were compensated with a \$25 gift card. Overall, we met with 8 households, and talked with 5 women and 5 men (age 21 to 70 years old). When recruiting, we prioritized participants with different living situations (responding to calls by [15,39,40]) as well as different amounts and types of IoT devices (between 1 and 60 items such as smart light

bulbs, smart thermostats, connected security systems including motion detectors and cameras, voice assistants, home hubs, smart plugs, etc.) in their homes, in an attempt to capture varied experiences with IoT data over other forms of diversity. Rather than finding a group of participants representative of a larger population (that would not be realistic with 10 participants), we were aiming to find interesting and unique positions, recognizing and respecting the partial quality this inevitably creates.

Home Visits

Each home visit was a single session consisting of: a Home Tour, Sketching Data, and Imaginary Data Interactions. We observed how each individual cohabitates with the IoT devices, focusing on the singular relationships between humans, home, and objects throughout to provide situated understandings and insights. Although this method does not yield the richly thick descriptions of ethnography, home tours open opportunities for researchers to enter the lifeworlds of interlocutors and to ground questions, observations and exchanges in the home itself [46]. The possibility for in situ ‘show and tell’ is also important for our work, as we aimed to understand the abstract and physical ways home dwellers engage with data.

Home Tour. After a short email exchange for screening, participants invited two researchers from the research team into their homes for 60 to 90 minutes. Together, we walked through the home and asked our interlocutors to point out each IoT device they had. For each device, we asked how and why they got it, and how they currently use it. We asked what data were associated with it, what those data look like, and how/if they engaged with those data. We also asked participants to show us which data they knew how to access. If they didn't know how to access them, we offered to investigate with them during the home visit. Participants took screenshots of these data interfaces to share with us.

Sketching Data. Having just explored the various IoT devices within their home, we then asked participants to sketch data from one or more devices. This builds on other ways of exploring network technology in the home through sketching [7,8,25] which were used to discover personal perspectives of home networks and home electronic devices. This helped us see how our interlocutors view data globally as well as in their home (amongst their things, neighbors, pets, etc.) and within their personal worldviews.

Imaginary Data Interactions. Whereas the first two activities inquired into participants' relationship to data, the final activity was designed as a primer to start opening up imaginary discussions about data, often revealing values, and hopes of our interlocutors. We built a card-based activity where participants would randomly select 3 pairs of cards, combining a verb or adjective with a noun, e.g. Thoughtful + Hammer, or Illuminate + Banana. With each participant, we tried to make short imaginary scenarios about data that could be exchanged, processed, or created using those two words as a starting point for imagination.

The sequence of research activities responded to our research questions by bridging participants' current data practices with more open and imaginary ways of being with data. We used data collected in the form of photographs, notes, audio recordings (and transcripts), interface screenshots, and participants' sketches to inform our analysis.

Analysis

We conducted two rounds of thematic analysis, using open and axial coding to help uncover and organize themes from our home visits [10]. In the first round of thematic analysis, we used open coding to reveal summative, salient, and evocative attributes from our data. In the second round, we formulated questions to direct our axial coding towards elements that would help us precisely describe the relationships between interlocutors and data. As we went through these rounds, we also used sketching as a way to further interrogate and eventually solidify our themes. Early themes included codes such as: data as other, perceived security, fidelity of data, human vs objective perception, quantified *shadow* self, data representations, and data inheritance, to name a few.

Postcards: Speculative sketches

The methods outlined above allowed us to uncover threads and idiosyncrasies in how participants encountered data. As design researchers (our studio is comprised of 1 interaction design professor, 2 graduate students in design, and 3 undergraduate students in interaction design), we also sketched speculative concepts in relation to these observations [1,49]. As mentioned previously, sketching conceptual proposals helped us solidify our findings by attempting to find physical forms and interactions that would respond to these abstract themes and become jumping off points for refractions, transformations, and improvisations of other modes of engaging with IoT data. Members of our research group were assigned themes to sketch, often building on anecdotes or quotes from participants as starting points. We shared and critiqued ideas as a group and pinned them to a wall to keep them visible to reference in future iterations. We chose five conceptual sketches, one for each theme, that we printed on postcards to share back with participants. The participants received their postcards by mail, responded to prompts in a predetermined area on the back of the postcard, then mailed them back to us. Feedback from the postcards provided additional insight (a process inspired by cultural probes, design workbooks, and zines [13,20,22,23]) which helped us imagine and explore data's unseen potentials, enriching the themes presented.

IOT DATA ENTANGLEMENTS IN THE HOME

Below, we present five themes that describe how participants engage with IoT data in their home. These themes describe usage of data, but also how data are conceptualized, and how they become part of living with connected devices at home.

Manifesting: Data's many forms

Here, we turn to the particular manifestations that either intentionally or unintentionally visualize data—for instance,

the design of user interfaces, but also less obvious things like pet behaviors or home work-arounds.

When reviewing the types of interfaces participants showed us during their home visit we saw many examples of smooth shapes, graphical representations, logs, and charts. While data visualizations often aim at presenting data in a simple, direct, and analytical manner (or smooth, as discussed in the related works), we found that these types of representations were at times not desired by home dwellers. For instance, participant Mikey (all names used are pseudonyms to ensure anonymity) commented on how he didn't like his home being represented through such analytical means, stating, "*I don't approach my home analytically... Like, it's warm in the home when I'm home... so I don't care that you're going to show me a graph that shows like, oh look, I happened to be home three days this week.*" The simple and unambiguous data representation made Mikey feel like it was redundant, that its treatment offered nothing new for him to make sense or meaning from. During our *Imaginary Data Interactions* activity, when talking about the cards 'Thoughtful' and 'Hammer' Mikey discussed how he is more interested in interpretational, or thoughtful data, than passive, list-form data. He mentioned that he would be more interested in data that helped interpret how a hammer strike impacts his home, wondering if something could tell "*how was it felt throughout the house? That's the thing that I would be very interested in because I'm always nervous about it. I don't like to hammer on things because I feel like there's repercussions and I would want to know what those repercussions are.*" This is a type of data that is more interpretive, it would be used as a means to communicate between home and home owner in a mutually transactional way instead of a passive list or graph of temperature data that shows when Mikey is or isn't home.

We also saw unexpected material and inter-species manifestations of data. In the case of Rachel, she mentioned one of her favorite features of her smart thermostat Ecobee is that she can turn down the temperature while she is on vacation, but then turn it up several hours before coming home. One of the ways she can tell the heat has been turned on when she gets home is by her cats' behaviors. She explains how the cats run back and forth from the heaters to their owners, saying "*they're, like, excited to see us but then running back and forth to the back, as you can tell, they're just sort of like, we've been so cold for so long.*" In this case the cats' behaviors are emergent manifestations of her thermostat data, which could be (and are) also represented in the accompanying app as numerical degrees, timestamps, and preferences. Rachel can 'read' those data points by being aware of her cats' movements just as one might read a graph.

In another example, with Yvan (the driving force behind his smart home with over 60 smart devices, and 3 roommates), we saw tension between physical or mechanical controls of lights and locks and their parallel smart interfaces, forcing hacks around the house. Discussing the tape over a door lock,

he states, “I had to put tape here because some people would, for the first couple months or weeks, impulsively lock the bottom [lock]. And that breaks everything because you can’t get in [via a smart lock].” In addition to tape on the door locks he also physically covered light switches to block smart bulbs from being turned on or off without a smart home app. In a home run by data, interfaces are currently either screen based or through voice, therefore prior interfaces—the hardware of the home—must be restricted and made inaccessible to all inhabitants. While this isn’t a manifestation of data points, this is the manifestation of where data flow in the home, forcing physical shifts in home hardware to assure a system that is coherent and un-glitching.

While companion apps show smooth data through rounded shapes and graphs representing a neat and clean exchange, Mikey finds these visualizations void of contextual and therefore interesting data. Yvan’s and Rachel’s examples show data that are, at times, physical, biological and hacky. This disturbs impulses to design or envision data as pure or smooth and starts to show data as situated, organic, active, enmeshed and rough.

Speculative Sketch: DR (Data Reality) Glasses

In our postcard to reflect data manifesting, we created the concept Data Reality Glasses (Fig. 1, also see supplementary materials in the ACM Digital Library for full scale postcards), a play on augmented/mixed reality. Data Reality Glasses make the unseen accumulations of data piling up in a house visible. This gives a material, organic, and active quality to representations of data which allow interpretations to emerge between the physical space of the home and the smart objects of the home. This enables us to view data almost as bacteria growing larger day by day. Responses to this sketch were mixed. Mikey took the accumulations to a literal place making them a chore to be tidied up along with dusting and straightening up the home. In a seemingly paradoxical remark, Lucy starts by discussing how Data Reality might make data more streamlined, but then writes: “it would be fascinating to watch and maybe just seeing how it all works would, in itself, direct changes in the relationships.” In this statement, she touches on how *seeing* data grow in this ambiguous and organic way has potential to inherently shift the relationship between inhabitant and

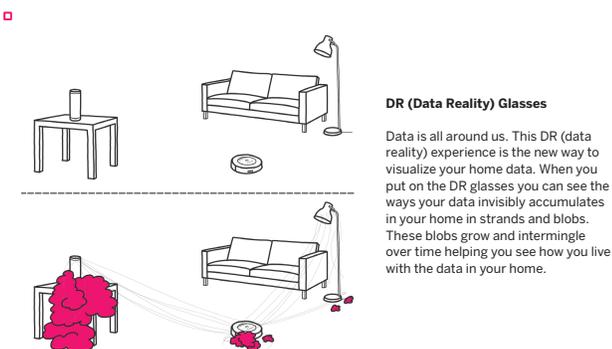


Figure 1. DR (Data Reality) Glasses

data. Acknowledging data’s many forms, first through our home visits and then by playfully exposing data’s growing accumulations through the DR glasses, helped our research team wonder if there are ways to design for more open-ended encounters between home dwellers and data.

Inquiring: Data as bread crumbs

In addition to observing how data manifest themselves in homes, we also inquired into how participants used data generated through their IoT devices, particularly in a way that could be described as a trail of ‘bread crumbs’. Bread crumbs were used to trace participants’ steps back through data logs to remember, understand and revisit previously accessed content. Following bread crumbs through personal data is facilitated by the data logs kept by devices. This type of engagement with data requires that device owners know how to (and want to) engage with those logs. While domestic IoT data is mainly desirable as a way to actuate a system (turning on the heat or cuing up a song), the logs of actuation and use are left rather undirected in terms of how they should be used.

In the simplest example of using data as bread crumbs, we saw the way that Aaron, a student living in a shared apartment, would use his record of Google Home queries to re-access recipes previously requested. When he wants to re-access the same recipe, he goes back through the transcripts of his requests on his phone instead of asking Google assistant again. This exemplifies one way that someone might use data as bread crumbs: instead of using the Google assistant’s direct interface to re-ask for something, Aaron engaged with his history of use through the data log, mostly to make sure he finds the exact recipe he was looking for.

In another example, however, we found that data logs often record glitches and can lead to unfinished narratives and unresolvable mysteries of what happened. We saw this in Mikey’s home, where he installed an IoT security system after his home was broken into. In this example, while he was away from home on vacation, Mikey’s security system took an interior photo of his home with a motion sensitive camera, signaling another possible break-in. However, it only showed the empty interior of his dining room and no other sensors were triggered by the event. Mikey described how he and his partner remotely puzzled their way through their data logs as they tried to deduce if it was a real break-in or not: “both of us... were looking at the app all the time and trying to back-rationalize... the glass break sensor didn’t turn on... the motion sensor went off but it didn’t capture anybody... so we actually had to kind of logic or puzzle our way through it” asking, “is this actually an alarm or is this just a weird false alarm?” This example shows that while the logs promise security and reliability, they can also show histories of glitches and misfires, in this case requiring Mikey to call his neighbor to check in on the house. The propensity to misfire was also discussed in relation to the glass break sensor which is often set off by loud noises such as the coffee grinder.

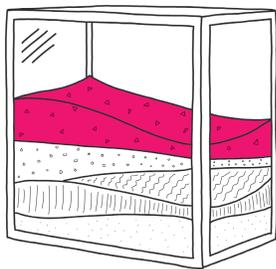
Finally, data as bread crumbs can offer traces of the conglomerate lives that interface with a single platform through a home device. For instance, when Rachel, a mother of two, uses the online music streaming platform Pandora, she can see every song that her children have verbally requested via Google Home over the course of the day spent with their caregiver. She explained that every time her kids use voice to ask for a song, their Google Home creates a new Pandora station. This makes her Pandora stations extremely repetitive and overwhelmed by her kids' music selections: "I'll go into my Pandora in my car or wherever and I'll have like 50 new stations that these guys have asked it to play." At this point she describes how she now uses her phone to access her listening history instead of using the stations, reporting that, "I'll play Pandora from my phone. It's a lot easier to do than actually requesting it." In this case, the bread crumbs are not used to navigate through the data logs, but rather the dynamic and ongoing mass of bread crumbs make data logs cluttered and unusable.

These examples highlight how bread crumbs are often used with a detailed knowledge of their larger sociotechnical landscapes. A successful navigation requires things like understanding other members who use the system, or how a home's unique quirks create the potential for false triggers. All of which are silently embedded in the logs; however, what is left behind is not a clear trail to trace back through, but rather ghostly murmurs which require situated knowledge to decipher and pursue.

Speculative sketch: Data Dunes

To respond to data as bread crumbs we created the concept Data Dunes (Fig. 2). In this concept, an imaginary product represents data as distinct layers of sand which display a stratification of historical actions. This serves as a physicalization of how bread crumbs function: as layers of data which can be seen through a log of interactions. However, in this case the data is mute and abstracted, offering a volumetric, stratified, and semi-solid layering of data which represent home dwellers' habits and interactions with the home. Interestingly, this design also gives the user the ability to manipulate the landscape (by opening the back door and displacing sand) which is a departure from data logs which endlessly track data chronologically without the possibility to revise or fix glitches or repetitive entries. In response, Aaron reflected on how this might impact

□



Data Dunes

Become an archaeologist of your data remains! Data collected from your home is represented as distinct layers of sand in a small terrarium. You can see the cross sections of your data history like a geological record supporting a deeper understanding of your data. The back of the terrarium lets you go in and manipulate the layers, removing, adding, or displacing the sand, changing the landscape forever.

Figure 2. Data Dunes

conversations with his two housemates and wondered whether he would obsessively try to manipulate his behaviors in the home to curate the data. Lucy notices the complexity of being able to shift the dunes writing, "being able to change it is like rewriting history and that just makes my brain hurt. I have even less of a clue how to deal with that." Their responses point toward new ways to think of data histories as open and malleable. Conceptualizing data as bread crumbs also opens avenues to track intersecting relationships (beyond the quantified individual self).

Exposing: Data as evidence?

The presence of data being collected in the home opens speculation and questions regarding the distinction between (objective) data and human (subjective) perception. In the following section, we describe ways in which data was used as evidence either to persuade others or to reframe participants' own ways of experiencing their home.

Aaron, a student living in a shared apartment with 2 roommates, described an incident in which previous tenants of his home used an indoor security camera to prove that their landlord was stealing from them. This motivated him to also install a smart camera in his apartment. However, Aaron rarely looks at the camera's recordings, stating "it's just kind of there, it's for insurance or security." For Aaron, knowing there is data accessible somewhere is enough to create some sense of security, something echoed by participants Samantha and Timothy as well. In both cases, while participants enjoyed the peace of mind, they were also concerned with what types of events (other than infractions) could be captured through videos of everyday moments. Aaron took measures to fully deactivate his security camera when at home, explaining: "I always just physically unplug it. There is an option to like switch it in the app. Um, but I don't use that I guess cause I don't trust it." Samantha and Timothy became cautious about having their camera operating when guests were visiting. They did not mind having the door sensor capture when guests came and went but the higher fidelity video seemed too inconsiderate to capture of guests without their permission. They were not motivated by hiding specific behaviors but instead felt uncomfortable with a detailed evidentiary record of their homes and selves.

We also observed how data as evidence can reframe everyday experiences. In an example of a participant tracking their own data every day for one year, Lucy photographed a tree that was planted between her window and a newly constructed apartment building across the street from her living room. Far from a compendium representing admiration, Lucy uses these images to prove that the tree is an abomination because it prevents her from seeing what her neighbors across the street are up to. In this instance Lucy's data take the form of images and allows for her own narrative to emerge from the album she calls 'A Tree That I Hate.' She states, "after I finished the year and then I could go back and look at it and see that it was, a) it wasn't my imagination, and

b) it wasn't as bad as I really thought it was, and c) there really is evidence.” By seeing a whole year at a glance, she uses the album to experience the tree on a different time scale. She also uses it as way to convince others for whom it may be unconceivable, to hate a tree. This quote illustrates the multifaceted roles that data play; it offers proof to her, it also reframes how much she hates the tree, and it serves as evidence to convince others.

Although data are often used to establish notions of truth, as in the previous example, they can also negate humans' sensory evidence which might contradict or complicate the narratives provided by the 'objectivity' of these systems—calling into question what *exactly* is being evidenced and how that changes its perceived authority. For example, Lucy tracked the amount of time she spent in her building's elevator over one week. She reported that over the course of that week she took the elevator 28 times, for a total of 14 minutes. Reflecting on this, Lucy was surprised, stating, “*I felt like I was wasting my life in the world's slowest elevator. I would have guessed it was at least an hour a week. Maybe I should go apologize to the elevator.*” In this case the 'evidence' showed that her previous experience of the elevator was false or wrong. Although she was not bothered by this (she even felt bad about her misinterpretation) she internalized that those data were objective and therefore overrode her bodily, and therefore subjective, sense of time.

While the evidence generated by data was used to provide feelings of insurance, protection, and awareness, and to support preferences and personal narratives, we saw how the back and forth between human perception and 'objective' data also opened a space for questioning, and reframing.

Speculative Sketch: Honest Time Blocks

In response to the findings from this section, we created the concept 'Honest Time Blocks' (Fig. 3), an object that tracks the amount of time it takes to complete a task such as tying one's shoes, boiling water, getting dressed, etc. The device then groups tasks that took a similar amount of time to complete. This information is visualized on a display where groupings of tasks are played in unison. Honest Time Blocks offer perspective through comparison, allowing both feelings of time as well as actual lengths of time to coexist. Participant's reactions to this concept echo previously mentioned critiques of the Quantified Self movement by viewing this as a tool for either self-knowledge or

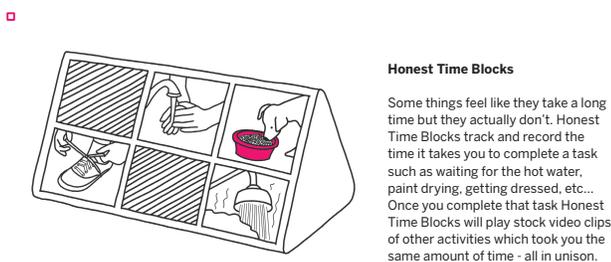


Figure 3. Honest Time Blocks

optimization. In her response, Lucy wrote, “*I spend a lot of energy worrying about being productive. This would be the perfect way to depict the reality of me easily.*” Implicitly stating that data could 'out' her as less inefficient than she thinks she is and therefore evidence the true, more real, her. Similarly, Mikey wrote, “*I feel guilty neglecting small maintenance tasks, those little things that can wait. A permanent perspective machine would compound this guilt.*” In his case, Mikey knows he often neglects these chores and thinks this outside perspective might threaten his ability to ignore those failings.

We see how data outside of their data setting (out of context) can easily assume an authoritative voice, as we observed in Lucy's elevator tracking, as well as Aaron's camera use. Yet, the tree photo album shows that a combination of human perception with the evidence of data can provoke generative or interesting experiences in the home.

Repositioning: Data through personal frames

In our study, we have encountered various ways of pushing back on the perceived objectivity and truth of data in the home. Following those lines, here we focus on how data have a partial quality for home dwellers because of their own positionality when making sense of data. In other words, inhabitants fill in the blanks of these incomplete data portraits of the home, and they do so from their own experiences, perspectives, and identities.

For example, Emily and her partner share a professional background in environmental justice that allows both of them to read their air quality monitor with a critical perspective. This professional expertise allows Emily to clarify that the air quality data tracked by her AirVisual Pro is in fact only presenting one side of air quality—particulate matter. She remarks that smoking and cooking are easily detected by the monitor: “*I boiled down the pumpkin to make pumpkin soup and that [indicator] went up. So it's not necessarily catching pollution. It's catching particulate matter.*” Her expert knowledge allows her to comment on data parameters and representations that might be more telling or helpful in understanding air quality: “*I've thought, jeez, it would be a lot better if it said, you know, pm 10, pm 2.5 particulate matter, which are measures of air quality or indicators of air quality, um, and, and things like that,*” instead of simplifying by showing a pie chart filled up to different fractions.

Past experiences were often also central in shaping participants' relationship to data and the perceived risks or implication of having certain data collected at home. For instance, Rachel's view of home data is influenced by a past relationship that involved domestic violence. For her, the actual existence of data about events or people in the home opened and engendered contradictory reactions: “*I was really glad, I was like, well, what if... this data... could be helpful for me. Um, and then, but there were also times when I was in a relationship that I was afraid that it would log information that I didn't want.*” This experience and view of domestic data for Rachel also permeates the way she

understands how tracked data shapes her children’s online identities. “As my kids get older, like kids do dumb things. Like if they ask or look up stuff on the computer like pornography or those types of stuff... like this isn't paper... it's like essentially someone could go capture that data.” Again, Rachel shows an ambivalent relation to data being collected, particularly when taken out of context (out of the context of a childhood ‘dumb thing’ or child development).

While Emily and Rachel used their own experiences to fill in the blanks around and between data and their broader settings, in the following example we see how data filled in a gap for Samantha—the gap being that we can only see ourselves with our own eyes, literally and figuratively. At night, Samantha and Timothy’s security camera captures the reflection of the kitchen (and whoever is in the kitchen) as a layer on top of what is happening in the dark backyard. While Timothy was away one weekend, Samantha was looking at the video recordings to see various ‘acts,’ and stumbled upon her own reflection—herself doing the dishes. She explains: “I kinda got like addicted to watching it when, um, when he was gone...it's super interesting to see yourself on camera when you don't, when you're not thinking about being on camera. It kinda looks like its other people. It sounds weird to say it, but...” Those data, when looked at this way, enabled Samantha to defamiliarize her own everyday mundane tasks and opened up a space to reposition herself from a perspective she can rarely access.

The examples presented above showcase how different types of experiences and histories color how data are understood and felt by participants. These participants, for example, felt a degree of protection and empowerment in their relation to these data, something that is not a given for all. Further, they illustrate how the unique positionality of not just home dwellers but data (e.g. as a tool for surveillance) also affects their lived experiences, reinforcing the contingent nature of human-data encounters in the home.

Speculative Sketch: Data Tarot Reading

In response to these findings, we created the concept ‘Data Tarot Reading’ (Fig. 4): a service where someone uses various interpreter cards to read through one’s home data. While in recent years, Tarot Cards have gained popularity as a design tool for divining product outcomes (e.g. [2,48]), our interpretations are focused on personal home data rather than commercial products. For instance, the Alchemist card mixes data sets to find new meanings, the Explorer card follows one line of data as deep as possible, the Architect card uses logic and reason to distill data, and the Oracle card reveals futures as well as hidden pasts. We proposed this concept to foreground how data are interpreted from the perspective of a particular positionality. We also wanted to show that various interpretations could co-exist even if they were divergent, once again highlighting how subjectivity might be an asset in finding deeper meaning in interpretation. In response, Lucy expressed delight: “This is a unique and very cool way to look at, explore and discover a bunch of different

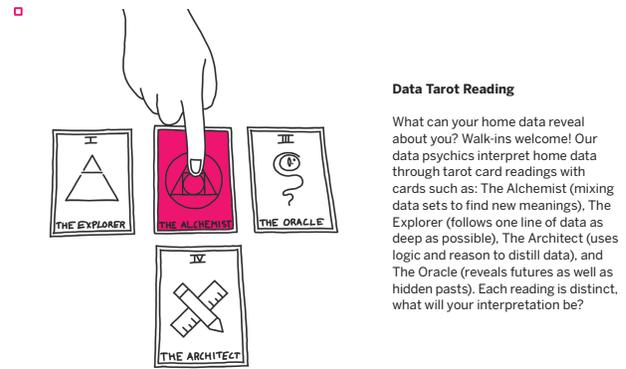


Figure 4. Data Tarot Readings

ways to mine the data collected in my house.” However, Mikey’s interest was beyond ‘mining data’, his interest was in how someone else might provide an important perspective for him to evaluate the value of the security system he installed. He writes: “is there a notion that the permanent surveillance apparatus I’ve installed in my home is actually valuable? An outsider helping me interpret this data might help understand if it’s worth it at all.” The theme of personal frames and various interpreters could lead to interesting future design proposals where positionality is acknowledged and where outside opinions might be sought after to read through home data.

Broadening: Data for others, data as others

Researchers and everyday users of domestic IoT devices have grown increasingly concerned with how data from these devices are shared, leaked, misused, or sold [42]. However, as the awareness of such issues (ex. Cambridge Analytica [6], Alexa sending private conversations to strangers [19]) grows faster than the rate at which IoT device makers divulge their data use practices, users are left to speculate and imagine what else is happening to their data. In this gap, data takes on another life—one of inflated grandeur, secrecy, or even malice. After all, how do we know where our data go, with whom they mingle, for what purpose, and what life they have beyond our walls? It is assumed that these data are not designed as part of the service, they are an afterthought for the users who generate it but the central currency for the businesses who are the real consumers.

During the activity where we asked participants to draw what they think their data looks like, Aaron’s immediate response was to ask himself out loud “what else [could] my voice be, like, relevant for?” This question was directed towards what Google might find useful, not what might be of interest to himself, his roommates, or home. Aaron does not see those data as intended for him to make meaning from or find relevance in. Instead, he sees Google using his data, in some unknown way, to better target him. He explains, “the way I see it, that data comes back to me, in the form of like services.” In Aaron’s understanding, data’s trajectories are from user to company and only back to user once they are passed through, parsed and monetized by Google.

When Timothy was describing his data sketch, he mapped his data's journey from his home, to a corporate building, to an individual tech worker who uses his data across many machines. Timothy explains: *“And this is some guy with all of these relationship databases saying [Timothy's] going in and out again! So, while I do feel like there is some service being provided here, I know that they're probably capturing every time a door or window opens up because they want to know how often the door or window goes up, when are we going in or out.”* Timothy believes that his data have the power to create connections, to build relationships as he puts it, about himself and his home. Like Aaron, Timothy sees these data as not for him, but he is sensitive not just to the power that data have but also the interpreter/s of those data. In his sketch, while databases offer a repository, it is ultimately a human who makes decisions based on and with those data.

To make some sense of these data and their particular velocities, trajectories, and immaterialities, participants often used rhetorical and cognitive devices like simile and metaphor. For example, when Samantha was asked to draw what her home data look like her immediate response was *“this is intimidating. I might not have, like, words for every emotion.”* When trying to grapple with the relationship between data's divergent nature and how that made her feel she creatively used the drawing materials themselves as an embodied metaphor to communicate these feelings. She explains how that data *“affects our environment. It feels like an unnatural environment in a natural piece of world. The markers versus the Crayons, this is like very, I don't want to say invasive, but I am going to say invasive.”* In this case, the permanent black and red lines with clean, harsh edges symbolized data. The soft, imprecise, and colorful Crayons symbolized the natural world—the world which has been invaded by this oppressive force or entity. The utensils' materiality has properties and characteristics which Samantha relied upon to communicate her feelings and thoughts about what was happening to her data.

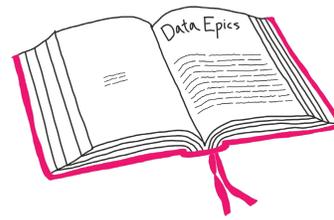
In broadening views of data, we see how data are often conceptualized as something mysterious, distant, even difficult to describe, and as something that has a life of its own, within an assemblage of services, things, and people.

Speculative Sketch: Data Epics

In response to these findings, our studio created the concept Data Epics (Fig. 5): a service where fiction writers use shared data from home IoT devices to create stories. One chapter might be about data's travels, the next their origins, who and what else they connected with, or how they changed throughout those adventures. This concept purposely accentuates data's liveliness, their separate yet dependent otherness which is at times both shadowy and curious.

Although this concept provoked reactions from participants which relate directly to the findings from the analysis, they also opened up nuances and refractions which develop this theme further. In response, Aaron wrote: *“Seeing where my*

□



Data Epics

Read about the myths, mysteries and misadventures of your data. Data sets from an IoT device in your home are shared monthly with a fiction writer. The data is translated into chapters of your Data Epic: stories about your data's origin, where it traveled, who or what it communicated with, and how it was transformed by the places it visited. The chapters are then sent back for you to read.

Figure 5. Data Epics

data goes might encourage me to utilize my home in different ways to get a new story.” Similarly, Lucy wrote *“The only down side I can think of is that I might want to start trying to manipulate the data to affect the story line. Probably that's an upside, as well. It would be fun to see what I could do with my devices and data collection to change the story line.”* Both participants expressed a nascent understanding that data are not just consumed or interpreted by the primary audience but also produced or performed by their creators and their environment. This element of fiction adds another layer of imagination that can help demystify the ways data move throughout their assemblages, and brings attention to how data evolve, seemingly on their own, as they move about, intersect with, and are interpreted within their worlds.

DISCUSSION

In our findings, we have shown how data related to home IoT devices manifest visually as well as behaviorally in the home, embodying but also pushing further Loukissas' focus on the locality of data [35]. We showed how this locality is dynamic and how data continue to grow in many forms. We also illustrated how data can act as trails to search back through information, and how data are mobile much beyond the walls of the home. These forms of data mobility broaden our understanding of data as active participants in the expanding assemblages [5,16] that make a home, portraying how, precisely, they might hold vitality. Finally, our findings also reveal how data complicate our notions of objectivity, and subjective perception, and, in turn how personal experiences influence how data are perceived and gain meaning in the home. Thus expanding on current ways of describing and critiquing data in the Quantified Self movement [36] where baselines and notions of 'normal' are often prominent. Below we offer reflections that build on those findings and point to new positions and roles for data in and about the home.

From residual to primary data

Throughout our work, we have outlined how data are rarely the main products for inhabitants in IoT services. Rather, the data that inhabitants can see and engage with are often presented as a second thought, as something that is residual to the data exchanges that happen between the home devices and service providers. While participants were still able to engage and encounter the data, we argue that these interactions could become more interesting if they were

designed to be more than residual. Our speculative sketches open doors to conceptualize how and when to make data more tangible, comparative, narrative, visible, and silent.

Although we see benefits to foregrounding data interactions within everyday home IoT, our inquiry shows how it might take on a more ‘real’ quality, forcing home dwellers to ‘deal’ with how those data are produced, where they travel, and to face who controls, handles, and manages them. The prospect of data perceptibly accumulating (as in the DR Glasses) is an unwanted burden for some participants, becoming a palpable heap to be tidied up, maintained, and kept track of. Perhaps this somewhat negative framing suggests there can be something freeing to some users about data remaining invisible, seemingly without consequence, like bills sent to the wrong address we wish were never redirected. When data remains unseen it emancipates home dwellers from these burdens, but simultaneously removes the potentially crucial possibilities to become aware, in control, and engaged with those data and associated data structures. As interactions with data become more intentional, designers will be responsible for balancing the benefits of seeing data with the unintended, but real, labor and anxieties it may impose.

Home data: Beyond reflection and self-improvement

Our work is a step towards expanding the types of encounters which are designed between domestic IoT data and inhabitants. While current discourses propose that data can be used for personal reflection, and behavior change (i.e. self-improvement), our findings suggest that encounters may also diverge from these relatively narrow ways of seeing the lively relation between people and their home data.

Diffuse ways of noticing. Current discourse on reflection and self-improvement assume they require active ways of seeing and analyzing data. However, our findings show that these moments of active data analysis are rare and that ambient ways of *being with the data* were more common in the dwellings we visited. Examples such as Rachel’s cats’ behavior show a certain way of knowing data without needing to look at the logs. This, and other diffuse ways of noticing data create space for reflective practices to emerge organically, or not, on an individual level. We suggest that in addition to making data logs open for reflection and self-improvement, when such is desired, designers might also be inspired to consider creating more diverse and situated opportunities to notice the liveliness of data as inhabitants and data co-evolve. This might expand what a data-inspired reflective practice could look like as well as acknowledge value in noticing without reflecting or acting.

Dormant data. The mere existence of data logs was sometimes enough for participants to gain peace of mind (often acting as a sort of security net), as in the case of Aaron and his security camera. Here, data play a double role: passively providing peace of mind while simultaneously offering tools for investigation, a much more pro-active and goal driven process. This presents another alternative to the promise of ongoing reflection. Rather than a steady flow of

data engagement, we see long moments of inactivity where data are entirely invisible until they are needed. Only then do data offer themselves up for analysis. These oscillations in perceptibility and engagement might inspire designers to embrace the value in those moments of silence and dormancy and treat them as a design material as much as more active and visible moments.

Imaginary leaps. While the two points above argue for stepping back from active or constant engagement with data, at last we argue for more abundant, playful, and imaginary encounters with home data. Between Lucy’s seriously silly goal of proving that there are real reasons to hate her tree, to data’s almost mystic flights as they leave the home towards service providers and corporations, we detect a hint of lightheartedness and creativity that we want to champion. Participants’ responses to the Data Epics and the Data Tarot Cards demonstrate a desire for imaginary narrative and communal interpretation as a way to potentially reconcile conflicting relationships with data. In designing interactions where people can imagine themselves in a state of ‘play’ with data (manipulating, interpreting, and imagining them flying through the air), designers might offer a reclamation of data for home dwellers.

CONCLUSION

In this paper we presented the findings and critical reflections from a design ethnography and RtD inquiry into the ways home dwellers engage with domestic IoT data. We described five emergent themes and speculative concept postcards which exposed the plural, situated, and messy ways data are entangled in and with a home, its inhabitants, and outside actors such as companies and other data. With these themes in mind we discussed the implications and advantages of designing at the extreme poles of visibility-invisibility to support diverse ways of noticing and engaging with data which move away from a central, dominant, and limited set of perspectives. Lastly, we emphasize how this work serves to reinforce domestic IoT data not as an undefined, ephemeral, position-less, and singular mass (although it might be conceptualized this way): these data are, in fact, of a home, in a home, and part of unique domestic assemblages which are important to recognize and honor when designing for them. We encourage designers to take up these themes and design *with* data in ways that are playful, imaginative, and balanced.

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