On the Making of Alternative Data Encounters: The Odd Interpreters

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Figure 1: The Odd Interpreters: Broadcast, Soft Fading and Data Bakery.

ABSTRACT

While data are the backbone for home Internet of Things' (IoT) functional and economic model, data remain elusive and abstract for home dwellers. In response, we present the Odd Interpreters (OIs): a collection of three artifacts that materialize alternative ways of engaging with IoT data in home environments. The OIs recast home data as imaginative sounds (Broadcast), fading fabric (Soft Fading), and cookie recipes (Data Bakery) with the intent to reveal the hidden human labor and material infrastructures of data and to critique data's assumed objectivity. Following a Research-through-Design approach, we unpack design events that mark our process for making the Odd Interpreters. We conclude with a discussion around the need for pluralizing data encounters, the tactic of designing between illusion and precision, and a reflection on living with the prototypes while designing.

CCS CONCEPTS

• **Human-centered computing/Interaction design**;

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1 INTRODUCTION

IoT devices are rapidly finding their way into people's everyday worlds. With projections of 30.9 billion units worldwide [126] and a global market of $1.6 trillion by 2025 [127], IoT devices—and the data they collect, use, and share—are becoming particularly entangled in everyday lives, often in intimate and private spaces like homes. While there are a multitude of home IoT devices and an even broader range of homes they exist in [35, 88], the interfaces created for home dwellers to engage their own data remain restricted by a narrow set of techno-solutionist and capitalist pressures. Home data are often presented (and understood by home dwellers) as a protective safety net [32], as a compromise for receiving the services provided by IoT companies [60, 67, 99], as a tool for self-knowledge [60, 104, 121], or as a mechanism to save money or energy [25], etc. Spreadsheets, apps, dashboards and smart recommendations associated with IoT systems are typically grounded in an objective view of data which ignores the deeply local, interpretive, and dynamic nature of data [36, 60, 75], qualities often more attuned to characteristics of home environments. The challenge is that these goals and orientation of data, while perhaps desirable on their own, create a closed set of design possibilities and foreclose exploration of other possible encounters with data that may be less about productivity or objectivity.

Our work builds on a long tradition of research in human-computer interaction (HCI) and design that investigates how people conceptualize and live with their own IoT devices and IoT data [25, 26, 66, 105, 122]. In particular, the Odd Interpreters (OIs) were designed in response to recent calls within empirical and critical research that call for diversifying data encounters [32, 88, 100] in everyday settings. In their work on Diffraction-in-Action, Sanches et al. [100] state "*Engaging data diffractively offers a way to understand data differently and reposition it as something that is lived, situated, and contextual, making designs that are closer to the entangled phenomena of being in the world.*" In other words, looking for alternatives means looking for ways to bring data back together with the material conditions of its production and the social context of its interpretation.

In this paper, we present design work that opens the door to engagements with IoT data that are open-ended, experiential, and embodied. We discuss a series of design events [89] that unfolded throughout the making of the Odd Interpreters (OIs). The OIs are research-through-design (RtD) artifacts which create experiences for people to encounter their own home data beyond questions of self-improvement, accuracy, or usability. We focus on the process of making the OIs because the process of designing 'against the grain' revealed important lessons for imagining IoT data encounters otherwise. Further, centering our process as a contribution of its own responds to recent calls in RtD scholarship for better documentation of the messy RtD processes, which can allow for a better understanding of the validity and rigor of the knowledge produced through the making of artifacts [6, 14, 24, 33, 106]. The Odd Interpreters include **Broadcast**, a wall-mounted device which plays ephemeral sounds to represent data's interwoven existence within broader infrastructures beyond the home; **Soft Fading**, a rotating fabric cylinder which collects traces of sunlight to explore analog, slow and imprecise data collection; and the **Data Bakery**, a system which transforms smart plug data into prints of cookie recipes to activate the dynamic and human labor intensive side of data systems (Fig 1). By emphasizing these alternative sides of data, we resist positioning data encounters within technosolutionist frames with the hope of creating a space for exploratory and experiential ways of being with data. This defamiliarization is meant to draw attention to data in home contexts and to encourage reflection about the broader assemblages of data and people that constitute home IoT systems.

Our methodological commitment is to Research-through-Design (RtD) [47, 125]: the material making of our conceptual ideas lead us to discover generative frictions while designing with home IoT data as a material and against the grain when it comes to the role data typically plays. We combined inspiration from design works as well as theoretical works by Science and Technology Studies (STS) scholars, philosophers, and media studies critiques of technology with the rich trial and error of 'making' with data and IoT. Our intention is to reveal what we learned about working with home IoT data in our efforts to move away from conventional data encounters centered on objectivity and productivity. We report on the making of the OIs with an attention to the process of conceptualizing, making and refining the artifacts. This approach is akin to research journeys [111] and design events [89], in the sense that it focuses on the 'through part' of RtD [33]. By purposefully exposing the messy side of our design process, our goal is to illustrate the complexities of working with data as material—in particular when aiming to design outside of conventional tropes with data.

Our contributions are as follows: (1) the OIs are unique design exemplars that pluralize and expand home data encounters, contributing to a growing repertoire of artifacts [16, 116] that start to define that design space ; (2) we articulate design events that were particularly telling with regards to revealing data's invisible infrastructures and assumed objectivity; (3) we conclude with a discussion around the need for pluralizing home data encounters, the tactic of designing between illusion and precision, and a reflection on living with the prototypes while designing.

2 RELATED WORKS: REFRAMING HOME DATA ENCOUNTERS

2.1 Discursive and speculative IoT in home environments

The Odd Interpreters contribute to a corpus of design and HCI works which speculatively and discursively reimagine home IoT, perhaps in response to a growing number of calls for action towards a more fair, ethical and appropriate IoT [44]. These works follow longer traditions in HCI and design to use ambiguity [51], defamiliarization [9], and openness to interpretation [102] as tactics to shift interactions with technology from a single focus on productivity (or technosolutionism) to multiple foci towards pause, surprise, reflection, playfulness and humor, that have the potential to align with some qualities of home life.

For instance, taking a discursive approach, researchers have questioned the homogeneous view of a home often seen as the backdrop for home IoT, and instead started to imagine IoT in the context of homes beyond a single family detached house, such as co-housing, rentals, shared living situations, and smaller or unconventional spaces [35, 66, 88]. Other works have used a discursive and ludic approach to explore themes of curiosity [49, 52], privacy [57, 93], care [68], creepiness [92], human connection [21], or voice assistants experiences [90, 97]. Of particular interest are works which position IoT as relational in home environments—exposing the ways humans and things are entwined [74], and between connected devices themselves [118]. Further, a small but growing corpus of work is particularly focused on home IoT data, with an emphasis on data legibility (e.g. the *Guess the Data* method by Kurze et al. [71]), as well as more open data narratives and open ended stories (e.g. the short fiction stories based on people's data in the *Data Epics* project [31]). Yet, these examples maintain a two dimensional representation of data (either as graphs or narratives) and the OIs emphasize an embodied, materialized encounter with data (see 2.2). Within design inquiries, design researchers also used probes [123], stories [31] and participatory activities [58, 71] to inquire into the relations between people and data, with a particular attention to modes of interpretation and perception.

Together, these works offer an expanding and diversified view of what IoT could be, emphasizing a move away from productivity to instead highlight entangled questions of pleasure and curiosity with concerns and anxieties around legibility, meaningfulness, surveillance, and privacy. The Odd Interpreters aim at further exploring not only the presence of IoT in home environments, but also the ways people might engage with IoT data, a supporting pillar of IoT.

2.2 Data materializations in domestic settings

With a simultaneous growth of data generated and with the advancements in interactive interfaces and digital fabrication, design and HCI scholars have investigated and proposed new paths for transforming data into physical representations [1, 59, 62, 65]. Data physicalizations strive for a balance between data readability [1], opportunities for self-reflection [113], and aesthetic and sensory qualities [77, 119]. By making data physical, sociologist Deborah Lupton argues that data which is always moving, always dynamic and part of various assemblages can now freeze "*providing data objects that help people make sense of their personal information*" [77]. Furthermore, this corpus of work on data physicalizations—sometimes called data visceralizations—often argue that "*multisensory experiences are richer and better understood than those that tend to emphasise only the visual dimension*" [77].

In the context of home environments, designers have been using data to create ambient displays, materializing data to raise awareness around energy usage (e.g. [25]), to visualize daily human activity (e.g. [96]), to increase situational awareness (e.g. [64]). Closest to the Odd Interpreters, we find a number of HCI and design research projects that materialize encounters with forms of data which would remain otherwise invisible, such as WiredRadio [54], the FeltRadio [55], the Desktop Odometer [115], the Morse Things [118], Gatehouse and Chatting's experiments with WiFi [46], the High Water Pants [13] and, to some extent, Dunne and Raby series in the Placebo project [39]. Furthermore, we are also inspired by Desjardins et al. [32] call for action for engagements with data that go beyond reflection and self-improvement as well as Wrifs-Brock's [120] recipes for making IoT data encounters more diversified.

The Odd Interpreters contribute three design exemplars for how to create physical, multi-sensory and visceral engagements with data, continuing to build a repertoire of nuanced takes on revisiting data encounters, and engaging with the material resistances in bringing these encounters to life. Following Gaver's definition of theory in RtD [47], we argue that it is through a large collection of examplars that we, as a community, will be able to define the design space for alternative engagements with data. Our designed artefacts both build on and extend prior work in important ways. Some of the work that inspired us include the Indoor Weather Stations [52], which offer a dynamic and immediate representation of indoor climate; the Datacatcher [48], a handheld device to engage with big data; or the Home Health Horoscope [50], which infers a home's health and encourages user interpretation. Other examples of visceral data engagements are seen in Odom et al.s work with photo and music archive meta data (e.g. [85–87]) or Desjardins and Tihanyi's ListeningCups which materialize everyday sounds in 3d printed porcelain cups [34]. The OIs extend these by allowing for longer periods of time for data collection and reflection [52], fading into the background of the home and focusing on ultra local and personal data [48], focusing on data both as and beyond an archive [85–87], and questioning directly what data are [34].

2.3 Data infrastructures, labors, and subjectivities

As a strategy to broaden IoT data encounters, we looked at scholarship in communications, media studies, and STS. These works highlight different dimensions of the broader sociotechnical contexts in which home IoT data are produced, moved, and consumed.

In *All Data Are Local* [75], Loukissas makes the argument that data are always grounded in a specific context (a place, a time, a culture, etc.) and it is impossible to make sense of these datasets if they are disconnected from their data setting. In the same vein, D'Ignazio and Klein, in *Data Feminism* [36], articulate how any data interpretation is subjective and especially how data visualizations are non-neutral. They argue for acknowledging the positionality of the people who are doing data science work (or any data interpretation), may it be in the collection, processing or visualization of data. They state "*Rather than viewing these positionalities as threats or as influences that might have biased our work, we embraced them as offering a set of valuable perspectives that could frame our work.*" [36:83]. Recognizing how data are situated in a context and molded through interpretation is key to going beyond the promise of data as neutral and solution oriented, and instead enter a space more rich and telling.

Furthermore, Sun-ha Hong [60] outlines how data are not perfect or clean or neutral. Hong interrogates how certain aspects of human life cannot be quantified, let alone datafied. He also refers to Bateson's [8] concept of warm data, data that can accommodate for the humanness of humans, data which by definition are "*less legible, calculable, manipulable and profitable*" [60:192]. When considering the private context of a home, these concepts of imperfection, humanness and locality resonate strongly and become important starting points to reimagine data encounters with people in their homes, as shown in [68].

Last, we draw on STS literature in infrastructure studies that reminds us that technical systems such as home IoT devices require specific social, political, and knowledge practices throughout development, implementation, operation, and maintenance [18, 41, 72]. While infrastructure is often invisible, it can be revealed in moments of breakdown [107], as an expression of political power [70, 72], or as a deliberate object of scholarly inquiry [17]. Surfacing these infrastructures means appreciating the ways that humans, machines, and environment are entangled in large systems. From an environmental perspective, the material infrastructure of IoT has real and scalar impact on climate change, such as undersea cables impacting marine life [108], to data centers consuming enormous amounts of electricity [37], IoT data are not simply 'in the cloud'. In addition, the human labor that supports everyday use of IoT systems is often downplayed in front-end experiences. Much of the intelligence imbued in IoT systems is not completely autonomous and requires humans—sometimes referred to as ghost workers [53]—to train models for machine learning (ML) and artificial intelligence (AI), the backbone of many IoT services like voice assistants. In *Atlas of AI* [27], Crawford describes the extractive nature of the labor pulled from low-cost information workers, labor that supports many of the intelligent systems behind IoT [4, 78, 91, 99]. Exposing the infrastructures behind IoT systems to home dwellers is a strategy we used with the OIs to broaden people's encounters with data that are beyond immediate concerns of usability or productivity. We hypothesize that by connecting data with its own material mesh, we are able to offer a new perspective for home dwellers to consider. Some design researchers have started to explore ways to engage with data infrastructure, for instance Barnett et al.'s experiment with Data Intermediaries (between people and infrastructure) in a pictorial of conceptual sketches [7]. The OIs further build on these ideas by creating fully functional artifacts.

3 METHODOLOGICAL APPROACH

We see the OIs as artifacts that invite the experience of data encounters that are intimate, polysemic, and multi-sensory in home environments. Our goal is to create space for engagements with data that allow home dwellers to consider data as a multifaceted phenomenon that goes far beyond their home or the IoT service they use. We specifically focus on revealing data's material infrastructure and hidden labor, as well as data's entangled relation to the common imaginary of data as objective and productive.

Our methodological approach builds on the traditions of discursive design [112], speculative design [5, 40, 81] and research-through-design (RtD) [47, 110, 125], but also responds to newer calls for making speculation more consequential and experiential [23, 43, 117]. In this paper, we share our process of designing and making the OIs. We particularly focus on the 'through' parts of RtD, as Desjardins and Key [33] note, to work through segments of our process that did not feel like a straight path yet yielded insights about how to design with IoT data as a material. The ability to discuss the messy, trial and error side of RtD is crucial when working against the grain of convention, as friction may be the most interesting part of the process. We also use Oogjes and Wakkary's idea of 'design events' as a scaffold for our analysis, as design events focus on particular moments within a project, without "*structure[ing] them by finished designs or samples.*" [89]. Our approach responds to recent calls for more transparent and honest documentation of RtD processes [6, 24, 98] and clearer articulation of intermediate level knowledge within design projects [6]. Within these calls, researchers have argued that rigor, in RtD, comes from a strong "chain of reasoning"[14,24,29], which connects design decisions towards the making of an artifact. While researchers have proposed methods for documenting RtD processes (e.g. critical journal / contextual portfolio [98], annotated portfolio [16], design events [89], etc.), this form of dissemination for RtD work still remains rare.

In addition, we interweave stories of iterative making with moments of living with the prototypes in our homes while we were refining them, further foregrounding our actual RtD process. Similarly to Odom et al.'s approach of the designer-researcher [87], and autobiographical design [30, 33, 83], our approach allows us to acknowledge and interpret our first-hand experiences with the artifacts. While autobiographical design relies on designing for a researcher's genuine need, our approach is closer to Odom et al.'s idea of designer-researcher which harnesses a "*first-hand account of key insights emerging through our process*"[87]. We chose a first-person research methodology [30, 42, 76, 83] because it allowed us to immerse ourselves in and document the messy RtD journey we were on. It allowed for a constant awareness of the process as we continued tinkering, debugging, and making adjustments to the Odd Interpreters [30, 83] while living with them. This offered an opportunity for our team to observe the designed behaviors unfold over long periods of time and to surface and work through unanticipated ethical considerations with the systems we designed [103] (see 3.3). A first-person approach also satisfied our own curiosity: while we had spent months developing the Odd Interpreters, it was hard to imagine how it would be to experience them over time, as part of our everyday routines.

3.1 Project background and context

Our team at Studio Tilt, a design research studio at University of Washington, Seattle, USA, is composed of a professor in interaction design, three graduate students in design, information science, and engineering, and five undergraduate students in design. During the concept development and prototyping phases, our studio was split into three sub teams, each responsible for one OI. In addition to team work sessions, we followed the format of a Directed Research Group (DRG) [114] where we met weekly for two hours to share progress, conduct critique and make decisions on next steps.

In addition to being inspired by STS literature broadening common understandings of data (as outlined in 2.3), we were intrigued by Desjardins et al.'s descriptions of novel data encounters [32]

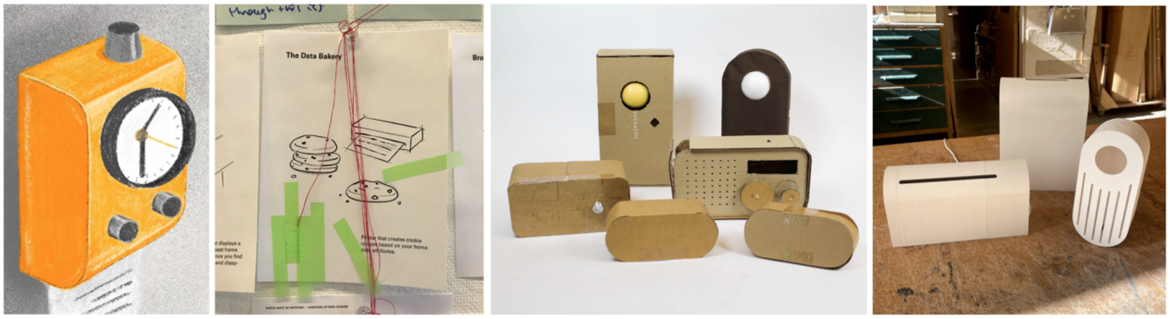

Figure 2: From left to right: Early sketches of Broadcast and Data Bakery; Form and function cardboard prototyping for Broadcast; 3D printed cases

as well as provocative views of what alternative IoT could be [35, 66, 68, 71, 88]. From this scholarship, we chose three concepts as starting points for sketching: **Diffuse ways of noticing,** which refer to slow, imprecise, and maybe unproductive ways of capturing data; **Imaginary leaps**, which reveal the broader material infrastructures data traverse during their journeys to and from a home; and **Performative ways of knowing**, which explores active ways of engaging the human labor behind data. We conducted three rounds of open and divergent sketching (Fig 2) adding up to over 100 sketches before doing a session of editing where we chose three concepts to develop:

- *Broadcast*: using sound to depict imaginary leaps beyond the home, focusing on data travel.
- *Soft Fading*: an analog data collection device to notice sunlight on faded fabric
- *Data Bakery*: an embodied and performative act for translating data into baked cookies.

With three directions in mind, our studio spent multiple group sessions dissecting, contextualizing, and adjusting our concepts so that they could stand alone but be companions to one another. Our making process moved from sketches and cardboard prototypes to hardware, code, and 3D prints (Fig 2).

3.2 Documenting the RtD process

Following Research-through-Design (RtD) practice [33, 47, 125], we documented the design process and the making process through weekly notes, photos of sketches and prototypes, videos of prototyped interactions, share-out presentations, and notes on debugging. After the prototypes were completed, we created a template for taking notes three times a week on our experiences living with the OIs (inspired by [12, 69, 98]), including a prompt for writing and a space for images and captions (as per Mackey's commitments when doing first-person research [80]). Along the way we shared our experiences and concluded with an exchange with the rest of our research studio to discuss our final impressions. Inspired by duoethnography [101] (a type of first-person method that invites researchers to compare their first-person experiences via dialogue), we organized our experiences of living with the prototypes in parallel so we could create dialogues between our households. Duoethnography is based on dialogic relations between the lived experiences of two or more researchers. The intent is to juxtapose various voices to highlight similarities and reflect on differences in experiences.

Each discussion was recorded, transcribed, and analyzed alongside our written/photographic notes. Prior to living with the OIs, we sought approval and guidance from our university IRB board and used consent forms within our own team to make sure studio members were comfortable with documenting their at-home experiences. We also prepared a consent form with information about the project for the people living with us at home (partners, roommates, family members). While they were not interviewed or required to reflect on the OIs, we sought consent in case we discussed their reactions while living with the OIs or if they wanted to provide feedback on their experience.

To ground our experiences living with the OIs, Table 1 describes our team's positionality and living situations at the time of the study. As a team, our experience with IoT devices at home ranged from no devices at all to a small ecosystem of smart bulbs and outdoor camera. Our own experiences of home, data, and IoT are partial and subjective, and influenced how we designed and experienced the OIs.

3.3 Ethical considerations while working with personal and home data

In our design process, we were intentional about the way the OIs would collect home IoT data and aimed at emphasizing privacy and security in the systems we built. Soft Fading is simple; it does not connect to WiFi and does not collect digital data. Broadcast only records a 30 second snippet of encrypted packet metadata (the timestamp and the source and destination addresses) related to a connected smart speaker before deleting it. Data Bakery is a more complex system: data is recorded by using the third-party service IFTTT [63] and a Google Spreadsheet. We investigated these services' policies and consulted with our technology department to assess what protections and risks were involved when using these services. For both Data Bakery and Broadcast, we needed to collect a home WiFi's name (SSID) and password, while Broadcast required the MAC address for the smart speaker. Each of these data were saved locally on each device and deleted after engagements were completed. Finally, Data Bakery required remote login to the networked printer, which was performed by a studio member with consent from the home dwellers.

Table 1: Design team for the Odd Interpreters

Pseudonym	Self description	Home	OI lived with
Audrey	North American professor in interaction design, white cisgendered woman	Renting, single family house, lives with husband	Broadcast Soft Fading
Chandler	North American college student studying interaction design, cisgendered man	Renting, one-bedroom apartment, lives with his partner and pet dog	Broadcast Soft Fading
Jena	Student in interaction design, white cisgendered woman	Owns, single family house, lives with partner, two cats and a roommate living in a detached apartment	Data Bakery
Philbert	University senior studying visual communication design, Asian man	Renting, living along, on-campus student housing	Data Bakery
Ruby	Visual communication design university student, white non-binary trans person	Renting, two bedroom apartment, living with their partner and cat	Broadcast Soft Fading
Justin	White-passing biracial cisgendered male	Renting a room in a house with three roommates	Did not live with an OI
Yuna	North American college student in interaction design, Korean-American cisgendered woman	Living with her family in a suburban single family house	Did not live with an OI

3.4 Analysis

We analyzed our templates and our discussions from living with the OIs, as well as our weekly meeting notes, in progress presentation slide decks, sketches, photos, and videos from our design and making processes. Our review process allowed us to trace back key conceptual, functional, and technical decisions and tease apart lessons learned when designing alternative encounters with IoT data. Throughout our analysis, we flagged data that helped us answer the questions: How do the OIs help imagine IoT data encounters differently? How do the OIs create friction with existing IoT systems and data structures? We conducted one round of thematic analysis [20] to identify main themes and followed a process of open and then axial coding. Below, we present the Odd Interpreters, the design rationales that led our process and the design decisions we made as we were designing alternative encounters with home data.

Table 2: 14 designed sounds for Broadcast[a]

Data Location	Data Movement
Data Center (1)	Uplifting, Spacious, Welcoming (2)
Desert (3)	Exciting, Adventurous, Playful (4)
Home (5)	Curious, Fraternizing (6)
Space (7)	Busy, Energetic, Buzzing (8)
Stock Market (9)	Dense, Clustered, Lively (10)
Tubes (11)	Congested, Teeming, Clogged (12)
Underwater (13)	Immense, Overwhelming, Rapid (14)

The sounds are played from top to bottom, alternating between Data Location and Data Movement.

[a] The sound files are added as supplemental materials to this submission, for those who might want to listen.

4 THE ODD INTERPRETERS: CONCEPT DESCRIPTION

4.1 Broadcast: Using sound to expose material data infrastructure

Broadcast (Fig 3) is a device that tunes into the network traffic related to a smart speaker (such as Google Home or Amazon Echo Dot) and represents the traffic into imaginative sounds that an occupant can hear once a day. Smart speaker data (including utterances in audio and transcribed format, with metadata) are often imagined as part of a recorded archive 'somewhere' in a distant data center. By design, Broadcast moves away from this type of encounter and instead fosters a more immediate connection to the broader infrastructure surrounding voice assistants and their data.

Broadcast highlights how data travel and where they are physically situated, including through data centers, connecting wires, fibers and more. Since it is difficult for occupants to perceive these infrastructures, with Broadcast we chose to use imaginative sounds as an analogy to represent this liveliness of data as they travel to and from the device [10, 19, 77, 79]. We collaborated with a sound designer to generate sounds that are recognizable yet odd, with the intention to keep a level of curiosity and 'otherness'. With the collection of sounds in *Data Location*, Broadcast inspires people to think about where data are stored (like in a data center) or the physical spaces that data encounters through its travels (like underwater cables, satellites in space, or tubes underground). The collection *Data Movement* represents the speed and intensity of data's movement and reveals the infrastructures that made travel possible: some movements are more congested such as travelling through data centers or dense cities, while other movements are more uplifting or adventurous (see Table 2). We were inspired by vivid texts reporting on Internet and data infrastructure when designing the sounds such as [15, 22, 37, 61, 109].

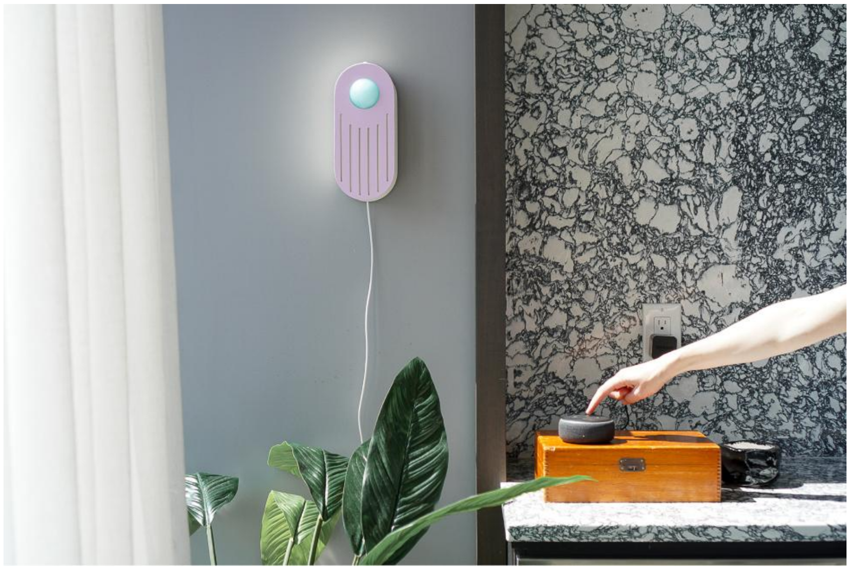

Figure 3: Broadcast alerts home dwellers when data are received or sent via a smart speaker in the home. Once a day, people can 'catch' an imaginative sound that represents data traveling.

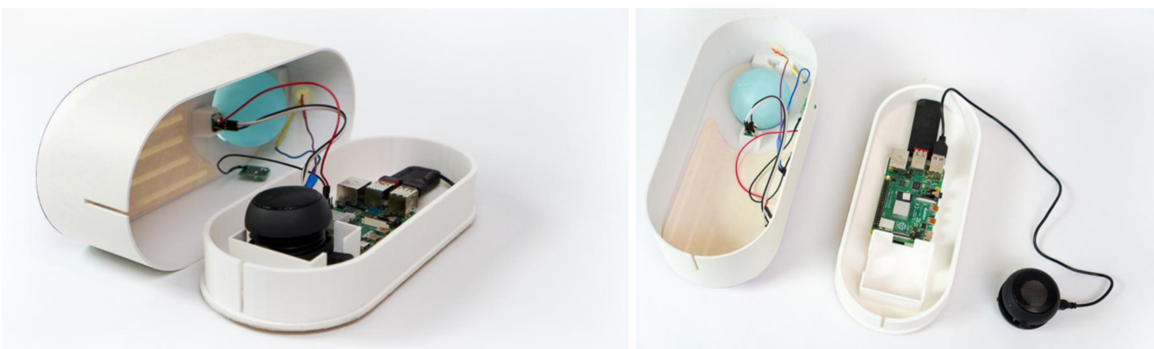

Figure 4: Broadcast is comprised of a Raspberry Pi microcontroller, a small speaker, and a 20-pin rotary encoder attached to the blue resin sphere.

4.1.1 How does Broadcast work? While Broadcast's sounds are imaginative and pre-recorded, they come into play only when actual voice assistant data is sensed in the home. Broadcast offers two ways of interacting with network data. First, every time a data packet to or from the smart speaker is detected, Broadcast's small top light gently glows, indicating that data are moving through the home. Second, once a day, people can listen to a data sound when Broadcast senses smart speaker traffic. When that occurs, the light on top of Broadcast blinks vividly, letting the person know a sound is accessible to play. From there, the person can turn the blue sphere. As though they were tuning in a radio station, they first hear static noise. As they turn the sphere and get closer, the data sound will become crisper while the static noise fades away. Once the turn they sphere on to the sound, the sound clip plays for 30 seconds. This ephemerality is important to demonstrate how data are always moving. Once a sound has been 'caught', no other sounds are accessible that day. If a sound is not caught in within 10 minutes, it might become accessible later that day once more data travels through the smart speaker.

The sequence of 14 sounds is pre-scripted and do not depend on the type of data sent or received. Broadcast recognizes that data packets *are moving*—but does not read them. Over the course of 14 sounds script, the congestion of *Data Movement*'s sound design progressively intensifies, and *Data Location* sounds are played in the order presented in Table 2. This rhythm allows for a slowed timeline to reflect on constantly travelling smart speaker data.

From a technical perspective, Broadcast captures the smart speaker's network activity by sensing data packets (see Fig 4 for internal components). First, we added a USB network adapter to our Raspberry Pi 4 and set the adapter to monitor mode, which enables local monitoring of nearby wireless network traffic packets. Broadcast uses the Linux version of the *tcpdump* library [128], a command-line packet analyzer, to record 30 seconds of network traffic packets to a text file, then searches this file for the device's

Figure 5: Soft Fading is an analog device that slowly collects sunlight data on a cylinder of revolving turmeric dyed fabric.

MAC address. Packets that contain a smart speaker's MAC address indicate data are currently traveling to or from the smart speaker. While our original goal was to avoid recording any traffic data for privacy reasons, the Raspberry Pi was computationally limited in its ability to filter sensed network traffic while also operating the light, sounds, and ball. As a result, we chose to temporarily record traffic data, search through that data, then delete the data.

4.2 Soft Fading: Analog capture to emphasize data's locality

While Broadcast draws attention to smart devices' relationship to broader data infrastructures, Soft Fading reinterprets what data capture might mean in the context of the home. Soft Fading (Fig 5) is a device that collects sunlight in a home over long periods of time. The sunlight is recorded as faded sections on a piece of fabric. Data collection in the context of home IoT is often regarded as objective, precise, and instant. In contrast, Soft Fading turns this convention on its head and instead offers an analog, local, and layered experience by embracing blurred edges and imprecision both in data collection and interpretation. By attending to softer ways of being with data, we also find resonance with Nora Bateson's concept of warm data: "*contextually and relationally rich forms of information that might be more accommodating of human contradictions and inconsistencies*" [8]. Our analog device, as Sun-ha Hong might put it, collects "*knowledge that is not easily datafied—the affects, the interrelations, the lived experiences, the tacit knowledge*" [60].

Soft Fading completes one rotation per day. In doing so, it purposefully superimposes every day's data on top of the past days, creating a layered archive of sunlight data. Over time, common patterns have a strong imprint on the fabric (e.g. the approximate time of sunrise or sunset), but more irregular moments will have only a subtle impact on the fabric (e.g. opening or closing blinds). Following the principles of Slow Technology [56, 84], Soft Fading refrains from constantly requiring attention from the user and instead uses its slow pace to fade in the background while slowly building anticipation. Soft Fading intentionally stands in stark contrast to Broadcast's high interaction requirements.

We chose sunlight as an input in order to experiment with the less dataifiable elements and subtle changes of a home. Sunlight can be experienced almost everywhere on Earth, and yet how it affects a home remains unique and local—the light one home experiences can be drastically different than light found in a home a few doors down depending on the shape of the house, window placement, trees, etc. We were fascinated by the natural process of fading, like a faded section of a post-it note sticking out of a book, standing as a trace of time passing (also see [38]). Finally, we point out the connection to Gaver et al.'s Light Collector [52], which has a similar purpose: to capture the changes in the light of a home. While Gaver used a digital sensor, we chose an analog route to purposefully question the process of data collection, described below.

4.2.1 *How does Soft Fading work?*

Soft Fading consists of a cylinder wrapped in turmeric dyed fabric. This cylinder is attached to a stepper motor controlled by an Arduino, which turns one full rotation per day (Fig 6). The fabric's fading is a natural process that happens when fabrics are exposed to UV rays. Dying the fabric ourselves with turmeric and without fixatives allowed the fabric to fade at a faster rate than commercial options (Fig 7). Using Soft Fading is simple: once the fabric is installed, the occupant positions the device in a place that can receive some sunlight (e.g. by a window) and orients the open slot towards the sun for a maximal chance of fading. Occupants can decide how long to leave Soft Fading in the same position, knowing that the longer they wait, the more fading will occur.

Figure 6: Soft Fading includes a rotating internal cylinder, onto which turmeric dyed fabric is secured with two elastic bands.

Figure 7: Left: Fabrics for testing fading. Center: original swatches with madder root and turmeric on three types of fabrics. Right top: original turmeric swatch. Right bottom: faded turmeric swatch after six and a half weeks in a window exposed to UV rays.

4.3 Data Bakery: Engaging human performance and labor in data meaning making

As a collection, we wanted the Odd Interpreters to offer a range of reflections on living with data at home. Broadcast focuses on the broad data infrastructures beyond the home and Soft Fading emphasizes the act of data collection as an analog, imperfect, and slow process. With Data Bakery, we aimed at creating space for the occupant to engage their own labor in the interpretation process with IoT data. Data Bakery (Fig 8) is a system that provides a cookie recipe based on smart plug data in a home. Data are often perceived as passive, in the background, and are kept "just in case" they are needed [32]. With this artifact, we bring data to the forefront and create a performative way of encountering one's home data: by baking them into cookies.

The act of reading the recipe, measuring precisely the ingredients, deciding whether or not to alter the recipe, and eating the cookies are meant to offer experientially tactile and gustatory ways to reflect on data [59, 62]. The cookies are materialized representations of living in a home with smart plugs. With the Odd Interpreters, we have aimed at expressing data (often seen as hard, objective and scientific) with some softer sides of home environments such as fabric (Soft Fading) and more ambiguous elements such as sound (Broadcast). Along those lines, baking cookies further plays with acts of home making that may be familiar to some occupants.

4.3.1 How does Data Bakery work? Data Bakery consists of a printer, five smart plugs, and a recipe booklet/guide. Creating a recipe begins with placing smart plugs in areas of interest around the home, perhaps to gain insight into their electronic objects. Through a third party app (IFTTT [63]) and Google spreadsheets, we log when the smart plugs are turned on or off (Fig 9). After recording two weeks' worth of smart plug data, a studio member (Philbert) manually translates that data into a recipe using a simple set of rules (or algorithm, Fig 10). Philbert's involvement was central to the concept: keeping a human touch in the process allowed us to think through concepts of human error and human interpretation [4, 28, 53].

Figure 8: Data Bakery prints a cookie recipe based on smart plug home data.

	A	B	C
1	Socket Switched on at April 26, 2021 at 04:41PM		
2	Socket Switched on at April 26, 2021 at 04:42PM		
3	Socket Switched on at April 27, 2021 at 07:30PM		
4	Socket Switched on at April 28, 2021 at 08:23PM		
5	Socket Switched on at April 29, 2021 at 09:04PM		
6	Socket Switched on at April 30, 2021 at 09:12PM		
7	Socket Switched on at May 1, 2021 at 04:42PM		
8	Socket Switched on at May 2, 2021 at 10:27PM		
9	Socket Switched on at May 3, 2021 at 09:00PM		
10	Socket Switched on at May 4, 2021 at 08:28PM		
11	Socket Switched on at May 5, 2021 at 08:54PM		
12	Socket Switched on at May 6, 2021 at 08:16PM		
13	Socket Switched on at May 7, 2021 at 07:36PM		
14	Socket Switched on at May 7, 2021 at 09:57PM		
15	Socket Switched on at May 7, 2021 at 10:02PM		
16	Socket Switched on at May 8, 2021 at 09:00PM		
17	Socket Switched on at May 10, 2021 at 09:19PM		
18	Socket Switched on at May 11, 2021 at 06:49PM		
19	Socket Switched on at May 14, 2021 at 09:42PM		
20	Socket Switched on at May 16, 2021 at 08:34PM		
21	Socket Switched on at May 16, 2021 at 10:58PM		
22	Socket Switched on at May 17, 2021 at 09:11PM		
23	Socket Switched on at May 18, 2021 at 09:00PM		
24	Socket Switched on at May 20, 2021 at 10:49PM		
25	Socket Switched on at May 21, 2021 at 07:05PM		
26	Socket Switched on at May 23, 2021 at 08:21PM		
27	Socket Switched on at May 24, 2021 at 08:42PM		
28	Socket Switched on at May 25, 2021 at 08:52PM		
29	Socket Switched on at May 26, 2021 at 08:56PM		
30	Socket Switched on at May 27, 2021 at 08:42PM		
31	Socket Switched on at May 27, 2021 at 09:52PM		
32	Socket Switched on at May 27, 2021 at 09:52PM		
33	Socket Switched on at May 27, 2021 at 09:52PM		
34	Socket Switched on at May 27, 2021 at 09:52PM		
35	Socket Switched on at May 27, 2021 at 09:52PM		
36	Socket Switched on at May 27, 2021 at 09:53PM		
37	Socket Switched on at May 27, 2021 at 09:53PM		
38	Socket Switched on at May 28, 2021 at 09:31PM		
39	Socket Switched on at May 29, 2021 at 09:08PM		
40	Socket Switched on at May 30, 2021 at 07:16PM		
41	Socket Switched on at May 31, 2021 at 01:24AM		
42	Socket Switched on at May 31, 2021 at 07:57PM		
43	Socket Switched on at June 1, 2021 at 09:01PM		
44	Socket Switched on at June 3, 2021 at 07:54PM		

Figure 9: Google spreadsheet 'raw data' listing timestamps for each time this smart plug was turned on.

Data Bakery records smart plug interactions in two-week intervals. First, it establishes a baseline of usage activity (the total number of times the smart plugs were (de)activated) over the first two weeks of living with Data Bakery, then compares subsequent usage activity with that baseline to determine cookie ingredients. The example in Figure 10 shows the baseline for white sugar is 0.5 cups when a plug is (de)activated 49 total times. The following week Data Bakery observed 37 (de)activations (Plug Count), leading to 0.38 cups of white sugar (Variable Output). The variables that change in the recipe are the cookie texture (based on the proportion of sugar, flour, egg, and butter), the ball size, the topping type (like almonds or candy cane chunks), the seasoning type (like matcha, cinnamon, cayenne, etc.), and the topping/seasoning amount. Some combinations might be delicious, others might be more questionable.

The recipe amounts were then remotely sent to the printer (Fig 11) by Philbert using VNCViewer, allowing the home dwellers to create their data cookies. We designed a bespoke recipe book (Fig 12) to collect the recipes and give context to the numbers printed by the Data Bakery. In the form of a mad lib, the printed numbers complete a recipe template already in the book's pages, which orchestrated surprise and a sense of 'reveal' while performing with the data.

5 EXPERIENCES IN MAKING AND LIVING WITH THE ODD INTERPRETERS

In this paper, we do not focus on the full process of designing and making the OIs. Instead, in this section, we highlight six design events [89] which help us qualify our designed alternative encounters of home IoT data. As Oogjes and Wakkary state, design events allow us to stay with the "ongoing-ness and dynamic nature" [89] of design research, qualities that are particularly relevant

	Butter	Eggs	Vanilla	White Sugar	Brown Sugar	Flour	Salt	Baking Soda	Topping Amount	Topping type	Seasoning Amount	Seasoning type	Dough Ball Size	Bake Time
	Tbsp	*Egg*	*Tbsp*	*Cup*	*Cup*	*Cup*	*Tsp*	*Tsp*	*Cup*		*Tbsp*		*Inches*	*Minutes*
BASELINE PLUG COUNT														
Plug Min:	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plug Med:	49	49	49	49	49	49	49	49	47	85	47	55	35	0
Plug Max:	98	98	98	98	98	98	98	98	94	170	94	110	70	0
TRANSLATION FROM PLUG COUNT TO RECIPE QUANTITIES														
Variable Min:	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Variable Med:	1.5	2	1	0.5	1	2	0.5	0.5	2	5	1	5	3	11
Variable Max:	3	4	2	1	2	4	1	1	4	10	2	10	6	14
THIS RECIPE														
Plug Count:	37	37	37	37	37	37	37	37	25	40	25	40	26	26
Variable Output:	1.13	1.51	0.76	0.38	0.76	1.51	0.38	0.38	1.06	2	0.53	4	2.23	10.23

	Topping		Seasoning
1)	Crushed Pretzels	1)	Cinnamon
2)	Raisins	2)	Ginger
3)	Candied Oranges	3)	Cayenne Pepper
4)	Popcorn	4)	Clove
5)	Chocolate Chips	5)	Cocoa Powder
6)	Almonds	6)	Lemon Zest
7)	Candy Cane	7)	Matcha Powder
8)	Coconut Shavings	8)	Turmeric
9)	Sprinkles	9)	Oregano
10)	Macademia Nuts	10)	Pumpkin Spice

Figure 10: This spreadsheet was our 'algorithm' for converting smart plug usage into amounts for a cookie recipe. The first three lines (Plug Min, Med and Max) are established the first two weeks, as a baseline. For each subsequent dataset, we input the Plug Count in row 9. This count is compared to the baseline (Plug Med) and generates the Variable Output (in yellow). The output also indicates which topping and seasoning to be used, from 1) to 10).

Figure 11: Left: Data Bakery includes a small WiFi connected printer that prints the recipe amounts for a cookie recipe (right).

Figure 12: The Data Bakery recipe book. Small pill shaped holes are cut through pages to let the information on the prints shine through and complete the recipe.

for our work, as the design, making and living-with were deeply intertwined. Further, this focus on the 'through' part of RtD [33] is relevant to demystifying both the conceptual, but also material and infrastructural complexities of designing data encounters that go beyond a technosolutionist framing. It is through these precise descriptions that we demonstrate the validity and rigor of our RtD work, and that we offer solid anchors for others to build upon.

5.1 Richness in the process: Anticipation while capturing sunlight

One of the first things we noticed while living with the Odd Interpreters was a de-emphasis of the final data archive and a renewed attention to the active process of capturing data, which also came with a new sense of *anticipating* data. It became apparent to us that data were being collected but we did not have access to them at all times. While some IoT services focus on always-available data, restraint (also see [94]) proved to be a generative tool for bringing more awareness to data. A clear example of anticipating data is illustrated in Soft Fading. Since occupants are unable to see the effects of the sunlight until weeks or months later, they spent more time imagining what the fabric would eventually look like. For months Ruby, Audrey, and Chandler pondered on the subject of sunlight; its locality, its intensity, and the movements they made within their home. They questioned data, even worrying about their fabric's outcome, as Ruby said, "My biggest worry was that the sun would fade the fabric beyond any recognition, so much so that no lines of data would be present." Further speculation involved directing attention to one's environment, as Ruby writes,

> "*I had been imagining the fading pattern on Soft Fading to be sort of geometric, with gradients of stripes. But seeing this leaf's shadow makes me wonder about how my little desk environment will imprint its data onto the fabric? Looking more closely at this photo [13], I notice that my plant's pot is reflecting light onto the window. I forgot that light can bounce around! And even the little folds and wrinkles on the fabric are creating shadows and patterns.*"

By having Soft Fading withhold instant access to data it forced Ruby to confront 'data' as it was happening, long before seeing the actual imprint on the fabric (which we get to in section 5.4). Audrey

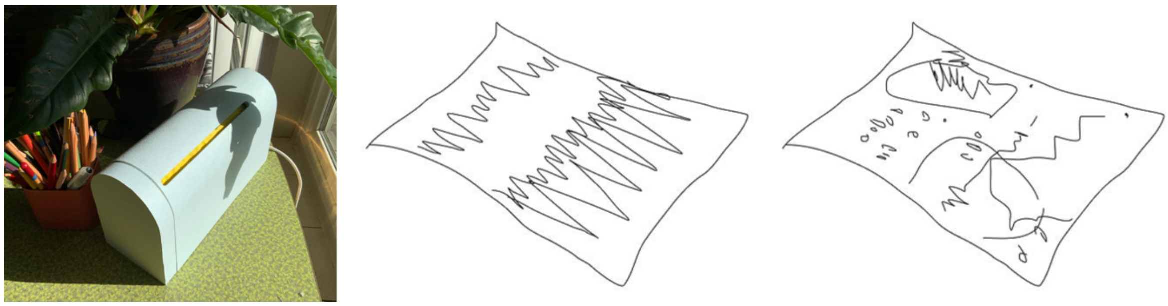

Figure 13: (Left) Ruby's plant casts a shadow on Soft Fading, potentially impacting the data collection in Soft Fading. (Center) Ruby's drawing: what they thought the fabric would look like at the beginning, and (Right) then revised after a few weeks of living with Soft Fading.

had a similar encounter with data, one that happened when she was not even in the home. She wrote, "It was so hot during our vacation, the sun was really strong, it made me wonder a bit - how much is this intensity impacting Soft Fading? What will the fabric look like?" These anticipatory and imaginative moments cast data in a new light, one where occupants need to carefully consider the conditions in which data are produced to envision data coming into existence.

5.2 Revealing infrastructure: Unpredictable patterns with Broadcast

While most IoT devices aim at hiding background processes to prioritize end user desires and needs, with Broadcast we intentionally augment smart speakers with a new device whose only function is to show when data are traveling to and from the device. This idea offers an important departure from common narratives of seeing data as 'in the background' [60, 75] and instead use this characteristic of data as a jumping off point to connect singular IoT devices to the broader (data) systems they exist in.

Both Audrey and Chandler described anxiety over "missing" sounds while they were out of the home, and rushing (sometimes running!) to the device when they heard the static or noticed the flashing light indicator. This combination of ephemerality and unpredictability led occupants to describe their interactions with Broadcast as "catching" sounds and data. While some sounds were heard clearly, other times "it was so quick. I only caught the last glimpse and then it was gone" (Audrey). This example expresses a sense of resignation: that nothing can be done to listen longer or catch a sound better, because the data represented has already moved on, and the intersection with the human world has disappeared.

We initially envisioned Broadcast would only actuate when an occupant interacted with a smart speaker—an assumption based on common promotional and instructional materials from Amazon and Google and shared with many users of voice assistants [73]. However, implementing and debugging Broadcast introduced practical and technical revelations. During debugging, we found that voice assistants consistently and periodically send data packets, often to addresses related to the service provider (e.g., Amazon or Google) or to other network devices such as the router. While these were likely routine synchronizing activities, we also found some voice assistants send a packet after the device appears to have completely powered down. These discoveries challenged both our understanding of how networks and devices operate and required us to revisit Broadcast's design.

At home, this discovery made the constant communication of networked devices material by actuating at unexpected times. This uncertainty led occupants to periodically attend to Broadcast's light (Audrey: "*giving little glances*") or to intentionally trigger Broadcast by interacting with the smart speaker. While Broadcast reliably captured packets after interactions with the smart speaker, many packets were not generated by human activity but by machines. Through Broadcast, occupants were able to both confirm that the smart speaker was sending packets without human activity, then to speculate at both the data and devices implicated in streams of "*invisible*" data (Chandler). Audrey was reminded that, even when out of the house, "*the house is still there, doing its thing, sending and receiving data, no matter what we do*". Through both designing and living with Broadcast, the persistent motion of network traffic packets were made experiential.

5.3 Embodied and experiential: Making cookies for meaning making

Once data are collected, a question of 'what to do with the data' remains. It is often understood that data are cleaned, prepared, organized, and visualized to generate a certain meaning. With the Odd Interpreters, we aimed at making that process of manipulation tangible in interactions with the artifacts. The most obvious example is the manipulation of data in Data Bakery—once a recipe is printed, it is up to the user to perform the recipe to the best of their ability (often inserting new human interpretation or error in the process).

Data Bakery offers home dwellers a novel route for understanding, and manipulating, their home data. Even interpreting a new Data Bakery recipe first requires a step of manipulation, since without the context of the recipe book the print feels nonhuman and ambiguous. Numbers float intermittently across the page and are disrupted with two words only: the topping type and the seasoning spice. After receiving her first print, Jena wrote "*The first thing I looked for was topping and mix-in type. I found myself placing more*

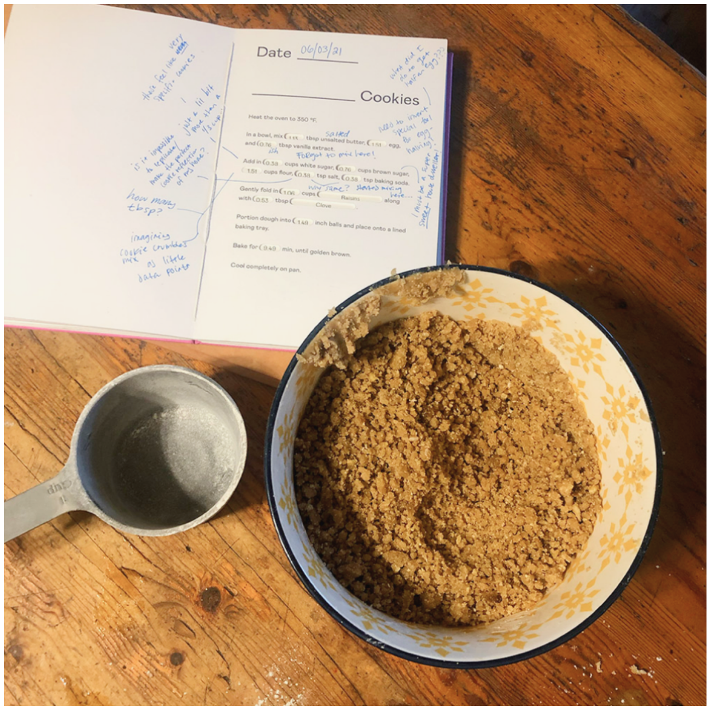

Figure 14: Jena's Annotated Data Bakery Book

priority on their relative plugs than others. I laughed at raisins, because I really wanted a wacky topping and I don't hate raisins, but I don't love them."

When placing the recipe into the book to reveal the correlation between data points and ingredients, Jena reflected "*What did I do to get half (0.51) an egg? Need to invent special tool for egg halving!*" In her process of interpretation, Jena annotated the recipes directly in the book (Fig 14), to make sense of the strange quantities presented on the print, but also to make these abstract numbers into actionable instructions in the kitchen. While baking is often seen as a precise activity, it isn't at the level of precision required by the Data Bakery print. In her annotations, we can see adaptations: "*0.76-ish tbsp vanilla extract*", where the "ish" suggests an approximation. We also see replacements: instead of unsalted butter, Jena used salted butter because this is what she had at home. Again, the rigidity of the data is confronted with the realities of her home, forcing further manipulation and making tangible the process of data cleaning or adjusting.

5.4 Aiming for Softer Edges: The Challenges of Precision

Part of our goals with revisiting home data encounters was to create space for capturing data that is not 'hard' but instead that can represent the affective and lived experiences within a home. With Soft Fading, we particularly aimed for slow impressions of sunlight. The making process of Soft Fading revealed an important dilemma in the fabrication of a tool for data collection. While our intention was to create an artifact that could generate soft, imprecise, and open to interpretation data (hence our choice of an analog approach), we were still faced with a need for a high level of precision to accomplish the basic functionality of our artifact. For instance, it was critical that the same fabric section to be exposed at the same time everyday. Our stepper motor has exactly 200 rotor teeth, meaning that each revolution would need to take 200 steps at precisely 1.8°rotation per step. In order to have the fabric line up after 24 hours (360°) we had to have the motor take one step every 7.2 minutes (432 seconds). While in theory this should work, in reality a small misalignment over a long period of time (weeks or months) would mean that any data interpretation would be skewed. We saw a certain irony in the need to fabricate a very precise instrument to collect something that was meant to be read and interpreted imprecisely.

Once we started to live with Soft Fading, this contrast became even more pronounced. In one of Audrey's early reflections she wrote, "*I plugged in SF at my desk. I put a dot on one of the elastic bands, and noted the time, to see if it would really turn in 24 hours.*" She continues "*After a couple days, the cylinder was still turning on time, which was very impressive.*" Curiously Audrey describes the precise turning of Soft Fading as impressive, already hinting at a doubt over the device's precision. Ruby also noted the rotating of Soft Fading, "*Sometimes when I'm working I'll hear the little tsssk of the cylinder turning. [. . .] Soft Fading is like its own little clock, telling time in 7 minute increments.*" The precision of soft Soft Fading is once again emphasized , similar to a clock. Both Audrey and Ruby's attention to the precision of the device highlight the connection between the instrument of data collection and the value and accuracy of the data collected—which was necessary to attain an 'effortless' feeling of softness (imprecision) on the faded fabric.

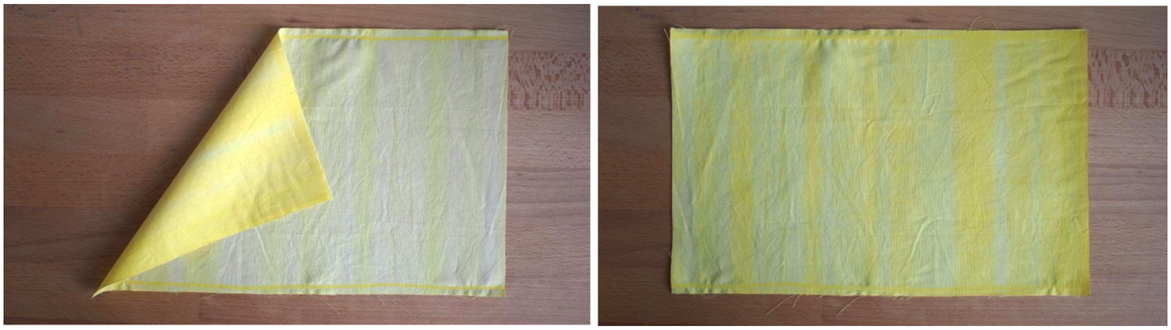

Figure 15: Front and back of the piece of fabric created in Audrey's home over two months.

Once Ruby and Audrey had taken their pieces of fabric out of Soft Fading (Fig 15), both had similar questions when looking at irregular stripe patterns: why are there so many stripes? why is this not a simple gradient at sunrise and sunset? Ruby wondered if this was caused by their plant casting shadows on Soft Fading. Audrey retraced the patterns of light coming in through her window, even noting light bouncing off the neighbor's house. They questioned the accuracy of Soft Fading. Had the cylinder stopped rotating for a few days? Is that why there was a very faded band here? Reading the final piece of fabric requires interpreting multiple layers of events: the house conditions, what Soft Fading's hardware was doing, what the participants were doing, how the UV rays were changing day to day. It becomes impossible to discern the various factors. The tension between the precise turns and the messy data collection was finally manifested.

After some investigation, we found that the revolving cylinder was slipping on the motor's axle causing a mismatch in fading. Before deploying Soft Fading into Chandler's home, we implemented a fix by designing a new hexagonal end piece for the cylinder that properly attached to the stepper motor and prevented slipping. The fabric generated from Chandler's home was closer to our original hypothesis: that sections exposed closer to noon would be most faded while areas exposed at night would remain bright yellow (Fig 16). This experience made it clear that the building of instruments for data collection are central to the data generated and impact how we might eventually interpret data. In this case, we saw how data manipulation can start even before any data are collected at all, just in the design (and glitches or mistakes) of an instrument.

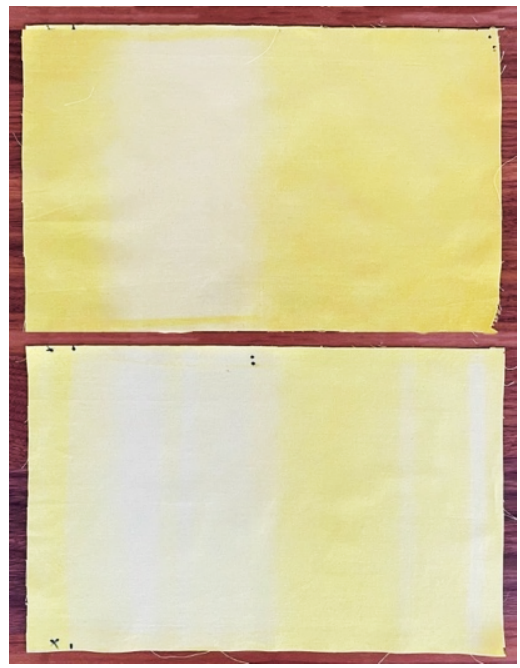

Figure 16: More consistent fading after two experiments at Chandler's house, after adjusting the end piece. Top: November 9, 2021 to January 8, 2022; Bottom: May 28, 2022 to August 21, 2022.

5.5 The human in the machine: Layers of labor

The actions directed by the Data Bakery help us make experiential the layers of labor involved in collecting, living with, and translating data that are otherwise intentionally hidden in mainstream IoT device systems. Collecting data, according to convention, is ideally done with minimal effort and with no personal connection to the ways in which it is translated and presented back to a user [36]. In contrast, the data collected with Data Bakery is not automatically rendered into digestible charts or visualizations, but is instead sent to Philbert who takes the time to semi-manually transform the data into a recipe: pluging the On/Off data into the algorithm spreadsheet, applying the decimal numbers to an image file, and then sending the file to be printed at the home through Data Bakery's networked printer.

While living with Data Bakery, Jena reflected on the comparison between automated and human translations:

> "*My expectation was that it would feel like an autonomous system. My data gets sent to Bakery and then I get a recipe and that's it. But it really became more of a pen pal system with acts of care between me and Philbert and that's where the magic happened. It wasn't because this magic algorithm was making judgments about my home dwelling, it was because I now have this very dispersed system between my home, a friend*

> *of mine, and the Bakery, which was not what I was expecting at all.*"

While we originally wanted to keep an element of human labor in the project, we did not anticipate that 'the human in the machine' would become a feature of the system that would draw as much attention as it did for Jena. Even as we tried to 'hide' Philbert's labor during Jena's experience, our technical debugging sessions and troubles with WiFi connectivity made Philbert's labor visible.

When the first printout arrived, Jena reflected on additional layers of labor required in order to interpret the recipe. In reference to having to fill out the baseline guide she stated "It felt like I had to provide for the Bakery before it provided for me." The acts of performativity we described in 5.3 are also moments of labor enacted by Jena. Not only did she need to interpret the recipe, but she had to actively go to the store and buy ingredients, physically make dough, roll it into balls, and bake the cookies.

With the Data Bakery, we were able to interrogate multiple levels of labor within an IoT system, from Philbert's processing tasks, to our team's debugging process and Jena's care for the smart plugs, the book, and the prints, and her baking activities. We can imagine in a future iteration of this project also inquiring into labor directly at the services we used (IFTTT and Google), as a way to continue mapping hidden labors in IoT.

5.6 Expansive and imagined: In contrast with the material realities of WiFi

The Odd Interpreters allowed us to enter the worlds of data and to imagine what might be happening behind the scenes. With Broadcast, Chandler and Audrey responded to the sonic representations of data by describing the sounds in terms of quality (e.g., "fast", "energetic", "airy") and location (e.g., "another world", "on a beach", "in the water", "in a large mechanical workshop or warehouse"). Using these interpretations, Audrey imagined her data traveling to and through unobvious locations: "what underwater cable it's taking". Chandler noted that Broadcast emphasized that "data is on journeys not just [at] destinations. . . it travels far". While we had designed two types of sounds (location and movement), the distinction between the two types was not as obvious as we had expected. Nevertheless, the images and imaginaries they provoked touched on both location and movement (as seen above).

While living with Broadcast offered an expansive view on where data might be in the world, echoing Yanni Loukissas' point that 'all data are local' [75], developing and debugging Broadcast emphasized this idea even more. As Broadcast lived in multiple homes, we realized it had different behaviors in different homes—in fact, each home had a different amounts of WiFi traffic as part of their techno-landscape.

Data's local quality became very evident in our development of Broadcast, in particular when monitoring the real movement of smart speaker data. In addition to showing how data are constantly moving in and out of smart speakers, our work with Broadcast also emphasized that home networks are deeply situational and contingent. Fabricating Broadcast required collaboration between developers and designers. As a practical consequence, Broadcast was connected and tested within homes, dorms, or apartments of designers and developers. While we imagined Broadcast would behave consistently in home networks, each WiFi network provided unique challenges during debugging, leaving a unique imprint on Broadcast's software. In homes where the smart speaker was physically distant from a network access point, we observed the smart speaker shifting between 2.4ghz and 5ghz WiFi. This required us to expand monitoring to both network bands. We also noticed performance drops in home networks with low signal-to-noise ratios (or a large number of adjacent networked devices). Exposing Broadcast to different amounts of network traffic helped expose performance bottlenecks in our software architecture. To account for differences in performance, we adjusted Broadcast to be over-responsive in homes with high noise and conversely, less responsive in homes with low noise. The experiences of designing, implementing, and living with Broadcast highlights that, while networks are built on shared protocols and technologies, each home network has unique contours and specifics that Broadcast had to accommodate.

6 DISCUSSION

6.1 Pluralizing data engagements at home

The Odd Interpreters (OIs) offer three alternatives to conventional home IoT data encounters. Pluralizing home data encounters is crucial for understanding the expanding breadth, reach, concerns, and potential of home data, and more broadly human interactions with IoT devices and systems. In the context of IoT, recent manifestos have called for such visibility: "*IoT product[s] will always be part of 'a complex, ambiguous and invisible network' and insists that parties associated with an IoT product are made explicit and visible: 'Our responsibility is to make the dynamics among those parties more visible and understandable to everyone'*" [44]. We are still only at the beginning of these types of entangled lives between humans, IoT data and home, and we contend that imaginative and experiential ways of being with data is a powerful starting point to challenge common assumptions or conventions about IoT home data. Through our design, making, and living-with experiences, insights point to a plurality of ways to engage with home data. Broadcast pulls the imagination towards data's distant places and other worldly movements; Soft Fading breaks convention with the perfection of digital data and instead surfaces the local, contextual, and situated nature of data collection and interpretation; and Data Bakery actively commands attention towards the many layers of often invisible labor involved in data interpretation and processing.

We wish to further examine the learnings that come from making visible, and experiential, something as abstract, opaque, and fleeting as IoT data. Our project intentionally aimed at bringing IoT data closer to humans in their homes as a way to resist current frames of datafication as 'out there', bringing data back on the "*horizon of individual experience and knowability*" [60]. In essence, this is an ontological project: how might we know data in our homes? The question here is not what can data tell us about ourselves or our homes (as data visualizations or materializations offer), but instead what tools, or tactics, do we need to know data better? We see this 'knowability' of data as a crucial step towards other important goals such as data literacy and agency around issues of privacy and ownership [44]. Without knowing data first, understanding data's implications might become even more arduous. Yet, knowing data is not a simple task—data are many things at once. In the words of Hong, data "*serve as evidence but also as objects of mystery. They are credited with radical transparency but also generate speculation and uncertainty*" [60]. We conclude with one last reflection from Audrey while living with Broadcast:

> "*Over the weekend we were paddle boarding in bays of salt water. No waves. Clear water. I could see this whole other world under me. The sea cucumbers. The algae. The fish. The seals. The starfish. The sand dollars. All just doing their thing as I was gliding above them. And just like that I thought of Broadcast and how it's like a similar window into another world. Except the sounds are imagined. But it's still letting me know another world is there and it brushes up against my world at home.*"

'Gliding above' and a 'window into another world' are evocative metaphors that are perhaps exactly the needed starting points for thinking about data as something we live next to in our homes. With a multiplicity of open-ended data engagements, we argue that each person could come to create these kinds of links with data, starting to build rich imaginaries about the intersecting worlds of humans and data.

6.2 Designing with IoT data: Between Illusion and Precision

As a second point of discussion, we reflect back on the challenge of designing with IoT data while incorporating inspiration from scholarly counternarratives about data. Our project displays a combination of ways to navigate the line between illusion and precision with data. With Broadcast's imaginary sounds, we aimed at representing data flows through sound. Here, imagination seemed to carry a power of representation that allowed visualizing other worlds. Discussing the intersection of fact and fiction, Wynants argues "*the power of a text, an image, or a work of art may lie precisely in its presentation of a worldview*" [124]. Yet, Broadcast goes one step further by threading these imagined sounds to real data traffic from a smart speaker. As a design principle, we prioritized grounding imaginative visions of data with technically 'true' movement of data. We found that this could be a generative space for capturing people's attention, while also bringing attention to the reality of data flows and pointing to existing sociomaterial infrastructure where smart speaker data continuously flow. In the design process, while we had spent hours conceptualizing, developing, and critiquing the imaginary sounds of Broadcast, one of our biggest revelations came from the engagement with the locality of WiFi networks. Broadcast's tumultuous debugging process was the result of our misunderstanding of the local factors that could influence its workings: we had not anticipated the differences in WiFi noise between homes. We found ourselves in somewhat of a paradoxical situation: we had been able to design the imaginative and abstract representations of data with a high level of precision (even prescripting the sequence of sounds to be played), and yet for this 'show' or 'illusion' to work in the context of a home, we were confronted with the invisibility, confusing opacity, and required specificity of WiFi network operation.

For designers aiming to represent the softer, more humanistic, and more ambiguous data of the home, tensions with precision might also emerge. As we saw with Soft Fading, maintaining the illusion of softness and effortlessness (no attention is needed until it is time to open the casing) required problem solving and a high degree of attention to the tool's precision. For the fabric of Soft Fading to tell its own story, as designers we had to make sure that the data collection instrument we had built was precise, or as Wynants proposes: "*Fact and fiction coincide in this game of make believe, meaning that a fictional story can be composed entirely of empirical truths*" [124]. For Soft Fading, the smallest misalignment could undermine months of sunlight collection.

Finally, breaking the illusion of artificial intelligence and data processing (as with Philbert's labor in the Data Bakery) opened a space for Jena to have another kind of relationship (she described it as a pen-pal-esque relation) with the algorithmic systems which often analyze and process data. We debated how much Philbert's labor needed to be foregrounded, and, in the end, it was the material constraints of the printer, plugs, and WiFi networks that determined how much of his labor was visible to the occupant.

Our design events further contribute to current design research discourse by bringing attention to the very material complexities of making something inspired by the concepts of ambiguity [51], openness to interpretation [102], defamiliarization [9], and non-deterministic art practices [3]. These material complexities were even more amplified when trying to materialize what STS scholars express when theorizing the human labor or material infrastructure of data or when critiquing the narrow focus on data's objectivity. For other researchers or designers using IoT data as a material for design or who are aiming at creating alternative data engagements, we want to foreground this tactic of balancing illusion and precision, as for us this was one of the only ways we were able to enact our desired design values as well as our theoretical inspirations.

6.3 About living with the Odd Interpreters while making them

The Odd Interpreters not only weave together illusion with IoT data infrastructures and structures of labor, they specifically did this work in the local context of our own homes—further weaving another layer of real, material, and social everyday life. We build on Loukissas' idea of engaging with data locally: "*More experimentally, reading locally can mean imagining how data might be seen in new ways, using speculative yet nevertheless locally imagined modes of visualization*" [75]. Here, we further ask: As design researchers, what does it mean to engage with data locally *while* we are designing and refining artifacts? This local engagement transforms not only our understanding of our own data, but of data as a design material within a local assemblage. These local—and by extension situated and partial—encounters with data also ask that we treat the designer, the team, and the home/studio as situated and partial as well.

An important aspect of our methodological approach was to have members of the studio live with the three Ois in parallel: at the same time, but in different homes[1]. In that way, discussions

[1]While living with the OIs had a significant impact on how we articulate and understand these alternative encouters with home IoT data, we note that future work will include

were possible between those living with Broadcast, Soft Fading and Data Bakery. The partiality of each view was nicely augmented by the other partial views within our group, via our discussions and the reading of each other's filled in reflection templates. Similar to duoethnography [45, 101], we noted moments of difference and contrast which allowed us to further refine the qualities of the interactions desired in each artifact. This adds a new layer to how Neustaedter and Sengers described fast tinkering in autobiographical design: "an extensive period of tinkering with the design, making frequent small changes based on what they experienced" [83:517]. Here, this fast tinkering was able to change hands and include more than one designer's needs or perspectives (as well as home configurations). This was not only valuable technically for our work, but also conceptually as it encouraged extensive verbalization of what it felt like to be with the OIs in a home.

7 CONCLUSION

In this paper, we presented the Odd Interpreters: three artifacts that materialize alternative ways of engaging with Internet of Things (IoT) data in home environment. As data materializations, these artifacts not only allow occupants to further understand parts of their home environments, but also jolt their sense of "knowability" towards data beyond existing conventions. By weaving imagination with precision, and illusion amongst truth, new pluralities of encounters and relationships begin to emerge. Together, the OIs render experiential some timely critiques and concerns of IoT: infrastructure invisibility, assumed objectivity, and hidden human labor. Through our RtD practice, we engaged directly in working closely with data and building new ontological bridges between home, IoT data and human. We hope that this work will further discussions within the design research and HCI communities around how we, as designers and researchers, know data (as plural, layered, diversified, part of infrastructures, and enmeshed with human labor) and how we embed data in present and future interactions.

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REFERENCES

[1] Jason Alexander, Yvonne Jansen, Kasper Hornb\a ek, Johan Kildal, and Abhijit Karnik. 2015. Exploring the Challenges of Making Data Physical. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA '15), ACM, New York, NY, USA, 2417–2420. DOI:https://doi.org/10.1145/2702613.2702659

[2] Tawfiq Ammari, Jofish Kaye, Janice Y. Tsai, and Frank Bentley. 2019. Music, Search, and IoT: How People (Really) Use Voice Assistants. *ACM Trans. Comput.-Hum. Interact.* 26, 3 (April 2019), 1–28. DOI:https://doi.org/10.1145/3311956

[3] Kristina Andersen, Laura Devendorf, James Pierce, Ron Wakkary, and Daniela K. Rosner. 2018. Disruptive Improvisations: Making Use of Non-Deterministic Art Practices in HCI. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI EA '18), ACM, New York, NY, USA, W11:1-W11:8. DOI:https://doi.org/10.1145/3170427.3170630

deployments into participants' homes beyond our design team to investigate how others will live with them (but that this was beyond the scope of this paper).

[4] Neda Atanasoski and Kalindi Vora. 2019. 3. Automation and the Invisible Service Function: Toward an "Artificial Artificial Intelligence." In *Surrogate Humanity: Race, Robots, and the Politics of Technological Futures*. Duke University Press, 87–107. DOI:https://doi.org/10.1515/9781478004455-005

[5] James Auger. 2013. Speculative design: crafting the speculation. *Digital Creativity* 24, 1 (March 2013), 11–35. DOI:https://doi.org/10.1080/14626268.2013.767276

[6] Jeffrey Bardzell, Shaowen Bardzell, Peter Dalsgaard, Shad Gross, and Kim Halskov. 2016. Documenting the Research Through Design Process. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (DIS '16), ACM, New York, NY, USA, 96–107. DOI:https://doi.org/10.1145/2901790.2901859

[7] Samuel Barnett, Nico Brand, William Odom, and Kaitlyn Andres. 2022. Exploring Data Intermediaries as Infrastructure for a Human-Centric Data Economy: Speculations & Critical Reflections. In *Nordic Human-Computer Interaction Conference* (NordiCHI '22), Association for Computing Machinery, New York, NY, USA, 1–20. DOI:https://doi.org/10.1145/3546155.3547286

[8] Nora Bateson. 2017. Warm Data | Hacker Noon. *Hackernoon*. Retrieved September 6, 2021 from https://hackernoon.com/warm-data-9f0fcd2a828c

[9] Genevieve Bell, Mark Blythe, and Phoebe Sengers. 2005. Making by making strange: Defamiliarization and the design of domestic technologies. *ACM Trans. Comput.-Hum. Interact.* 12, 2 (June 2005), 149–173. DOI:https://doi.org/10.1145/1067860.1067862

[10] Jane Bennett. 2009. *Vibrant Matter: A Political Ecology of Things*. Duke University Press. DOI:https://doi.org/10.1215/9780822391623

[11] Frank Bentley, Chris Luvogt, Max Silverman, Rushani Wirasinghe, Brooke White, and Danielle Lottrjdge. 2018. Understanding the Long-Term Use of Smart Speaker Assistants. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3 (September 2018), 1–24. DOI:https://doi.org/10.1145/3264901

[12] Heidi R. Biggs, Jeffrey Bardzell, and Shaowen Bardzell. 2021. Watching Myself Watching Birds: Abjection, Ecological Thinking, and Posthuman Design. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–16. Retrieved January 12, 2022 from http://doi.org/10.1145/3411764.3445329

[13] Heidi R. Biggs and Audrey Desjardins. 2020. High Water Pants: Designing Embodied Environmental Speculation. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI '20), Association for Computing Machinery, Honolulu, HI, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376429

[14] Michael A. R. Biggs and Daniela Büchler. 2007. Rigor and Practice-based Research. *Design Issues* 23, 3 (2007), 62–69.

[15] Andrew Blum. 2013. *Tubes: A Journey to the Center of the Internet* (Reprint edition ed.). Ecco, New York.

[16] John Bowers. 2012. The Logic of Annotated Portfolios: Communicating the Value of "Research Through Design." In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), ACM, New York, NY, USA, 68–77. DOI:https://doi.org/10.1145/2317956.2317968

[17] Geoffrey C. Bowker, Karen Baker, Florence Millerand, and David Ribes. 2010. Toward Information Infrastructure Studies: Ways of Knowing in a Networked Environment. In *International Handbook of Internet Research*, Jeremy Hunsinger, Lisbeth Klastrup and Matthew Allen (eds.). Springer Netherlands, Dordrecht, 97–117. DOI:https://doi.org/10.1007/978-1-4020-9789-8_5

[18] Geoffrey C. Bowker and Susan Leigh Star. 1999. *Sorting Things Out: Classification and Its Consequences*. MIT Press, Cambridge, MA, USA.

[19] Rosi Braidotti. 2018. A Theoretical Framework for the Critical Posthumanities, A Theoretical Framework for the Critical Posthumanities. *Theory, Culture & Society* (May 2018), 0263276418771486. DOI:https://doi.org/10.1177/0263276418771486

[20] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (January 2006), 77–101. DOI:https://doi.org/10.1191/1478088706qp063oa

[21] Margot Brereton, Alessandro Soro, Kate Vaisutis, and Paul Roe. 2015. The Messaging Kettle: Prototyping Connection over a Distance Between Adult Children and Older Parents. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), ACM, New York, NY, USA, 713–716. DOI:https://doi.org/10.1145/2702123.2702462

[22] Ingrid Burrington. 2016. *Networks of New York: An Illustrated Field Guide to Urban Internet Infrastructure* (Illustrated edition ed.). Melville House, Brooklyn.

[23] Stuart Candy and Jake Dunagan. 2017. Designing an experiential scenario: The People Who Vanished. *Futures* 86, (February 2017), 136–153. DOI:https://doi.org/10.1016/j.futures.2016.05.006

[24] Caroline Claisse, Daniela Petrelli, and Nick Dulake. 2019. Design synthesis: An act of Research through Design. DOI:https://doi.org/10.6084/m9.figshare.7855826.v1

[25] Enrico Costanza, Joel E. Fischer, James A. Colley, Tom Rodden, Sarvapali D. Ramchurn, and Nicholas R. Jennings. 2014. Doing the Laundry with Agents: A Field Trial of a Future Smart Energy System in the Home. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '14), ACM, New York, NY, USA, 813–822. DOI:https://doi.org/10.1145/2556288.2557167

[26] Andy Crabtree and Richard Mortier. 2015. Human Data Interaction: Historical Lessons from Social Studies and CSCW. In *ECSCW 2015: Proceedings of the 14th European Conference on Computer Supported Cooperative Work, 19-23 September*

2015, Oslo, Norway, Springer International Publishing, Cham, 3–21. DOI:https://doi.org/10.1007/978-3-319-20499-4_1
[27] Kate Crawford. 2021. *Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence*. Yale University Press, New Haven.
[28] Kate Crawford and Vladan Joler. 2018. Anatomy of an AI System. *Anatomy of an AI System*. Retrieved February 21, 2021 from http://www.anatomyof.ai
[29] Peter Dalsgaard and Kim Halskov. 2012. Reflective Design Documentation. In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), ACM, New York, NY, USA, 428–437. DOI:https://doi.org/10.1145/2317956.2318020
[30] Audrey Desjardins and Aubree Ball. 2018. Revealing Tensions in Autobiographical Design in HCI. In *Proceedings of the 2018 Designing Interactive Systems Conference* (DIS '18), ACM, New York, NY, USA, 753–764. DOI:https://doi.org/10.1145/3196709.3196781
[31] Audrey Desjardins and Heidi R. Biggs. 2021. Data Epics: Embarking on Literary Journeys with Home Internet of Things Data. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, ACM Press, New York.
[32] Audrey Desjardins, Heidi R. Biggs, Cayla Key, and Jeremy E. Viny. 2020. IoT Data in the Home: Observing Entanglements and Drawing New Encounters. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI '20), Association for Computing Machinery, Honolulu, HI, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376342
[33] Audrey Desjardins and Cayla Key. 2020. Parallels, Tangents, and Loops: Reflections on the "Through" Part of RtD. In *Proceedings of the 2020 ACM on Designing Interactive Systems Conference* (DIS '20), Association for Computing Machinery, Eindhoven, Netherlands, 2133–2147. DOI:https://doi.org/10.1145/3357236.3395586
[34] Audrey Desjardins and Timea Tihanyi. 2019. ListeningCups: A Case of Data Tactility and Data Stories. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (DIS '19), ACM, New York, NY, USA, 147–160. DOI:https://doi.org/10.1145/3322276.3323694
[35] Audrey Desjardins, Jeremy E. Viny, Cayla Key, and Nouela Johnston. 2019. Alternative Avenues for IoT: Designing with Non-Stereotypical Homes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19), ACM, New York, NY, USA, 351:1-351:13. DOI:https://doi.org/10.1145/3290605.3300581
[36] Catherine D'Ignazio and Lauren F. Klein. 2020. *Data Feminism*. MIT Press.
[37] Monika Dommann, Scherwin Bajka, Sascha Deboni, Kijan Espahangizi, Lena Kaufmann, Moritz Mahr, Ioana Marinica, and Silvia Berger Ziauddin. 2020. *Data Centers: Edges of a Wired Nation*. Lars Müller Publishers/Collegium Helveticum, Zürich.
[38] Tao Dong, Mark S. Ackerman, and Mark W. Newman. 2014. "If These Walls Could Talk": Designing with Memories of Places. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (DIS '14), ACM, New York, NY, USA, 63–72. DOI:https://doi.org/10.1145/2598510.2598605
[39] Anthony Dunne and Fiona Raby. 2001. *Design Noir: The Secret Life of Electronic Objects*. Springer.
[40] Anthony Dunne and Fiona Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press.
[41] Paul N. Edwards, Steven J. Jackson, Geoffrey C. Bowker, and Cory P. Knobel. 2007. *Understanding Infrastructure: Dynamics, Tensions, and Design*. Retrieved September 8, 2021 from http://deepblue.lib.umich.edu/handle/2027.42/49353
[42] Carolyn Ellis, Tony E. Adams, and Arthur P. Bochner. 2010. Autoethnography: An Overview. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* 12, 1 (November 2010). Retrieved October 31, 2014 from http://www.qualitative-research.net/index.php/fqs/article/view/1589
[43] Chris Elsden, David Chatting, Abigail C. Durrant, Andrew Garbett, Bettina Nissen, John Vines, and David S. Kirk. 2017. On Speculative Enactments. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17), ACM, New York, NY, USA, 5386–5399. DOI:https://doi.org/10.1145/3025453.3025503
[44] Ester Fritsch, Irina Shklovski, and Rachel Douglas-Jones. 2018. Calling for a Revolution: An Analysis of IoT Manifestos. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18), ACM, New York, NY, USA, 302:1-302:13. DOI:https://doi.org/10.1145/3173574.3173876
[45] Patricia Garcia and Marika Cifor. 2019. Expanding Our Reflexive Toolbox: Collaborative Possibilities for Examining Socio-Technical Systems Using Duoethnography. *Proc. ACM Hum.-Comput. Interact.* 3, CSCW (November 2019), 190:1-190:23. DOI:https://doi.org/10.1145/3359292
[46] Cally Gatehouse and David Chatting. 2020. Inarticulate Devices: Critical Encounters with Network Technologies in Research Through Design. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (DIS '20), Association for Computing Machinery, Eindhoven, Netherlands, 2119–2131. DOI:https://doi.org/10.1145/3357236.3395426
[47] William Gaver. 2012. What should we expect from research through design? In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems* (CHI '12), ACM, New York, NY, USA, 937–946. DOI:https://doi.org/10.1145/2208516.2208538
[48] William Gaver, Andy Boucher, Nadine Jarvis, David Cameron, Mark Hauenstein, Sarah Pennington, John Bowers, James Pike, Robin Beitra, and Liliana Ovalle. 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), Association for Computing Machinery, New York, NY, USA, 1597–1607. DOI:https://doi.org/10.1145/2858036.2858472
[49] 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), Association for Computing Machinery, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3290605.3300532
[50] William Gaver, Phoebe Sengers, Tobie Kerridge, Joseph Kaye, and John Bowers. 2007. Enhancing Ubiquitous Computing with User Interpretation: Field Testing the Home Health Horoscope. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '07), ACM, New York, NY, USA, 537–546. DOI:https://doi.org/10.1145/1240624.1240711
[51] William W. Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a resource for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '03), Association for Computing Machinery, New York, NY, USA, 233–240. DOI:https://doi.org/10.1145/642611.642653
[52] William W. Gaver, John Bowers, Kirsten Boehner, Andy Boucher, David W.T. Cameron, Mark Hauenstein, Nadine Jarvis, and Sarah Pennington. 2013. Indoor weather stations: investigating a ludic approach to environmental HCI through batch prototyping. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), ACM, New York, NY, USA, 3451–3460. DOI:https://doi.org/10.1145/2470654.2466474
[53] Mary L. Gray and Siddharth Suri. 2019. *Ghost Work: How to Stop Silicon Valley from Building a New Global Underclass* (Illustrated edition ed.). Houghton Mifflin Harcourt, Boston.
[54] Erik Grönvall. 2018. WiredRadio: A Study of Living with Radio Awareness. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '18 Companion), Association for Computing Machinery, New York, NY, USA, 123–127. DOI:https://doi.org/10.1145/3197391.3205423
[55] Erik Grönvall, Jonas Fritsch, and Anna Vallgårda. 2016. FeltRadio: Sensing and Making Sense of Wireless Traffic. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (DIS '16), Association for Computing Machinery, New York, NY, USA, 829–840. DOI:https://doi.org/10.1145/2901790.2901818
[56] Lars Hallnäs and Johan Redström. 2001. Slow Technology & Designing for Reflection. *Personal Ubiquitous Comput.* 5, 3 (January 2001), 201–212. DOI:https://doi.org/10.1007/PL00000019
[57] Karey Helms. 2017. Leaky Objects: Implicit Information, Unintentional Communication. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '17 Companion), ACM, New York, NY, USA, 182–186. DOI:https://doi.org/10.1145/3064857.3079142
[58] Michael Hockenhull and Marisa Leavitt Cohn. 2021. Speculative Data Work - Dashboards: Designing Alternative Data Visions. *Proc. ACM Hum.-Comput. Interact.* 4, CSCW3 (January 2021), 264:1-264:31. DOI:https://doi.org/10.1145/3434173
[59] 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), ACM, New York, NY, USA, 753–756. DOI:https://doi.org/10.1145/2839462.2854112
[60] Sun-ha Hong. 2020. Technologies of Speculation: The Limits of Knowledge in a Data-Driven Society. NYU Press.
[61] Tung-Hui Hu. 2015. *A Prehistory of the Cloud* (1st ed.). The MIT Press. DOI:https://doi.org/10.7551/mitpress/9780262029513.001.0001
[62] Samuel Huron, Pauline Gourlet, Uta Hinrichs, Trevor Hogan, and Yvonne Jansen. 2017. Let's Get Physical: Promoting Data Physicalization in Workshop Formats. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (DIS '17), ACM, New York, NY, USA, 1409–1422. DOI:https://doi.org/10.1145/3064663.3064798
[63] IFTTT. IFTTT. Retrieved July 26, 2019 from https://ifttt.com
[64] 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 Cconference Summary on Human Factors in Computing Systems* (CHI '98), ACM, New York, NY, USA, 173–174. DOI:https://doi.org/10.1145/286498.286652
[65] Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornb\a ek. 2015. Opportunities and Challenges for Data Physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), ACM, New York, NY, USA, 3227–3236. DOI:https://doi.org/10.1145/2702123.2702180
[66] Tom Jenkins. 2018. Cohousing IoT: Design Prototyping for Community Life. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and*

Embodied Interaction (TEI '18), ACM, New York, NY, USA, 667–673. DOI:https://doi.org/10.1145/3173225.3173244

[67] Jenny Kennedy and Yolande Strengers. 2020. *The Smart Wife: Why Siri, Alexa, and Other Smart Home Devices Need a Feminist Reboot*. MIT Press.

[68] Cayla Key, Fiona Browne, Nick Taylor, and Jon Rogers. 2021. Proceed with Care: Reimagining Home IoT Through a Care Perspective. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, ACM, Yokohama Japan, 1–15. DOI:https://doi.org/10.1145/3411764.3445602

[69] Cayla Key and Audrey Desjardins. 2019. REP(AIR): An olfactory interface for bike maintenance and care. In *RtD'19*. DOI:https://doi.org/10.6084/m9.figshare.7855769.v1

[70] Olga Kuchinskaya. 2014. *The Politics of Invisibility: Public Knowledge about Radiation Health Effects after Chernobyl*. MIT Press, Cambridge, MA, USA.

[71] Albrecht Kurze, Andreas Bischof, Sören Totzauer, Michael Storz, Maximilian Eibl, Margot Brereton, and Arne Berger. 2020. Guess the Data: Data Work to Understand How People Make Sense of and Use Simple Sensor Data from Homes. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI '20), Association for Computing Machinery, Honolulu, HI, USA, 1–12. DOI:https://doi.org/10.1145/3313831.3376273

[72] Brian Larkin. 2013. The Politics and Poetics of Infrastructure. *Annu. Rev. Anthropol.* 42, 1 (October 2013), 327–343. DOI:https://doi.org/10.1146/annurev-anthro-092412-155522

[73] Josephine Lau, Benjamin Zimmerman, and Florian Schaub. 2018. Alexa, Are You Listening? Privacy Perceptions, Concerns and Privacy-seeking Behaviors with Smart Speakers. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW (November 2018), 102:1-102:31. DOI:https://doi.org/10.1145/3274371

[74] Matthew Lee-Smith, Tracy Ross, Martin Maguire, Fung Po Tso, Jeremy Morley, and Stefano Cavazzi. 2019. The Data Hungry Home. In *Proceedings of the Halfway to the Future Symposium 2019* (HTTF 2019), Association for Computing Machinery, New York, NY, USA, 1–10. DOI:https://doi.org/10.1145/3363384.3363390

[75] Yanni Alexander Loukissas. 2019. *All Data Are Local: Thinking Critically in a Data-Driven Society*. The MIT Press, Cambridge, Massachusetts.

[76] Andrés Lucero, Audrey Desjardins, Carman Neustaedter, Kristina Höök, Marc Hassenzahl, and Marta E. Cecchinato. 2019. A Sample of One: First-Person Research Methods in HCI. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion* (DIS '19 Companion), ACM, New York, NY, USA, 385–388. DOI:https://doi.org/10.1145/3301019.3319996

[77] Deborah Lupton. 2017. Feeling your data: Touch and making sense of personal digital data. *New Media & Society* 19, 10 (October 2017), 1599–1614. DOI:https://doi.org/10.1177/1461444817717515

[78] Deborah Lupton, Sarah Pink, and Heather Horst. 2021. Living in, with and beyond the 'smart home': Introduction to the special issue. *Convergence* 27, 5 (October 2021), 1147–1154. DOI:https://doi.org/10.1177/13548565211052736

[79] Deborah Lupton and and Ash Watson. 2020. Towards more-than-human digital data studies: developing research-creation methods. *Qualitative Research* (July 2020), 1468794120939235. DOI:https://doi.org/10.1177/1468794120939235

[80] Angella Mackey, Ron Wakkary, Stephan Wensveen, Annika Hupfeld, and Oscar Tomico. 2020. Alternative Presents for Dynamic Fabric. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (DIS '20), Association for Computing Machinery, New York, NY, USA, 351–364. DOI:https://doi.org/10.1145/3357236.3395447

[81] Matt Malpass. 2019. *Critical Design in Context: History, Theory, and Practice* (Reprint edition ed.). Bloomsbury Visual Arts.

[82] Jimmy Moore, Pascal Goffin, Miriah Meyer, Philip Lundrigan, Neal Patwari, Katherine Sward, and Jason Wiese. 2018. Managing In-home Environments Through Sensing, Annotating, and Visualizing Air Quality Data. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3 (September 2018), 128:1-128:28. DOI:https://doi.org/10.1145/3264938

[83] Carman Neustaedter and Phoebe Sengers. 2012. Autobiographical Design in HCI Research: Designing and Learning Through Use-it-yourself. In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), ACM, New York, NY, USA, 514–523. DOI:https://doi.org/10.1145/2317956.2318034

[84] William Odom, Richard Banks, Abigail Durrant, David Kirk, and James Pierce. 2012. Slow technology: critical reflection and future directions. In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), ACM, New York, NY, USA, 816–817. DOI:https://doi.org/10.1145/2317956.2318088

[85] William Odom and Tijs Duel. 2018. On the Design of OLO Radio: Investigating Metadata as a Design Material. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, Association for Computing Machinery, New York, NY, USA, 1–9. Retrieved September 8, 2021 from http://doi.org/10.1145/3173574.3173678

[86] William T. Odom, Abigail J. Sellen, Richard Banks, David S. 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), ACM, New York, NY, USA, 1961–1970. DOI:https://doi.org/10.1145/2556288.2557178

[87] William Odom, Ron Wakkary, Ishac Bertran, Matthew Harkness, Garnet Hertz, Jeroen Hol, Henry Lin, Bram Naus, Perry Tan, and Pepijn Verburg. 2018. Attending to Slowness and Temporality with Olly and Slow Game: A Design Inquiry Into Supporting Longer-Term Relations with Everyday Computational Objects. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–13. Retrieved February 17, 2022 from https://doi.org/10.1145/3173574.3173651

[88] Doenja Oogjes, William Odom, and Pete Fung. 2018. Designing for an Other Home: Expanding and Speculating on Different Forms of Domestic Life. In *Proceedings of the 2018 Designing Interactive Systems Conference* (DIS '18), ACM, New York, NY, USA, 313–326. DOI:https://doi.org/10.1145/3196709.3196810

[89] Doenja Oogjes and Ron Wakkary. 2022. Weaving Stories: Toward Repertoires for Designing Things. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (CHI '22), Association for Computing Machinery, New York, NY, USA, 1–21. DOI:https://doi.org/10.1145/3491102.3501901

[90] Emmi Parviainen and Marie Louise Juul Søndergaard. 2020. Experiential Qualities of Whispering with Voice Assistants. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–13. Retrieved January 25, 2021 from http://doi.org/10.1145/3313831.3376187

[91] Thao Phan. 2019. Amazon Echo and the Aesthetics of Whiteness. *Catalyst: Feminism, Theory, Technoscience* 5, 1 (April 2019), 1–38. DOI:https://doi.org/10.28968/cftt.v5i1.29586

[92] James Pierce. 2019. Smart Home Security Cameras and Shifting Lines of Creepiness: A Design-Led Inquiry. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19), ACM, New York, NY, USA, 45:1-45:14. DOI:https://doi.org/10.1145/3290605.3300275

[93] James Pierce and Carl DiSalvo. 2017. Dark Clouds, Io&alt;#!+, and [Crystal Ball Emoji]: Projecting Network Anxieties with Alternative Design Metaphors. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (DIS '17), ACM, New York, NY, USA, 1383–1393. DOI:https://doi.org/10.1145/3064663.3064795

[94] James Pierce and Eric Paulos. 2014. Counterfunctional Things: Exploring Possibilities in Designing Digital Limitations. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (DIS '14), ACM, New York, NY, USA, 375–384. DOI:https://doi.org/10.1145/2598510.2598522

[95] Martin Porcheron, Joel E. Fischer, Stuart Reeves, and Sarah Sharples. 2018. Voice Interfaces in Everyday Life. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18), Association for Computing Machinery, New York, NY, USA, 1–12. DOI:https://doi.org/10.1145/3173574.3174214

[96] Zachary Pousman, Mario Romero, Adam Smith, and Michael Mateas. 2008. Living with Tableau Machine: A Longitudinal Investigation of a Curious Domestic Intelligence. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (UbiComp '08), ACM, New York, NY, USA, 370–379. DOI:https://doi.org/10.1145/1409635.1409685

[97] Jon Rogers, Loraine Clarke, Martin Skelly, Nick Taylor, Pete Thomas, Michelle Thorne, Solana Larsen, Katarzyna Odrozek, Julia Kloiber, Peter Bihr, Anab Jain, Jon Arden, and Max von Grafenstein. 2019. Our Friends Electric: Reflections on Advocacy and Design Research for the Voice Enabled Internet. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19), ACM, New York, NY, USA, 114:1-114:13. DOI:https://doi.org/10.1145/3290605.3300344

[98] Zoë Sadokierski. 2019. Critical Journal / Contextual Portfolio: A framework for documenting and disseminating RtD as scholarly research. In *Proceedings of the 4th Biennial Research Through Design Conference*, 1–16. DOI:https://doi.org/10.6084/m9.figshare.7855829.v1

[99] Jathan Sadowski, Yolande Strengers, and Jenny Kennedy. 2021. More work for Big Mother: Revaluing care and control in smart homes. *Environ Plan A* (June 2021), 0308518X211022366. DOI:https://doi.org/10.1177/0308518X211022366

[100] Pedro Sanches, Noura Howell, Vasiliki Tsaknaki, Tom Jenkins, and Karey Helms. 2022. Diffraction-in-action: Designerly Explorations of Agential Realism Through Lived Data. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (CHI '22), Association for Computing Machinery, New York, NY, USA, 1–18. DOI:https://doi.org/10.1145/3491102.3502029

[101] Richard D Sawyer and Joe Norris. 2012. *Duoethnography*. Oxford University Press, Oxford, New York.

[102] Phoebe Sengers and Bill Gaver. 2006. Staying open to interpretation: engaging multiple meanings in design and evaluation. In *Proceedings of the 6th conference on Designing Interactive systems* (DIS '06), ACM, New York, NY, USA, 99–108. DOI:https://doi.org/10.1145/1142405.1142422

[103] Katie Shilton. 2013. Values Levers: Building Ethics into Design. *Science, Technology, & Human Values* 38, 3 (May 2013), 374–397. DOI:https://doi.org/10.1177/0162243912436985

[104] Samarth Singhal, William Odom, Lyn Bartram, and Carman Neustaedter. 2017. Time-Turner: Data Engagement Through Everyday Objects in the Home. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '17 Companion), ACM, New York, NY, USA, 72–78. DOI:https://doi.org/10.1145/3064857.3079122

[105] Stephen Snow, Awais Hameed Khan, Stephen Viller, Ben Matthews, Scott Heiner, James Pierce, Ewa Luger, Richard Gomer, and Dorota Filipczuk. 2020. Speculative

Designs for Emergent Personal Data Trails: Signs, Signals and Signifiers. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI EA '20), Association for Computing Machinery, New York, NY, USA, 1–8. DOI:https://doi.org/10.1145/3334480.3375173

[106] Pieter Jan Stappers and Elisa Giaccardi. Research through Design. *The Interaction Design Foundation*. Retrieved September 19, 2017 from https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/research-through-design

[107] Susan Leigh Star and Karen Ruhleder. 1996. Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research* 7, 1 (March 1996), 111–134. DOI:https://doi.org/10.1287/isre.7.1.111

[108] Nicole Starosielski. 2015. *The Undersea Network*. Duke University Press Books.

[109] Nicole Starosielski and David H. Lawrence XVII. 2016. *The Undersea Network* (Unabridged edition ed.). Audible Studios on Brilliance Audio.

[110] Erik Stolterman and Mikael Wiberg. 2010. Concept-Driven Interaction Design Research. *Human–Computer Interaction* 25, 2 (2010), 95–118. DOI:https://doi.org/10.1080/07370020903586696

[111] Miriam Sturdee, Sarah Robinson, and Conor Linehan. 2020. Research Journeys: Making the Invisible, Visual. In *Proceedings of the 2020 ACM on Designing Interactive Systems Conference* (DIS '20), Association for Computing Machinery, Eindhoven, Netherlands, 2163–2175. DOI:https://doi.org/10.1145/3357236.3395590

[112] Bruce M. Tharp and Stephanie Tharp. 2018. *Discursive design: critical, speculative, and alternative things*. The MIT Press, Cambridge, Massachusetts.

[113] 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), ACM, New York, NY, USA, 154:1-154:13. DOI:https://doi.org/10.1145/3173574.3173728

[114] Jennifer Turns and Judith Ramey. 2006. Active and Collaborative Learning in the Practice of Research: Credit-based Directed Research Groups. *Technical Communication* 53, 3 (August 2006), 296–307.

[115] Jeremy Viny, Lucy Copper, and Audrey Desjardins. 2021. Examining Opaque Infrastructures with the Desktop Odometer. In *Designing Interactive Systems Conference 2021* (DIS '21), Association for Computing Machinery, New York, NY, USA, 1941–1953. DOI:https://doi.org/10.1145/3461778.3462146

[116] Ron Wakkary. 2021. *Things We Could Design: For More Than Human-Centered Worlds*. The MIT Press, Cambridge, Massachusetts.

[117] Ron Wakkary, William Odom, Sabrina Hauser, Garnet Hertz, and Henry Lin. 2015. Material Speculation: Actual Artifacts for Critical Inquiry. In *Proceedings of the 5th Decennial Aarhus Conference on Critical Alternatives*, ACM Press, Aarhus, Denmark, 97–108. DOI:http://dx.doi.org/10.7146/aahcc.v1i1.21299

[118] Ron Wakkary, Doenja Oogjes, Sabrina Hauser, Henry Lin, Cheng Cao, Leo Ma, and Tijs Duel. 2017. Morse Things: A Design Inquiry into the Gap Between Things and Us. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (DIS '17), ACM, New York, NY, USA, 503–514. DOI:https://doi.org/10.1145/3064663.3064734

[119] Yun Wang, Xiaojuan Ma, Qiong Luo, and Huamin Qu. 2016. Data Edibilization: Representing Data with Food. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA '16), ACM, New York, NY, USA, 409–422. DOI:https://doi.org/10.1145/2851581.2892570

[120] Jordan Wirfs-Brock. 2019. Recipes for Breaking Data Free: Alternative Interactions for Experiencing Personal Data. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion* (DIS '19 Companion), Association for Computing Machinery, New York, NY, USA, 325–330. DOI:https://doi.org/10.1145/3301019.3323892

[121] Gary Wolf. 2009. Know Thyself: Tracking Every Facet of Life, from Sleep to Mood to Pain, 24/7/365. *Wired*. Retrieved August 20, 2019 from https://www.wired.com/2009/06/lbnp-knowthyself/

[122] Allison Woodruff, Jay Hasbrouck, and Sally Augustin. 2008. A Bright Green Perspective on Sustainable Choices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '08), ACM, New York, NY, USA, 313–322. DOI:https://doi.org/10.1145/1357054.1357109

[123] Peter Worthy, Ben Matthews, and Stephen Viller. 2016. Trust Me: Doubts and Concerns Living with the Internet of Things. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (DIS '16), Association for Computing Machinery, New York, NY, USA, 427–434. DOI:https://doi.org/10.1145/2901790.2901890

[124] Nele Wynants (Ed.). 2020. *When Fact Is Fiction: Documentary Art in the Post-Truth Era*. Valiz, Amsterdam.

[125] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '07), ACM, New York, NY, USA, 493–502. DOI:https://doi.org/10.1145/1240624.1240704

[126] Global IoT and non-IoT connections 2010-2025. *Statista*. Retrieved July 14, 2021 from https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/

[127] IoT market size worldwide 2017-2025. *Statista*. Retrieved July 14, 2021 from https://www.statista.com/statistics/976313/global-iot-market-size/

[128] TCPDUMP/LIBPCAP public repository. Retrieved September 8, 2021 from https://www.tcpdump.org/