

Alternative Avenues for IoT: Designing with Non-Stereotypical Homes

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ABSTRACT

We report on the findings of a co-speculative design inquiry that investigates alternative visions of the Internet of Things (IoT) for the home. We worked with 16 people living in non-stereotypical homes to develop situated and personal concepts attuned to their home. As a prompt for co-speculation and discussion, we created handmade booklets where we took turns overlaying sketched design concepts on top of photos taken with participants in their homes. Our findings reveal new avenues for the design of IoT systems such as: acknowledging porous boundaries of the home, exposing neighborly relations, exploring diverse timescales, revisiting agency, and embracing imaginary and potential uses. We invite human-computer interaction and design researchers to use these avenues as starting points to broaden current assumptions embedded in design and research practices for domestic technologies. We conclude by highlighting the value of examining divergent perspectives and surfacing the unseen.

CCS CONCEPTS

• **Human-centered computing** → *Interaction design theory, concepts, and paradigms.*

KEYWORDS

Home; Internet of Things; non-stereotypical; bespoke; domestic technology; smart home; research-through-design.

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1 INTRODUCTION

In recent human-computer interaction (HCI) research, designers and researchers have turned their attention to designing for ways of dwelling that go beyond traditional, normative, or stereotypical home life. While HCI has a long history of designing for domestic settings (e.g. [1,17,32,40,45]), this new collection of work is proposing a deliberately more diverse look at what dwelling is. It offers careful and multifaceted directions for the future of domestic technologies, considering situations like divorced families, co-housing, or mobile housing (e.g. [14,35,41–43,54]).

Yet, we observe that current approaches to designing domestic IoT systems often fail to recognize this broad diversity of living situations. One-size-fits-all products, as well as do-it-yourself (DIY) kits (e.g. [20]), are repeatedly designed for a streamlined (and idealized) vision of what the home is, often a stereotypical home: a North American, single-family detached house, occupied by parents with children. This trend is often seen in concept images for technological innovation (e.g. see Fig 1).



Figure 1. Idealized view of a connected home. (Adapted from <https://pixabay.com/>).

As HCI research continues to investigate the design of domestic technologies—and more specifically IoT in the home—it is timely to reexamine what visions of the home we use as the starting point for design, and to explicitly showcase a more diverse set of representations. We argue that this juxtaposition of varied visions may not only open new opportunities for meaningful, appropriate and

relevant IoT design, it may also trouble the very motivations for having IoT in the home in the first place.

In this paper, we report on a co-speculation with 16 people dwelling in non-stereotypical housing situations. Through Bespoke Booklets of imaginary IoT proposals situated in their homes, we exchanged with our participants to investigate the question: ***What new avenues for domestic IoT arise when designing with non-stereotypical homes?*** By being situated in a houseboat, old theater box office, boat, 8-person house, micro apartment, etc., our study challenges common assumptions that home is immobile, that it houses family members only, or that it is private (e.g. [11,12,18,19]). The proposals we developed for and with participants living in non-stereotypical homes broaden understandings of what home is, and as a result, opens a series of new questions and opportunities for domestic IoT design. With this paper, we contribute:

- (1) A series of 5 new avenues to consider when designing IoT for the home. These new avenues are not meant to replace current approaches to IoT; rather they broaden and expand opportunities for design. For each avenue, we propose a set of questions for designers and researchers to guide investigation and prompt ideation.
- (2) A reflection on the benefit of examining divergent perspectives and of revealing the unseen.

2 NON-STEREOTYPICAL HOMES IN HCI

While HCI researchers have a long history investigating the home, we observe a lack of precision around which homes are at the center of these works. Albeit unintentional, this lack of precision often leaves the home at best undefined, and at worse idealized or stereotyped (for example see [11,12,18,19]). This lack of precision also leads to a lack of explicit diversity and inclusivity in the homes we might design with and for. In response, our work turns to a diversity of homes to offer an array of ways to represent home. We break apart definitions of the home where permanence and immobility are expected, where social configurations exclude non-family dynamics, and where size and configuration are standardized.

In [42], Oogjes et al. created a series of speculative responses that imagine connected devices in various non-normative homes. Their proposals open the definition of the home to new qualities such as “adaptable, dynamic boundaries, orientated, exchange, and dispersed” [42:324]. Their work can help designers imagine what new domestic technologies would be needed or welcome in homes that

are mobile, temporary, or minimalist. Our work builds on theirs to continue expanding the implications of taking seriously varied modes of dwelling. While some of our findings overlap (e.g. a reconsideration of boundaries), our work also highlights other areas of interests (e.g. neighborly relations and imaginary uses) that further open definitions of the home.

Other works have been engaging with specific living situations. Studies on mobile homes (recreational vehicles, boats, vans, etc.) have generated insights around the challenges of living in small spaces, of being off the grid, and of frequently changing location (e.g. [21,54]). Revisiting definitions of home encompasses a new look at family structures. The idealized version of the home pictures a nuclear family with two parents and children. Odom et al. [41] challenge this picture-perfect view through ethnographic work with divorced families. In the same vein, Jenkins explores possibilities for interpersonal communication in co-housing properties [35].

Beyond house shapes and family structures, HCI researchers have also contested common assumptions about the home in terms of values and culture. For instance, topics like religion, sustainability, and minimalism have also served as starting points for smart home and IoT research (e.g. [15,52,53]). Through a comparative ethnography of Asian families and homes, Bell et al. [6] point beyond efficiency as a central tenet for design and beyond an individualistic view of home living. Instead, their work reveals the need to consider, amongst others, the uniqueness of all inhabitants, relationships between homes and communities, and gendered legacies in the home.

As a collection, these works present design challenges and opportunities that are invisible when designing for a generic vision of the home. In addition, this corpus of literature challenges the idea of a one-size-fits-all approach to designing domestic technologies; instead, it points to the need for more unique, situated, and personal designs. While this collection of works is starting to broaden definitions and contrast assumptions about the home, more work is needed to push HCI and design communities to proactively research and design for a range of values, goals and needs for home dwellers.

3 DOMESTIC IOT

Our work is focused on rethinking IoT through proposals for non-stereotypical homes. This work follows a long tradition in HCI research that aims at making homes more interactive to support better everyday practices [22].

Smart homes [19,31], and more recently IoT [38], build on previous conceptual and technical approaches such as ubiquitous, pervasive, and ambient computing [7,34,49,50]. While early days of ubicomp and smart homes envisioned spaces as complete computational systems, the IoT focuses on the design of connected, computational, and interactive artifacts as a way to sustain a new level of ubiquity and interaction [37,38]. At its core, IoT is a collection of heterogeneous, identifiable, and self-capable objects and ad hoc interoperable networks [10]. In terms of user experience, one of the key goals in this corpus of works is to make technology as invisible and seamless as possible, echoing Weiser’s original vision for ubiquitous computing [49]. However, these works rarely incorporate a discussion around the home (or the space) that is being designed for.

Current domestic IoT products on the market are often designed to facilitate smart resource management regarding temperature, light, and sound (e.g. Nest products [39]). Other products let users surveil and control who has access to the home or who might be in and around the home at all times (e.g. August lock [5], Amazon Key [3], Nest cameras [39]). Finally, home assistants play the role of hubs for these products, supporting voice interactions to control connected devices in the home (e.g. Amazon Echo Show [4], Google assistant [30]). These products are mass produced and designed to accommodate the most homes possible, with underlying goals such as efficiency and productivity. This one-size-fits-all approach is often tempered by the possibilities of customizability and programming personal IFTTT (if this then that) rules. Similarly, DIY toolkits, including a variety of sensors and actuators, can be installed by home dwellers themselves regardless of the type of home (or space) [20,46,51]. One-size-fits-all services and DIY approaches still reside in a conceptual space where the home is not defined, relying on assumptions and idealized perspectives. We argue that by acknowledging and precisely situating the homes we design for and with, we can uncover new approaches or areas of interest for IoT.

4 OUR APPROACH: BESPOKE BOOKLETS

We developed a method called *Bespoke Booklets* as a way to co-speculate with dwellers of non-stereotypical homes. The Bespoke Booklets are constituted of 10 to 12 situated, imaginary and bespoke conceptual sketches designed specifically for and with dwellers of non-stereotypical homes. Our intention was to create a method that would (1) situate speculation in real world situations as a generative approach to develop new concepts for IoT and provoke

concrete reactions, and (2) encourage co-speculation: “*the recruiting and participation of study participants who are well positioned to actively and knowingly speculate with us in our inquiry in ways that we cannot alone*” [48:1]. The Bespoke Booklets were inspired by and are aligned with other design research methods such as probes [27,33], workbooks [26], partial catalogue [24] and experiential speculation [13,23]. Below we describe the study participants as well as the method.

4.1 Study participants

We recruited participants based on their varied living situations, in the city of Seattle, Washington, USA. Because of its geography, climate, values, and socio-economic landscape, Seattle hosts a diversity of ways people house themselves, making this city a relevant location for our study. We recruited participants through our personal networks, on Craigslist, and through our university’s networks. We made efforts to work with, and select, people who lived in homes that were mobile, very small, shared, that hosted inhabitants beyond family members, as well as assistive living situations, tiny homes, and more. Our goal was not to represent every way of dwelling (the diversity of ‘homes’ is indeed endless) but to reach as many as we could in an effort to illustrate that very diversity. Participants were compensated with a \$25 gift card. Table 1 offers an overview of our participants’ homes. Overall, we met with 11 women and 5 men. Some homes were mobile (a van, a trawler), others were unconventionally small (an apodment, a micro-apartment). We worked with dwellers of shared spaces (an 8-person communal home) and others whose homes departed from the stereotypical single-family vision in other ways (a carriage house, a basement apartment, a houseboat). The periods in which our

Table 1. Overview of participants and their homes

Pseudonym	Home	Sqft	Years	Ppl
Abby & Leonard	Van	82	5	2
Charles	Carriage House	800	3	1
Daphne	Apartment	700	2	1
Grace	Boat (trawler)	350	1.5	1
June	Cinema Apartment	500	1	1
Karey	Basement Suite	1180	0.33	3
Karl	Apartment	400	1.5	1
Kate	Apartment	800	1.5	1
Lauren	Shared House	2450	2	8
Oscar & Lindsey	Apartment	750	2.5	2
Patricia	Apartment	700	1	2
Penelope	Apodment	198	0.16	2
Samuel	Micro Apartment	400	1	1
Susan	House Boat	1900	40 +	2

participants had been living in their homes ranged from a few months to over forty years, with the majority of participants newer to their homes. Samuel (all names are pseudonyms), for example, is the first to live in his home, while others had a long and multifaceted history (June's home is a converted cinema box-office).

4.2 Bespoke Booklets method

4.2.1. Home tour and photographs. To start the process, participants invited us into their homes and gave us a tour inside and out (between 35 and 80 minutes). The participants were asked about the primary and secondary functions of areas throughout the home, and to point out elements they found surprising or unique. With the participant's consent, we took photos of the home. At the end of the interview, we handed the camera to them to capture anything meaningful that we missed or that they wanted to share.

4.2.2. Creation of the Bespoke Booklet. After the interviews and tours, our team worked together to develop ideas for possible IoT concepts based on qualities of each home that were unusual, special, or that we found inspirational. Our team comprised 3 undergraduate students in design, 4 graduate students in design, and one faculty member in design. After multiple rounds of iteration, we selected 5 to 7 bespoke concepts to include in a small (3.5 x 5.5 inch) personalized booklet to be used as a conduit for co-speculation (see Fig. 2). In the booklet's first half, we sketched on top of photos taken in the participants' homes with short descriptions added below. These sketches were on the left page of each spread, and the right spread was left for participants to describe how they would live with the connected object, what was the most surprising, and least relevant aspect of the idea. In the second half of the

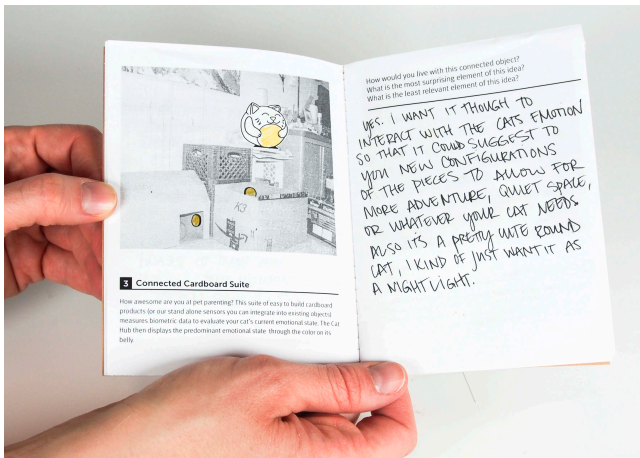


Figure 2. Bespoke Booklet: Left pages included photos of the home, right pages allowed space for comments.

booklet, we included pictures of the participants' homes where we invited them to sketch their own ideas for connected objects.

4.2.3 Participants with the booklets. Participants received their booklets and were given 1-4 weeks to comment, imagine, and sketch.

4.2.4 Exit interview. We reconnected with each participant for a co-speculation session and exit interview (between 40 and 60 minutes). Participants shared their reactions as well as new ideas about bespoke IoT for their homes. The booklet served as a conversation starter for the exit interview. This often took the form of a generative discussion, where we would collectively brainstorm new concepts, riff off an existing sketch, or explore how life with a concept might evolve over time.

4.3 Data analysis

Our data includes the audio recordings and transcripts of the home tours and exit interviews, around 80 concepts we designed, around 70 concepts designed by the participants, and the participants' written reflections in the booklets. Through affinity diagramming of the transcribed interviews as well as the concepts themselves, we organized the data to reveal ways in which the IoT concepts were directly connected to the homes they were situated in as well as avenues that showcased potential areas for domestic IoT. In the following section, we present the results of this analysis.

5 ANALYSIS: AVENUES FOR DOMESTIC IOT

We present five areas of interest in response to our research question: *What new avenues for domestic IoT arise when designing with non-stereotypical homes?* The areas we propose are meant to provoke novel reflections and open new areas for exploration when designing domestic IoT. For each avenue, we present examples of concepts developed in the booklets and excerpts from discussions we had with co-speculators. We conclude each section with generative questions to guide researchers and designers to revise assumptions about the home and open opportunities for IoT.

5.1 Acknowledging porous boundaries

The co-speculations with dwellers of non-stereotypical homes allowed us to revisit what the physical and psychological boundaries of the home are. We discovered that the four walls encompassing the house are not always the most relevant way to understand what the home is (as also explored in [16]). Instead, we acknowledge that a more



2 Plum Tree Burglar Birds

Every summer the tree in the front yard produces lots of plums. If the housemates don't pick plums, local birds swoop in to eat them. The plum tree sends photographs of the fruit-eating birds to the housemates to reveal their competition and remind them to come pick plums.

6 Salmon Telephone

Grace might move often, but she makes great friends at every marina. Salmon Telephone helps everyone stay sort of connected. Each marina has a message carrying salmon that picks up and delivers messages between marinas. However, messages get a little jumbled in the salmon's stomach (but it's the thought that counts).

1 The Project - Or

The Project - Or turns on when the living room chair is sat in. Once they are settled, it projects potential crafting and sewing projects given the available materials in the apodment. Although the full set of instructions are also projected, each project is only on display for a few minutes. It then fades away, and a new possibility drifts into view.

Figure 3. Excerpts from the Bespoke Booklets, left to right: Plum Tree Burglar Birds, Salmon Telephone, and The Project Or.

porous and malleable definition of the boundaries of homes could be the starting point of future IoT domestic devices. The examples we present below demonstrate that while traditional IoT focuses on relationships within the home we might also look at this technology as an opportunity to put into conversation elements of the exterior setting with interior living spaces.

5.1.1 Indoor-outdoor. When talking with participant Karey, we found that bringing natural elements from the outdoors indoor could spur poetic reflections. Since Karey's home is in a basement that gets little direct sunlight, we proposed a concept called Here Comes the Sun¹: in a nearby park, a kinetic sculpture moves its reflective surfaces to send sunlight to her apartment through a translucent vessel in the window. Karey enjoyed this device since it seemed to transport the sun's light as experienced at the park and bring it into the home. She remarked: *"It's like a daylight moon, you know what I mean? Because the moon is just reflecting the sunlight. And then this is also reflecting the sunlight, but it's inside your house, so it's your own little moon."*

For Abby and Leonard², their van is an inherently non-local home: it has visited 13 provinces or states in Canada and the USA in five years. Abby and Leonard described their van as a *"place for dreaming"*. One of the concepts we proposed to Abby and Leonard was called Sleep Talk Alarm Clock: a modular alarm clock that wakes Abby and Leonard by replaying anything that they may have said while sleeping. Sleep Talk Alarm Clock was initially conceptualized as an IoT device that dealt with intimate

and subconscious happenings within the van. Rather than discussing its inner-intimacy, Abby and Leonard began to speculate about what it would mean if the concept focused more on an intimacy with what lies beyond the van's aluminum shell. Abby recalled a recent ski trip with Leonard, saying: *"We were on the lift, and the slope was closed, so it was unmarked except for these crazy animal tracks. The tracks moved along a circuitous path meeting and separating. So, the whole time we were on the lift, it was like we could imagine their life."* This anecdote became the basis for Abby and Leonard's new idea: a device that would display animal tracks within a certain radius of the van while Abby and Leonard slept. In the morning the tracks would be mapped onto the inside of the van. Through its interconnectedness their IoT device blurs the boundaries of home and the surrounding environment.

5.1.2 A new awareness for urban wildlife. Within the broader theme of acknowledging porous boundaries between the indoors and outdoors, we explored how dissolving boundaries between home inhabitants and the wildlife who share its urban environment might lead to novel and increased engagements between the two. For example, Squirrel Sketch combines Penelope's love of inspirational quotes and the fact that her only window to the outside world is at ground level. In Squirrel Sketch, every time a critter passes by, a new graffiti art appears on the wall in front of Penelope's window. The graffiti is based on which animal passed by as well as inspirational quotes Penelope collects. In response, Penelope openly embraced the possibilities of this new relation with animals: *"I'm most surprised that it is based off of the animal that passes by. I*

¹ A high resolution version of each concept photo and sketch can be found in our supplementary materials in the ACM Digital Library.

² Abby is a member of the research team (Desjardins). Before meeting participants, we experimented with the method of Bespoke Booklets ourselves.

like that a lot.” She continued by expressing enthusiasm for this newly formed connection to wildlife out her window: *“I would want to have my window open all the time with this one.”* Her basement apodment isolates her from the bright blue sky, but it affords her a unique view of the urban wildlife just outside her window.

Another example showcasing how domestic life isn’t exclusive of the surrounding wildlife is the concept Plum Tree Burglar Birds (see Fig. 3). The plum tree sends photographs of fruit-eating birds to Lauren and her housemates (of an 8-person house), with the intention of inviting the housemates to pick and eat the fruits instead of leaving them to the birds. In her response, Lauren agrees that this might entice the household to pick fruit (and even get competitive), but also states that *“it would be fun to have a whole wall of bird polaroids. We could name them!”* Her response highlights how this device could support a closer and friendly relationship with their plum tree as well as with the visiting birds.

Above, we demonstrate that the boundaries for many homes are more porous than assumed, opening up opportunities to support an interest in bringing more of the outdoors in. We conclude this section with questions and opportunities to consider:

Questions about the home:

- What aspects of the outside world act to broaden the boundaries of this home?
- How do things or beings cross these boundaries?

Opportunities for IoT:

- How might domestic IoT devices support exploration and contemplation of the outside world?
- How might IoT devices transpose natural qualities of the outside to elements of this home inside?

5.2 Exposing neighborly relations

In this section, we continue to reconsider relationships beyond stereotypical home boundaries by attending to neighborly relations. We found that many participants had already modified routines and habits based on their past interactions with neighbors. For example, we found that Susan renovated her houseboat so that her living room window no longer faced her neighbor’s home, and instead looked out onto the water. Karl adjusted his bathroom routine based on his neighbors’ schedules, since the walls of his converted efficiency studio were so thin he could hear when somebody left for work.

5.2.1 Seeing while remaining unseen. Concepts and discussions around neighborly relations sometimes

involved the close physical proximity to neighbors and the often-asymmetrical awareness of others’ voices and activities while remaining unseen.

In a functional response to asymmetrical neighborly relations, we discuss a concept for Penelope who lives in an apodment with a communal kitchen shared across the building’s 10 units. She expressed annoyance with the constant issue of communal kitchen scheduling and said she might use that space more if she could see when it was available. As a response, we sketched Three-Way Mirror: a round mirror in Penelope’s small kitchen that displays the building’s common spaces, informing her if they are being used. Remarking on the device Penelope said, *“I really loved this one, especially since I don’t want to walk up to the kitchen to see if it’s free”*. Further reflecting on the potential use of this device in the specific context of her building, she said: *“the Three-Way Mirror is super cool for this type of building, where spaces are being shared with other people that you don’t know. To be able to kind of monitor when might provide some privacy in those public spaces.”* Penelope’s reflection offers insights on balancing privacy in shared spaces: it would allow tenants to be more in control of moments when they want privacy versus moments where they would welcome social interactions with neighbors.

June lives in an apartment that used to be a cinema’s box office. Due to the apartment’s thin walls, June can hear conversations coming from the street, her neighbors, and the salon next door. June said she could hear the conversations so clearly that she was aware when people stopped working at the salon because she would stop hearing their voice. In the bathroom of June’s apartment is a vent where she could *“listen to the upstairs neighbors play World War II documentaries.”* June said, *“I feel like I’m both intruding, and being heard.”* In June’s booklet was a concept called Silence and Sass; a pair of noise canceling headphones that would provide silence, except for a playback of random conversations from the salon next door every hour, for two minutes. While the headphones had been designed to provide silence, June instead saw their function to be the short snippets of recorded salon conversations. For June the goal was not to isolate herself from the world around her but to allow her and her neighbors to be more conscious of one another. Remarking on her home, June said, *“So there’s a lot of connection to the outside world and just to everybody that I think I should embrace.”* For June, domestic IoT became a way to make conscious those shared experiences with neighbors.

Oscar and Lindsey, a couple living in an income-restricted one-bedroom apartment within a large building, were

presented with Media Manuscript, a device that listens for and anonymously repeats random snippets of media (book, music, TV, etc.) being consumed by a neighbor. While the concept was meant to be light-hearted and to open curious contemplations about neighbors, they reacted strongly to this breach of privacy. Lindsey stated: *“What I don't like is the anonymous aspect of it and, like, freaks me out. I don't like it, especially in this huge building where we don't know anybody. [...] There's such a potential for misuse and like, weirdness.”* Oscar was also skeptical about the use of Media Manuscript in their current apartment building. Instead, he imagined a building that would lead to a more interesting set of media snippets: *“I would want this if I lived in a building with a bunch of artists... I could be more guaranteed to see quality content that I'm actually interested in versus in this building.”* This is a strong contrast to the way June embraced her relation to neighbors. These examples illustrate different practices and desires around neighborly proximity, often depending on the wider context and relations between neighbors.

5.2.2 Experiencing Subtle Connections. Relationships with neighbors do not always manifest themselves in the foreground. Our inquiry also highlights the potential for subtle connections between neighbors, drawing on the ambient presence that might exist between them.

For example, Grace, who lives on a boat and routinely travels between marinas, mentioned that the human connections within a dock community happen much faster than traditional neighborhood settings. In Grace's booklet, we included a concept called Salmon Telephone (see Fig. 3), a connected salmon that delivers hand written messages by swimming from one marina to another. While the messages often were unreadable (being garbled by the salmon during transportation), they remained symbolic attempts at connection. In our discussion, Grace expressed how similar this concept was to an existing community radio system she used at her old dock: *“Yeah, it was kind of fun. Like, you know all of your neighbors, not by sight, but just like hearing them log in with that thing.”* Because the Salmon Telephone did not transfer legible messages, it embodied how invisible links between neighbors constitute a constant and ambient presence for one another. There can be a sense of comfort in knowing that the people surrounding a home are regularly present, even when that knowledge is not consciously reinforced by direct interaction.

In more intimate spaces subtle connection can be challenging to achieve. We presented Karey, who lives with her son and one roommate (whom she barely sees), with Please Pop-in for Tea: two connected curtains, one placed

in her room, the other in her roommate's, that mimic each other. The movements of the curtains were open to interpretation between Karey and her roommate, with the hopes that certain motions would develop particular meanings for them over time. However, Karey's reaction demonstrated that this proposal was in fact providing too much transparency: *“I wouldn't want it. I would take it down and not like, um...I tend to be a really private person and I would feel like, even like my son, I wouldn't necessarily want him to know all my moods.”* Inadvertently, this attempt at a subtle connection proved to be a more straightforward messaging system within this intimate setting, one where the right balance of privacy and connection is crucial to Karey's comfort.

The co-speculations presented above showcase the difficult balancing act of imagining IoT devices that can build on existing enjoyable practices with neighbors (as in Grace's case) while respecting the need for privacy (as we saw with Karey). Neighborly relations are complex, personal, and at times asymmetrical. The examples above open up questions worth consideration in design:

Questions about the home:

- How do current neighborly relations manifest in this home?
- How do neighbors balance connectedness and privacy?

Opportunities for IoT:

- In IoT design, what mechanisms could support individual negotiations between neighborly relationships and privacy, mystery or ambiguity?
- In IoT design, what mechanisms might support distance between neighbors?

5.3 Extending temporality

The following examples help provide insights on the ways IoT technology might depict an alternative perception of time; and by doing so reveal new and novel perspectives of the home for its inhabitants.

Kate rents a one-bedroom apartment that she also uses as a home office. During the initial home tour Kate expressed that the home office can, at times, make it difficult to find a balance between work and leisure. In Kate's booklet, we included a concept called Sculpting Chandelier: a real-time 3D-printed chandelier hovering just above a desk where Kate works. The chandelier reflects how Kate spends her time at home: striations in the chandelier's cylindrical form signify the quantity of time spent working vs periods of leisure. In response, Kate said she saw the device's ambient effect as *“symbolic nostalgia”* and went on to say that

eventually when she moves she would like to leave the device because *“it belongs with the activity of the home itself. It can change owners and still be meaningful.”* Kate’s quote exemplifies how the Sculpting Chandelier might work on two different timescales: Kate’s life in the space, and a unique historical timeline of the home.

We also experimented with concepts situated in homes with longer histories to see how IoT devices might help revisit those histories today. For June, who lives in an old cinema box office, we proposed a concept called Pushy Projector: a projector that would select and play films from the 1930’s (the building’s heyday) onto June’s wall. June appreciated the historical link: *“I did like it, I like the inclusion of history and films.”* But, when probing deeper, June realized she didn’t know a lot about the history of the cinema itself. She said: *“I just know that the place that’s my apartment used to be a box office. But I don’t know what kind of films are shown.”* She continued, pensively: *“Where do you find building histories?”* This historical curiosity came back in one of her own concepts which built on the Pushy Projector. In that concept, she imagined that when 1930’s films would be projected, *“some kind of sensor [...] would then produce an apparition of a 1930’s actor.”* While many of our discussions with June were centered around the thinness of the apartment’s windows and walls (see 5.2.1), this thread of reflection revealed a new interest in the history of her place that had remained unexplored for her.

In contrast to the long histories explored in Kate and June’s apartments, Samuel lives in a new micro-apartment that has never been lived in before. The possibility of being the first person to leave a trace in a place spurred our imagination. Samuel sleeps on a roll-out mattress pad. Every morning he rolls up the mattress and places it in the closet and every night he lays it out on the floor before going to bed. In relating to these aspects of Samuel’s home we proposed a concept called Bed Impressions which leaves slight imprints of Samuel’s body on the floor as if he had been sleeping in that position for decades. Samuel takes pride in caring for the apartment: *“I clean my floor and bathroom usually in the morning because it’s easy. I do it maybe once every two or three days.”* However, in spite of his attentive cleaning, evidence of his life there is inescapable if hard to see, caused by a slow rate of change. Bed Impressions directs attention to the footprint left by living in a space through a visualization of projected long-term effects.

Lastly, Susan has lived on a houseboat for over 40 years. In her booklet, Susan pointed out that engaging with the past may not always be a welcomed practice. She responded to

a concept called Time Machine Window which uses past images to show what it would be like to look out that window at different times in the home’s history, writing, *“It would continually pull you into the past. Which is not always a good thing.”* Susan explained how the history of the home is related to histories of loss, neighborly problems, or houseboat gentrification; hence, she prefers to stay in the present. Susan’s response illustrates that the capability to experience the past via connected devices may not always be a productive or fruitful interaction.

While IoT products are generally designed to support real-time dwellers’ needs, above we saw cases where IoT might be able to provide new insights about the home by adopting longer temporal perspectives. As indicated by our research, using connected devices gives inhabitants a lens to understand the home as a history of events which they add to and the larger contexts their homes are situated in. Pursuing this reflection, designers and researchers might ask:

Questions about the home:

- What are the traces of the past in this home?
- How are current social events and material practices of this home recorded?

Opportunities for IoT:

- How will the data collected from IoT devices today be interpreted, used or experienced in 100 or 200 years?
- How can IoT devices surface historical elements of this home in a way that is relevant and meaningful to current inhabitants?

5.4 Revisiting agency in the home

The fourth avenue we consider in this analysis is how the Bespoke Booklets concepts questioned how agency is allocated, ceded, distributed and negotiated between people, artifacts, and space in the home. While the topics of object agency and subject agency have previously been discussed in HCI, STS, and design works (e.g. [2,9,36,47]), our study exposes specific and novel tensions with mitigating agency beyond the current conversation on privacy and control in IoT and smart home design.

5.4.1 Reallocating autonomy. By definition, IoT devices are meant to communicate between each other, and to attain a level of autonomy that requires minimal human intervention. Here we look at how co-existing with IoT autonomous devices can open up a dialogue about what meaning might be inferred, projected, and created as a result of ambiguity of purpose and loss of control. For example, Chatting Companions is a connected mirror and

clothes rack who communicate with one another in a secret language. The soft pulse of a single white light informs inhabitant Kate that they are communicating, without providing any hints on what is being communicated. This concept was designed for Kate's apartment; as the sole inhabitant she often maintains control and agency on most things. This concept, however, reserves no autonomy for her; Kate is at most an observer. Kate fully acknowledged her lack of human input in this concept but met it with an innate curiosity, saying *"even if it was totally random, I think I would start reading into when they were chattering or not chattering, or lighting up or not lighting up...like, what are they thinking? Does this have anything to do with me?"* Kate did not outwardly need to reconcile this lack of autonomy—she was content to have their conversations remain forever unknowable. She instead was genuinely curious about how life between them would evolve over time saying, *"I'd be curious to know what the timeline is of living with it, and what my reaction would be to it."* Kate had fun with this concept: elaborating where she wanted to make it meaningful to her and leaving intact the fundamental imbalance of the relationship.

Similar to the Chatting Companions, Craigslist Microwave has a purpose and a life of its own, not allocating any agency to Lauren or her 7 roommates. Craigslist Microwave lists duplicated appliances and kitchen tools on Craigslist.org to help them find new homes where they would be used and loved. Lauren responded with concern: *"Craigslist Microwave. I was worried. I was surprised at how much control this microwave has over the objects in our house."* She knew that some of the duplicate artifacts in her home were not used, but she felt uneasy letting one automated object take on the role of getting rid of others, a role usually played by human actors in the home. She reflected: *"It would be nice to have some sort of like human, like last check before you like get rid of stuff."* This example illustrates how displacing agency from a traditionally human position to a non-human actor provoked worry and a desire to recover that control.

Our work also underlines an interesting or uncomfortable space for some participants when realizing that theirs are not the only voices who can advocate within the home. Inspired by Penelope's unique use of the limited space in her apartment, we imagined Competing Cupboard: a cupboard where the dishes and cleaning supplies compete with toiletries for odorous dominance over the storage space by conscripting other connected objects (and supplies) to join their side. Penelope uses the 'kitchen' sink and cupboard during her morning routine because her

bathroom has neither. When describing that area of her home she would unconsciously shift between calling it her kitchen and her bathroom. In Competing Cupboard, objects advocate for their category of items in an attempt to convince Penelope to pick a side once and for all: kitchen or bathroom. In this interaction, Penelope's actions are subordinate but necessary to the objective of the objects. The human has become a channel for action that the connected artifacts leverage.

Penelope's reaction to this concept illustrates her desire to be an active participant in IoT interactions saying *"It doesn't do anything to include me... I want to be competing. Like, I felt left out with this idea."* She assumed that its purpose was to entertain her, and it failed because she was only passively included. In this case the tension is not about fear of being manipulated for mysterious or nefarious ends but arises from fear of missing out on engaging interactions which can be perceived but not *directly* controlled.

5.4.2 Negotiating agencies. While the examples above present cases where participants reacted with curiosity or a sense of exclusion to a lack of agency, below we examine how participants Lindsey and Oscar responded by reimagining and renegotiating levels of agency with the concept Connected Cardboard Suite.

The Connected Cardboard Suite was initially a set of sensors attached to the cardboard boxes Oscar and Lindsey leave out for their cat. It would collect biometric and behavioral data and display the cat's emotional state. As we co-speculated, however, this concept evolved into a fully autonomous pet-care object where the cat *"walks into a box and suddenly the box becomes a jungle gym transformer... a box that I could not go into"* (Oscar).

The couple also discussed the emotional downsides to giving control to a machine who might be a better caretaker than themselves. As she thought about how the device would be so good that the cat would not want to leave, Lindsey rued, *"you get the notification that he's purring and he's so happy, the happiest he's ever been...he wouldn't need us anymore."* Lindsey tried to reconcile this loss by positioning the machine as an arbiter of agency via the notifications. Oscar further renegotiated the amount of agency over caring for the cat by saying *"I guess...they're going to have like cameras and viewing windows and stuff. So, you could take part..."*

Through this co-speculation, care for the cat shifted from Oscar and Lindsey exclusively (their lives today), to being shared with a connected object who advocates on the cat's behalf (our proposed concept), to an all knowing, acting,

and informing device that reallocates some agency back to the couple (co-speculation). Current commercial IoT often paint agency as binary, as something one either has or does not. The examples in this section showcased how agency is more fluid and complex than this binary opposition. As a result, opportunities for design and areas for consideration around agency and IoT might include questions such as:

Questions about the home:

- How do objects in this home currently shape agency with home dwellers?
- How does the structure of this home emphasize or silence human agency?

Opportunities for IoT:

- How might domestic IoT navigate these complex yet rich negotiations between agency in humans, non-humans, objects, and this home?
- In what ways can IoT devices make more visible the current allocations and exclusions of agency in this home?

5.5 Embracing imaginary and potential uses

In this last section of our analysis, we discuss ways participants responded to concepts that encouraged dreaming without the necessity of doing. We found that participants were often confronted with constraints related to their home's unique size or configuration. These personal and unusual situations lead to an exploration on imagining alternatives to the home or home activities.

Penelope (living in a 198 square foot apodment) studied fashion design and continues to enjoy sewing and crafting. She holds onto many different fabrics and materials, stating that while she has not worked on any projects lately, she keeps the materials because of their potential to be made into something special. Referring to her collection stored in a translucent box, Penelope said: *"I love to just sit and stare at the fabrics and think of what projects I can come up with."* She continued: *"I need to not be having all those projects out, staring at me because I need to study for the GRE."* Given Penelope's constraints on time and space, her desire to be creative is often satisfied by visualizing possible projects: *"I just love to think of ideas and not actually complete all of them."*

With this in mind, we proposed to Penelope a concept called Project-Or (see Fig. 3), a device that projects images and instructions for potential crafting projects based on the materials available in her apodment. The device displays potential projects for brief intervals, moving from one possibility to the next. Penelope responded: *"OMG, I love, love, love this idea mainly because I love designing, creating*

ideas, mixing and matching the fabric. Simply imagining the design more than actually spending the time to design this would be an everyday sort of game app for me." For her, Project-Or was enticing because of its ability to show actual possibilities without requiring any action. This concept would allow Penelope to satisfy her craft enthusiast needs without taking precious space away from essential home functions.

For Abby and Leonard, who have periodically lived in a van, we proposed a concept called Lonely Fishing Rod, which is based on a fishing rod they keep in the van but have never actually used. Lonely Fishing Rod suggests different uses and appropriations based on Abby and Leonard's location and current activity. For example, the fishing rod could propose to attach marshmallows on the fishing rod's hook to roast over a fire while camping. In the booklet Abby wrote, *"I like the humorous side of this and the emotional side too."* Abby found this device's ability to suggest ideas to be delightful because of the endless funny and absurd possibilities the fishing rod might come up with. For Abby and Leonard, as well as for Penelope in the previous example, part of their appreciation of the concepts was in the way it validated and acknowledged the imagined practices in their homes. These IoT-aided performances of imagined or possible realities are exempt from the current constraints of a home and therefore complement 'real' activities in the home in ways unseen and intrinsic.

Grace, who lives on a trawler, would like to put a bathtub on the top of her boat. We proposed a concept called Turtle Tub-Dream: a turtle with a snow globe-like shell that displays potential views from her aspirational rooftop bathtub. This example is about aspirational use; something that *will* happen, as opposed to the potential and imaginary uses above. After comparing the concept to something from a Harry Potter book, Grace stated: *"the bathtub is practical and creative"* and explained she was surprised that this concept touched on envisioned futures about her boat. Engaging aspirational visions of homes are not often considered as the purpose of IoT, provoking surprise in Grace's case.

In this section, we looked at connected devices as a vehicle to imagine possibilities within the home: possibilities about home transformations, and about how to use forgotten materials or objects. IoT, which by nature has digital components, has the material (and immaterial) qualities necessary to project and provoke imaginary uses while respecting the physical constraints (or timelines) of the home. With this in mind:

Questions about the home:

- How do home dwellers engage in imaginary practices in this home?
- What barriers are currently restraining potential or aspirational uses in this home?

Opportunities for IoT:

- How might domestic IoT support dreaming and planning practices in this home?
- How might IoT systems combine everyday functionality with imagined uses in this home?

6 DISCUSSION

Our findings articulate five new avenues of interest for future domestic IoT design and research. Our work broadens definitions of the home and challenges assumptions in IoT by bringing revived attention to the porous quality of boundaries in and around the home, by opening the home to a world beyond its walls which includes neighbors, wildlife, and natural as well as artificial elements, and by positioning the life of domestic IoT systems on a longer timescale. We extend current postulations about IoT agency in the home by reflecting on ways that connected artifacts and home dwellers negotiate, trade, and are actively taking part in home life. Finally, we also position IoT as a valuable tool for considering and energizing another type of use in the home: imaginary uses. Below, we come back to the simple premise we made in the introduction: what could be discovered by looking beyond the stereotypical view of the home in domestic IoT.

6.1 Examining divergent perspectives: Alternative IoT

When designing for a stereotypical vision, what is missed? The co-speculations with non-stereotypical home dwellers opened new definitions of homes that helped avoid mainstream visions of what IoT is or what it is for. A technical definition of IoT is: a collection of heterogeneous, identifiable, and self-capable objects and ad hoc interoperable networks [10]. These characteristics of connected objects do not specify applications that are necessarily grounded in values of surveillance, control, resource management, and efficiency. These same technical characteristics of IoT could be applied to interaction design and HCI approaches such as ludic design [25], or values like interpretation [44], imagination [8] and ambiguity [28]—values we saw emerge in the Bespoke Booklets.

The sketches co-developed are divergent: they each stem from a unique home and might never be relevant to other homes. But, together, they paint an extraordinary picture

of parallel alternative visions of IoT. Taken together, these visions act as a reminder that designers and researchers are not constrained to current visions of IoT; rather, we are at the beginning of an exploratory era to conceptualize what it means to live with connected and smart objects at home. Even further, some of the examples above offer glimpses into different futures where IoT might not even be relevant or welcome. Examples such as Susan’s Time Machine Window, Oscar and Lindsey’s Media Manuscript, and Karey’s Please Pop-In For Tea put into question the assumed inevitable place of IoT in the home.

6.2 Surfacing the unseen: Non-stereotypical homes

Our approach stemmed from a precise goal: commit to examining non-stereotypical homes as a generative starting point to explore alternatives for domestic IoT. After purposefully recruiting participants who live in homes that display a diversity of forms and practices, we attended to the specificity of each home with their inhabitants through the home tours, the co-speculative booklets, and the exit interviews. Specificity and careful attention for each home (and each participant) carried through our process. While the findings above present high-level themes that were found across homes, we find it extremely difficult to conclude by presenting the reader with design recommendations for all IoT domestic products. Instead, we argue that our work is a reminder of the necessity to look beyond stereotypes and assumptions to reveal things that would otherwise remain unseen. For instance, the van and the boat emphasize the relationship between the indoor and outdoor by the nature of their mobility and size. That relationship is present for many homes, but often remains uncharted because it is eclipsed by other more common foci of design or interest such as privacy and security. Similarly, buildings with rich histories, like June’s old box office apartment, make it difficult to ignore the long temporal scale of some of the places we live in. While newer homes don’t have that history, many homes are in the process of creating those long-term traces—making temporal consideration highly relevant, but often forgotten.

Similarly to Giaccardi et al. [29] who highlight the ethical responsibility for designers to go beyond stereotyped views of older adults in gerotechnologies, we urge designers and researchers to actively uncover facets of home buried behind idealized perspectives. We encourage designers and researchers to add to the questions we outlined in our analysis and to build questions that are narrow and pointed to the unique qualities of the homes they are studying or designing within.

7 CONCLUSION

In this paper, we presented five new avenues for domestic IoT. These avenues are the result of a co-speculative study with 16 people living in non-stereotypical homes, with whom we created Bespoke Booklets to collect an array of unique and imaginative sketches representing alternative IoT concepts. The avenues we propose touch on the boundaries of the home, people, neighbors, and animals in and around the home, novel agency considerations, and historical, future, and imaginary uses of homes.

While our first contribution in this paper is revealing and articulating these new avenues, our second contribution lies in our demonstration that focusing on divergent perspectives might help surface eclipsed or forgotten aspects of home and IoT. We reiterate our message: we invite designers and researchers to pay close attention to (and to acknowledge) what home they are designing within when they are designing or researching IoT in ‘the home’. By being more precise about the qualities of those homes, we resist the blanket term ‘home’ and open a space for more specific, situated, and human designs.

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