

Article

Cohousing IoT: Technology Design for Life in Community

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Abstract: This paper presents a research-through-design project to develop and interpret speculative smart home technologies for cohousing communities—Cohousing IoT. Fieldwork at multiple sites coupled to a constructive design research process led to three prototypes designed for cohousing communities: *Cohousing Radio*, *Physical RSVP*, and *Participation Scales*. These were brought back to the communities that inspired them as a form of evaluation, but also to generate new understandings of designing for cohousing. In discussing how they understand these prototypes, this paper offers an account of how research through design generates knowledge that is specific to the conditions and issues that matter to communities. This contributes to design research more broadly in two ways. First, it demonstrates how contemporary ideas of smart home technology are or could be made relevant to broader ways of living in the future. Second, it provides an example of how a design research process can serve to uncover community values, issues, and goals.

Keywords: community research; research through design; prototypes; design research; publics; public design; cohousing



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1. Introduction

Cohousing IoT is a research-through-design project that prototypes social Internet of Things devices for cohousing communities. Cohousing provides a rich context for exploring an Internet of Things—commonly abbreviated IoT—that is designed to support social values in ways that are currently excluded from contemporary technology conversations. Existing home IoT platforms promise seamless interconnectivity, where devices do their part to make human homes and lives simpler and more efficient. In general, “smart home” technology is designed for what are considered “traditional” homes: free-standing, single-family residences. This narrow definition backs a design philosophy that excludes a great deal of people and their homes that are configured in non-traditional ways.

This paper describes a research project that led to a series of prototypes designed for cohousing and how cohousing residents understood them. An environment like cohousing offers a new setting to consider what a domestic Internet of Things could be like. This Internet of Things operates across multiple residences, but only one home. One of many outcomes from this research project is a set of three prototypes designed to explore sustaining this living together: a community radio, a platform for RSVPing to community events, and a set of scales that represent participation in community life. These prototypes provide a material platform through which cohousing residents can reflect upon both the particulars of IoT in the context of cohousing, as well as on cohousing practices and values more generally.

In addition, these prototypes generate new contexts for existing products and services as well as new understandings of how they might operate in different social worlds [1]. In this way, technology prototyping instantiates new arrangements of social forces, and not simply objects in themselves [2–4]. This paper discusses how these prototypes were brought together with cohousing communities using a series of design workshops to evaluate their applicability and uses the results of those workshops as an opportunity to reflect on how design research can support cooperative inquiry into the social settings that it designs with and for. As an alternative style of living, cohousing offers a template to consider alternative

approaches to the Internet of Things—an IoT that accesses social and civic infrastructure rather than product or service infrastructure [5]. Based in this setting, this paper asks, “how can design research articulate the values, issues, and goals of shared living?” The goal in this work is not simply to produce proof-of-concept systems, but also to collaboratively explore the feasibility and desirability of different configurations of technology applied to different conditions of living together [2,6,7]. This paper offers a set of contributions to future community-based design researchers. First, it represents a methodological contribution to use prototype-based workshops to understand the fundamental concerns and conditions of a community in a new way. Second, and more narrowly, it articulates the concerns that drive cohousing conditions in particular, offering reflections on the values and practices that should be supported in future ICT design.

1.1. Cohousing

Cohousing is a style of living that is meant to provide a functional alternative to social disconnectedness that has made contemporary living untenable for many [8]. Cohousing builds strong community among its residents by design and is a reaction to contemporary single-family houses that lack vibrant social connection between and among neighbors. In *Creating Cohousing: Building Sustainable Communities*, McCamant and Durrett describe their own journey that led them to plan, build, and eventually become residents in cohousing [8]: *So many of us seemed to be living in places that did not accommodate our most basic needs . . . We dreamed of a better solution—an affordable neighborhood where children would have playmates and we would have friends nearby, a place with people of all ages, young and old, where neighbors knew and helped one another* [8]. For some, the solution to issues like these has been cohousing [9]. Cohousing is a collaborative community that aims to replicate a village-like atmosphere. Cohousing comes in all kinds of shapes and sizes. In the most traditional form, residents each own their own self-contained house and share ownership of common spaces, like open outside areas, storage facilities and a large “common house” for events, entertaining, and occasional meals. Most cohousing communities have common meals a couple of times a week. Many cohousing communities are committed to social values like resource sharing, collaboration, sustainable living, and diversity. Residents are responsible for maintenance and upkeep and are expected to provide a small amount of their time monthly to keep up with the work that helps the community function. This labor can be landscaping, cooking, cleaning, and so on—the work of a traditional home, scaled up.

Cohousing originated as a specifically ideological practice in Denmark in the late 1960s. In particular, two Danish articles helped to inspire and form the foundation of the nascent cohousing movement: journalist Bodil Graae’s *Children Should Have One Hundred Parents* (1967); and architect Jan Gudmand-Hoyer’s *The Missing Link between Utopia and the Dated Single-Family House* (1968) [8]. Lucy Sargisson describes the tones of this movement as “firmly utopian,” intrinsically offering a feminist, communitarian critique of contemporary institutions and practices. Graae and Gudmand-Hoyer claim that the design of the city has created ever-more extreme isolation and alienation, and even further, that urban housing has played a causal role in that shift [10]. This critical perspective provided an ideological foundation for what became cohousing, or in the original Danish, *bofællesskaber* (“living communities”). Here, multiple independent households coalesced into new developments combining the advantages of community with the autonomy of private housing. They sought to restore what they saw as disintegrating community values, to build stronger families, and to create ‘villages’ in an urban context. While this mode of living is becoming more popular in the USA and Europe, it is of course not a novel approach to habitation. Historically, single-family homes are the aberration, and indeed, across much of the world, intergenerational and multi-family living arrangements are the norm. Shifting trends in the USA and Europe, though, point towards economic and social rationales that incentivize making a choice to live together. It is this trajectory that motivates this research project—if homes do not look like the ones that are being designed for, what are the real needs of people that are not being met?

While cohousing communities vary in terms of size and physical structure, there are some commonalities that are shared among communities. For example, many design decisions serve to facilitate a sense of shared kinship and safety. Cars stay on the periphery of the property, leaving space between the homes to become play spaces for children. Common houses are in the center or near commonly accessed parts of the property. Homes are oriented towards pathways and front windows in residences are large enough to let passers-by see inside. The role of site planning and design is essential in considering how and why cohousing communities look and act the way that they do. Cohousing communities are neighborhoods that are expressly designed for social interaction [11]. Beyond this, though, cohousing communities constitute homes across buildings. The common house, for example, is both common space as well as a continuation of an individual residents' home. Cohousing stretches the definition of home in ways that can provide provocative and interesting inspiration for design.

1.2. Design Research in Cohousing

This project finds its roots in many different aspects of contemporary HCI research. Domestic research has been a long and winding thread in HCI [12]. Most visions of the domestic IoT or smart home extend from Weiser's vision of the computer for the 21st Century [13] or Tolmie's notion of "unremarkable computing" [14]. To this point, depictions of future life in Internet of Things-enabled smart homes frequently portray standalone residences with garages and pools as being representative of typical domestic life. Cohousing offers a different understanding of what a smart home could be. Here, there are three different kinds of life in the community: public life in a broader city, public/private life within the cohousing community, and the private life of the individual family home. Cohousing features like the common house exemplify this variety of shared space. Considering how these three layers interact could serve as part of a model for how alternative IoT design might support different types of communities [15,16]. Fundamentally, cohousing is invested in certain values that drive living together [2,17].

In particular, this work comes from a research-through-design approach that postulates novel and unexpected experiences in domestic life [18]. It draws from design approaches like ambiguous design [19], reflective design [20,21], ludic design [22] and slow design [23,24], that all produce domestic objects making claims about what roles technologies can or should be playing in the home. This paper builds on this tradition of domestic speculative design, hoping to validate and understand how research through design can produce technologies that are both appropriate to intentional communities such as cohousing, as well as articulating alternative implementations for existing technical practices. This is part of a long line of HCI technologies that are aimed at developing richer social connections in the home. These include using techniques like habituation and ritual to produce connection between geographically distant kettle users [25], tablecloths that leave traces of domestic activity [26], fostering visibility for elderly residents of a housing project [27], and providing a venue for community narratives to be both recorded as well as travel through a deprived community [28]. In a similar vein, this set of three prototypes offers a different cultural imaginary for the Internet of Things in order to explore cohousing's human, social relationships with proto-infrastructures [29] as well as the community-driven domestic life that they are a part of [30].

Recently, intentional communities themselves have been a topic of interest to HCI researchers—ecovillages [31], cohousing [30], simple living communities [32], collective and mobile living arrangements [33], and non-stereotypical domestic spaces [34,35] all are in tension with contemporary living and offer different perspectives on everyday domestic life. Living outside of the mainstream provides an opportunity to consider what roles and practices new technologies can take on, as well as the role of prototypes to support intentional practices in living [36]. In supporting these alternative practices, this project is rooted in speculative design [37,38]. Speculative design is predicated on imagining social and technical worlds that are different from the ones we live in at present. Here,

by designing technologies for a smart home shared across multiple houses—an IoT for cohousing—different values and applications for existing technologies can be explored, and through interpreting them, drive future technologies to support and sustain novel social arrangements at the margins of current practice, and through that process generate ideas and concepts for more mainstream contexts [16].

This paper is structured as follows. First, it discusses the methods used to get to know cohousing, as well as a brief overview of the research sites visited as a part of this project. This is followed by a discussion of the goals in prototyping speculative IoT devices for cohousing and describe the codesign workshops that were used to introduce the devices to cohousing residents. In the next section, the prototypes are introduced, with scenarios to situate them as part of cohousing life. After that, the workshop results are discussed and interpreted to understand how these prototypes led to a better understanding of what the communities could make use of in terms of future devices.

2. Engaging with Cohousing

In order to understand cohousing on the ground, the author made research visits to three cohousing communities using a strategy of “diverse engagement.” This took place in three broad steps: first research on the ground in cohousing communities; second, design prototyping to make speculative IoT objects for cohousing based on the fieldwork; and finally, workshops with residents of cohousing to understand what works with the prototypes, what did not work, and what might be preferable in the future.

In the first phase, a combination of different approaches over a period of four years provided a unique perspective on what cohousing is and how it operates at five communities across three U.S. states. Over that time, the author conducted interviews with residents, took tours of the communities, and was a guest at common meals. These engagements each provided a different way to understand cohousing. Semi-structured interviews, for example, provided a way to get cohousing residents’ experiences in their own words, while still retaining flexibility to respond to unexpected aspects of conversations with residents [39]. Attending common meals and going on tours of cohousing sites offer a means of doing what Wright and McCarthy describe as *knowing the user*: “knowing the user in their lived and felt life involves understanding what it feels like to be that person, what their situation is like from their own perspective” [40]. As community-based research through design, this approach is grounded in participatory design methods [41–44] that strive to simultaneously contribute to design-based invention while producing opportunities to explore new modes of living together that can be enabled through design practice [44,45].

This messy, contingent process of engaging with communities in multiple ways offers advantages in terms of thinking through cohousing as a space for smart home technology design. Once a designer has a sense of cohousing, built through a wealth of different kinds of materials, design concepts and insights can be generated via a process of “abductive sensemaking” [46]. In this process, design research materials can be synthesized into concrete design ideas through multiple iterations of prioritization, judging, and forging connections based on the stuff gathered through design research coupled with a researcher’s own experience and insight. This process leads to design concepts that are rooted in and inspired by research materials but are not directly for a particular user or context. Instead, they are manifestations of how the design researcher imagines an IoT for cohousing to be like. To get an even more concrete understanding of the possibilities for connected community technologies in real-world cohousing, the prototypes are returned to communities to both understand the prototypes better, and to see what might make better sense in their place.

In that sense, as a research-through-design project [47,48], Cohousing IoT intends to understand how people live together and speculate about the role that computing technology can take on in that living together. This work uses multiple ways to engage with cohousing communities to understand how cohousing operates in practice. This combination of methods informs prototyping, as bits and pieces of these approaches are

integrated into the design process [30], leading to provocative prototypes [49] that become a means of better understanding what role design can play in these communities.

2.1. Cohousing Communities

While the shape and structure of cohousing communities varies from location to location, the goals and practices of cohousing are often the same: residents seek to build community with their neighbors. The sections that follow are brief overviews of six different cohousing sites visited as part of this project. Each are somewhat different in physical form, while remaining similar in social structure. All are driven by a sense of values and goals that motivate residents' participation in community life [30]. Often, these cohousing communities look quite similar to more traditional neighborhoods and subdivisions. The difference is in the details of each community: whether and how cars have been excluded to create pedestrian paths, or in tradeoffs that have been made as part of the development process. Individual homes are smaller than average, or whether particular ecological features have been implemented. In this way, the role of site planning and design is essential in considering how and why cohousing communities look and act the way that they do. As mentioned above, cohousing communities are neighborhoods that are expressly designed for social interaction [11]. So far, though, all of these design considerations are architectural and relate to planning social interaction through manipulating space and arrangements of residences and buildings in different, intentional ways. As smart technologies become more common in the home, interactive devices and systems might serve to construct social interactions as much as a site plan.

2.1.1. Touchstone Cohousing, Scio Township, MI USA

Touchstone Cohousing is located just east of Ann Arbor, Michigan, and is one of three adjacent communities there (Figure 1). Together with Great Oak Cohousing next door, and Sunward Cohousing nearby, they form Ann Arbor Cohousing. Each of these communities are independent, but there is a lot of knowledge that transfers among them regarding management and technical infrastructure. Touchstone itself is the youngest of these three cohousing sites. A total of 24 homes are built into 7 buildings, sharing walls to improve energy efficiency and decrease costs during Ann Arbor's winters. Approximately 60 residents live at Touchstone of all ages and family sizes.



Figure 1. An aerial view of Touchstone, and garden plots. Some plots are private, others shared.

When visited in 2016, Touchstone was in the middle of building its own common house. The community's construction process was interrupted by the economic crisis in 2008, meaning that another two or three residence buildings as well as the common house had not been completed in the first building phase. Until its own was completed, Touchstone had shared the common house of Great Oak Cohousing next door, meaning that in many ways, there were two cohousing communities overlapping. One side effect of this developer-driven model of cohousing was that when the money ran tight, the relatively

low cost of cohousing residences meant that people bought into the community with little intent to participate in the social lives of the community. Especially without a common house of their own, Touchstone was in many ways more similar to a condo community than living in an intentional community. Over time, turnover among residents less committed to the aspects of cohousing and more committed residents moving in has created a tight-knit community.

2.1.2. East Lake Commons, Atlanta, GA USA

East Lake Commons (ELC) is the largest cohousing community in the USA. It is built on 20 partially wooded acres located 4 miles east of downtown Atlanta (Figure 2, left). There are 67 townhouses in that space, a large common house, and “Gaia Gardens,” a 3-acre organic garden and orchard, greenhouse, apiary, blueberry patch and pond. The garden and orchard together supply a CSA, or community-supported agriculture, and provide fruit and vegetables to the surrounding neighborhoods.



Figure 2. East Lake Commons, with organic farm Gaia Gardens, and a view of the open space next to the common house.

What became ELC was originally intended to be government-subsidized housing for low-income residents. A community of Quakers looking for a site to create a faith-based intentional community entered a discussion with the property developer and established a cohousing community instead. The community no longer has any formal religious affiliation, however. Now, is a burgeoning cohousing community of approximately two hundred residents. This is many more than it was originally designed to accommodate. Originally, ELC was intended to be two separate cohousing communities, but development costs meant that the second common house was never built.

2.1.3. Lake Claire Cohousing, Atlanta, GA USA

Lake Claire Cohousing (LCC) is among the smallest cohousing communities in the USA. In contrast to ELC, it sits on a half-acre plot in a densely populated residential part of East Atlanta. Surrounded by detached, craftsman-style homes, the 12 townhouses at LCC cluster tightly around open space in the center, with a common house and garden plot at the west end of the property (Figure 3).

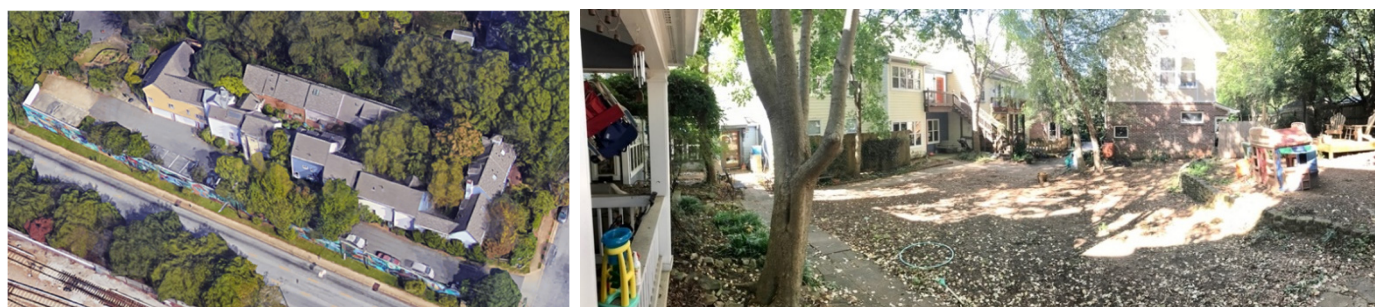


Figure 3. Lake Claire Cohousing. Its structure provides an inner play space for children and families.

LCC was built in 1997, and the first residents moved in the following year. Unlike ELC, LCC was self-funded by a group of people inspired by McCamant and Durrett to create a cohousing space. These residents followed the guide of books like *Creating Cohousing* [8] and *The Cohousing Handbook* [47] in finding land, architects, planners, and so on to build a community that fit their needs and resources.

2.1.4. Pacifica Cohousing, Carrboro, NC USA

The Research Triangle in North Carolina is home to a number of cohousing communities. Pacifica Cohousing consists of 46 residences that are a mix of townhomes, detached dwellings and stacked houses on eight acres approximately a mile from Chapel Hill (Figure 4). The first residents moved into Pacifica in 2006, but the community's history stretches back to approximately 2001. At that time, architect Giles Blunden and a group of interested people sought to create a cohousing community close to downtown Carrboro. Construction began in 2005, and the community celebrates its anniversary on 1 May 2006, when the first homeowner moved in.



Figure 4. Pacifica Cohousing from the air, left and on the ground.

As with many cohousing communities, environmental sustainability is a major factor for residents. Pacifica includes two large rainwater cisterns (5000 and 15,000 gallons), organic community gardens, passive solar heating, and solar hot water and radiant floor heat in many buildings. Notably, Pacifica's common house has the largest residential photovoltaic solar array in the triangle area.

2.1.5. Eno Commons, Durham, NC USA

Eno Commons is a 22-household cohousing neighborhood also in Durham, North Carolina (Figure 5). The 11.2 acre contain twenty-two households, creating a community size that residents believe near optimal for balancing privacy and participation. Eno Commons offers the privacy of your own home and yard, as well as the option of gathering with neighbors in the common house, community gardens or orchard.



Figure 5. Eno Commons. Houses in Eno Commons generally spread along two pedestrian paths.

Like many other cohousing communities, Eno Commons is built to support ecological sustainability. Each home at Eno Commons is heated and cooled by a geothermal heat pump, the most efficient, low maintenance heating and cooling systems available. Power bills for residents are quite low, meaning that efficiency works for residents in towards both sustainability and affordability. As with other cohousing communities, Eno Commons is built using a design which focuses on people, not cars. By limiting road access, they feel that they create a neighborhood that is safer and more pleasant for children and adults and that preserves large portions of their land undisturbed for both wildlife and recreational uses.

As sites that are built in a particular way with particular goals in mind, the design, layout, and space planning of cohousing is built to enhance social interaction and help residents know one another better. Beyond the physical infrastructure, there is a network of social relationships and bylaws that expressly articulate how cohousing should operate as a shared endeavor. As a site for HCI research, though, cohousing is interesting as a model of shared living where these social needs and practices can be mediated through emerging technologies. The contemporary vision of the smart home as a house for a single family breaks down in the context of cohousing. In order to imagine material possibilities for a smart home shared across multiple houses, research through design offers an opportunity to imagine new devices and systems that might help more active participation in shared living.

2.2. Prototyping Speculative IoT

The research strategy of diverse engagement was followed by design prototyping that led to a set of three prototypes. These prototypes imagine the possible role of technology to support and sustain cohousing and result from a research-through-design process. Research through design (or RtD) is a mode of design research where knowledge is built from designing and constructing artifacts that can provoke or assert new visions of contemporary design spaces [37,50]. As mentioned above, this work builds on prior work exploring the roles technologies can or should be playing in the home. The design space of “smart home technology for cohousing” is being explored via speculative design to create prototypes that help people imagine alternatives to their current situation. In RtD, design methods become ways of exploring or learning about design spaces like these [50]. In this mode, design materials like prototypes offer proposals of what design can do in a particular situation but also ask questions about what design should do in new or unusual circumstances. One characteristic of RtD is the production of design artifacts that are used as part of a research agenda to learn more about a condition rather than to offer a solution or to be expressly “useful” [50]. The prototypes described below—a community-based radio system, a platform for RSVPing to common events, and a device to help residents reflect on community participation—instead seek to articulate current issues in cohousing, while simultaneously proposing new opportunities for community collaboration via smart home technology. Each of the devices reflect problems gleaned from the research into cohousing

communities described above. Social cohesion, organizing and coordinating community events, and being responsible for labor in the community are common issues when living together, and these form the basis for the design work.

These designs are not functional enough to be deployed in the long term or to be used for any real length of time. Instead, they operate as design or technology probes [51,52] that help to enlist residents of cohousing to imagine possible futures for connected home technology in cohousing. These prototype objects strive to represent “matters of concern” that are important to cohousing [18] and help residents of cohousing invested in those concerns understand the possible role of technologies for their unusual living situation. In this way, the prototypes are intended to support cohousing residents to approach their community life from a new perspective, imagining the capacities that future technologies might offer them. As described earlier, these three prototypes are the result of a design process with a public orientation [2]. This means that the prototypes work to support a cohousing public: they provide material scaffolding to support the construction of this public around issues that matter to cohousing residents by encountering proposed technologies and reflecting on them together. These prototypes offer a different perspective on smart home technology for cohousing to support knowing a condition differently by experiencing its qualities in a new way. In this case, this knowledge is built from workshops that provide residents an opportunity to approach the material conditions of computation and sensing rooted in their own lives and personal experiences.

2.3. Codesign-Inspired Evaluation Workshops

To understand how the prototypes might fit into cohousing, a series of workshops inspired by codesign methods were used to reveal how cohousing residents conceive of the relevance or value of smart home technologies or IoT in their daily lives (described in detail in Section 3.2). The three prototypes described below were taken to communities to see both how they were understood, as well as to offer a platform for speculating towards possible roles of future technologies in cohousing life. As such, these workshops were prototyping endeavors using design games [53] where both residents of cohousing as well as researchers could collectively explore how to make a future or alternate-present condition. Because the goal of this evaluation is less focused on the success or failure of the prototypes themselves, and more focused on the opportunities that connected technologies might bring to cohousing, the methods used were open-ended, exploratory, and story based. Halse et al.’s landscape game [54] offers a way of building stories around the roles of various objects and routines that are at play in cohousing at various times of day or during different activities. The narratives and conversations that emerge from the landscape game reflects the situated knowledge of cohousing residents as they reflect on the possibilities for smart home technologies in the cohousing context. In this exploration, participants and researchers are together doing a second kind of prototyping imagining the configuration and experience of a broader system. In the case of this research project, what was at issue in these workshops was less the specifics of any particular technology application or device concept, but instead how the Internet of Things as a socio-technical system could be made relevant to cohousing. The prototypes became prompts to understand what could make sense for cohousing, what does not make sense for cohousing, and the rationales or context that could drive future design in this space.

These workshops provided a venue for speculation: residents were meant to imagine possible futures for cohousing and the roles that technology—taken broadly—should or should not play in those futures. From this perspective, it was important to hold these workshops at real-world cohousing communities to discern how these prototypes operate in real contexts, even imagined ones. Cohousing communities feature a perfect venue in their common house. The common house provides a space that is at the same time both “shared” and “home” for all residents of the community and offers a unique venue for workshops to explore cohousing practices. These include the daily routines of residents, what kinds of already-existing devices and objects are implicated or affected by technological prototypes,

and finally, what kinds of new routines or practices would be required for these prototypes to make better sense in context. Using workshops to understand designing technology for cohousing makes sense: because maintaining a community is rooted in face-to-face negotiation about issues that matter to the community, engaging thoughtfully with issues and practices is something that residents are familiar with, comfortable doing, and skilled at already.

3. Results

This section presents the cohousing IoT prototypes that were inspired by site visits and initial data gathering, goes into more detail about the structure and materials for the interpreting workshops held at cohousing communities, and finally discusses high-level workshop results.

3.1. Cohousing IoT Prototypes

The three prototypes presented here operate at the edges of the current smart home and provide an opportunity to consider how design can work can help us to understand the social role of technology in cohousing life. While these prototypes work enough to illustrate their intended functionality, they are only as functional as they need to be in order to be used as topics of conversation in the context of cohousing workshops. Rather than real proposals for technology to be built and turned into products, they are examples of technology designed for discussion [55], a way to help residents into imagining future smart home technologies for cohousing. The prototypes are a radio system, built to connect residents together in a subtle, private way; an RSVP platform that links physical and digital worlds together around issues of participation in cohousing events; and a set of scales that foster an opportunity to reflect on an individual's participation in the cohousing community at large (Figure 6). Each is introduced with a scenario [56,57] that is used to describe its intended function in community life. These scenarios are how the prototypes were introduced to cohousing residents in the workshops.



Figure 6. From left to right, the Cohousing Radio, Physical RSVP, and Participation Scales.

3.1.1. Cohousing Radio

Robert has been a resident of cohousing for a few years now. At first, he did not really know what to expect in his new community—for him, the biggest appeal was how inexpensive the homes were compared to other standalone houses in the neighborhood. They are smaller than average, but the social amenities more than make up for it, he has found. Ready to start his day, he heads downstairs, sets up the coffee pot, and taps his Cohousing Radio to listen while it brews. He finds the radio is an interesting way to keep up with the community's musings and goings on. Residents send sound clips, music programs, or notices to an email address, and the files are queued for broadcast to devices like these in every home. Frequently funny, sometimes cute, often informative, Robert appreciates the link it provides to his community.

This concept is inspired by cohousing not quite being as community oriented as one new resident had hoped for. The promise of living together was appealing, but in practice there was perhaps not as much social interaction as she had expected: "I wouldn't say I'm best friends with anyone here. It would be cool to be even closer with some people,

like to hang out more often. There's one person that I kind of hang out with regularly, we have wine, but it's hard. We're all so busy. I think that's the one thing. It's like you kind of imagine that we're all going to be hanging out every night, but we're so busy. Everyone's got a zillion other organizations that they're parts of, so there's not as much time for us to socialize together as ... It also just takes a little bit of legwork. Like, someone's got to have the idea and make it happen. It's easy to sit back and like, not make it happen."

The goal of this system is to help residents feel more connected to one another even when life gets in the way of living intentionally. *Cohousing Radio* (Figure 6, left) is built to connect residents in cohousing in an informal, asynchronous way using audio sent to devices placed in the everyday lives of cohousing members. Residents can use this device to send audio files to all the other members of their community. Inside the radio housing is a Wi-Fi-enabled Raspberry Pi Zero driving an amplifier connected to an external speaker. Residents send audio files that they create to an email address. A script then adds the music file attachment to an internet radio station's playlist. The radios are tuned to that station and play what they receive over the air. The prototype can then queue announcements, music, or shows that residents create into one another's homes. As a smart home device, this concept builds on contemporary domestic IoT devices like the Amazon Echo or Google Home. Each of these smart speakers offer ways of connecting residents to a variety of data streams—a smart home metaphor that is already familiar to many. The conceptual shift here is that the data streams offered by the *Cohousing Radio* are based in and produced by the community. This radio prototype is designed to create an ambient understanding of the social life of cohousing through creating, sharing, and listening to short audio pieces. These are meant to connect residents together in a way that would not otherwise be available.

The asynchronous nature of the system is meant to provide an opportunity for residents who cannot always schedule time to meet face to face a way to feel more connected to one another outside of more traditional events. In this way, the radio offers residents a hyper-local "backchannel" to share bits and pieces of their lives. This concept builds on top of other modes of communication that can be found in current cohousing communities. For example, at one cohousing community in Atlanta, Georgia, USA, residents have a monthly "stick-passing ceremony" to discuss issues and experiences that they have with the broader community. One resident describes this ceremony: *"You can share joys, concerns, things going on in your life and anything that's bothering you, or things you're really happy about, and it's just connecting with one another and sharing what's really going on that you might not bring it up in conversation over dinner."* The radio provides a community a channel for things that are different than lighthearted dinner conversation or the more formal discussions that already have ongoing venues. *Cohousing Radio* offers a way for residents to share personal creative projects like songs or poems, or enthusiasm for old jazz LPs in a casual way that fits into the domestic routines of others, such as preparing morning coffee or doing the dishes.

3.1.2. Physical RSVP

After breakfast, Robert heads out towards his car to go to work. As he grabs his keys, he also picks up two clay balls lying nearby. One is maroon, his favorite color, and the other is turquoise, his son's favorite. Heading past the common house on his way to the parking area, Robert drops the balls in a bowl on its porch to let his neighbors know that they will come to this week's common meal. He smiles when he hears them clatter among other balls in the bowl and continues towards his car.

Later in the day, Ken is at the common house to get his mail. He sees the maroon ball in the bowl and remembers he needs to return the soldering iron he borrowed from Robert. He makes a mental note to bring it to this week's meal.

Physical RSVP (Figure 6, center) provides residents of cohousing a way to materially respond to invitations to events within the community. In cohousing, all kinds of events need to be scheduled and coordinated, such as common meals, committee meetings or social events. One resident of cohousing described the confusion around planning these over email as *"all these different things are going at the same time and sometimes the chains get too long. Sometimes depending on what email platform people are using, how the emails are showing*

up, they miss out on something that was said before.” As the primary way of organizing social life in cohousing, email is two sided—it is broadly accessible and almost everyone has access to it, but messages being asynchronous makes it hard to know whether people are on the same page. This prototype is meant to merge intention and action into something physical in order to increase legibility, while still being viewable remotely in a calendar event for coordination purposes.

By placing a clay ball in a bowl, a resident indicates their intent to attend the event so that event’s organizer can plan for the correct number of people. These balls are embedded with NFC chips that are unique to each resident. By dropping their ball into a bowl, an Arduino-based reader on the underside of the prototype detects the user’s string from the NFC card, sends the resident’s ID to a webserver, where finally a script updates their attendance for an event on a shared community calendar. As an IoT device, the *Physical RSVP* is inspired by existing technologies for coordination and planning in office settings. It combines ideas from card readers and shared calendars to imagine a system to help residents of cohousing coordinate more easily. The *Physical RSVP* prototype is meant to make information material and easier to interact with, while remaining linked to a digital record that can be shared widely. Instead of materializing information from a single user or family, the balls represent the intention of all residents to participate in the social life of the community. The balls are meant to be left by residents, and be recognizable to other residents as well as event organizers, but the information that they concretize remains accessible through online calendars and phone applications.

Unlike the other two prototypes presented here, which are meant to be placed in individual homes, the bowl and its tray are meant to be placed in a common area and be centrally available to all residents as they use the shared space. The visibility of the balls in the bowl becomes a way of marking intent clearly and unequivocally. The physical presence of clay balls replaces murky and impenetrable email chains. By having specific NFC-linked balls for each resident, their participation becomes tied to a totem that stores their needs. Allergies, food preferences or other dietary requirements could be associated with an event to make planning the details of a common meal easier, for example.

3.1.3. Participation Scales

It is after 10pm, and Rachel is just getting home. She had had an emergency committee meeting at the common house on top of a common meal. It looks as though the roof might be leaking, meaning the community emergency fund will be exhausted. On top of this, work has been busy. Rachel is feeling like there’s not enough of her to go around, but all of the things she’s committed to feel essential. As she takes off her coat, she notices her Participation Scales in the corner. She does not think about them often—they have faded into the background for her over the past few months. Stepping closer, she notices that they are wildly out of balance. The pan representing her own life is as high as it can go, while the one for community is all the way to the bottom. She realizes that she has taken on too much community responsibility right now. Resolving to spend more time for herself, she places all the weights on the pan for her personal time. It does not quite balance, but it is getting closer. Maybe she should hand off directing the community’s fall play to someone else.

The third prototype is a set of scales that help a resident reflect on how they live together. In many interviews, residents expressed anxiety or frustration about their participation, particularly around the monthly work hours that residents are expected to complete: “I wasn’t excited about having to do seven hours of work, and I still don’t really put in seven hours of work, but I guess I was like, a little bit more optimistic [that I would]. It does become a drag after a while—when you’re like, ‘Oh I forgot to do my hours’ and you feel this guilt like, ‘I should cook but I hate cooking, and we need somebody to cook, and I can’t clean, because I have to put my kid to bed.’ It’s just feeling guilt, like I’m not putting in my dues sometimes, but then there’s also some annoyances when I feel like I am putting in a lot of time to being on the common house committee, and like, trying to get the flooring for the kitchen, you know?”

In the *Participation Scales* prototype (Figure 6, right), the position of the scales’ arms represents an individual household’s level of participation in the community. This is

measured by attendance at events, work hours, and so on. The arms' position is controlled by a servo motor connected to a Wi-Fi-enabled microcontroller that reads participation data from a server. The left pan is the average level of participation for the community as a whole, and the right pan corresponds to the participation level of a particular home or family. If a resident is not spending enough time for themselves or their household, the left pan will drop. A force sensor on the right pan detects weight placed on it. A resident can place weights on the right pan to balance the scale. Placing a weight becomes a symbolic gesture to take more time for yourself or your household, or, if no weight is needed, to realize that your own participation is actually close to the community average.

This scales prototype is not meant to be punitive. Instead, it is intended as a tool for self-care, and making sure that you are not overextending yourself within the larger community. It is an artifact that offers a means of reflecting on your participation and the effects that this participation might have on your own well-being. In this way, these scales shift current ideas of domestic IoT as monitoring the condition of your home to understanding the conditions of your participation in a community. This is a relatively new context for the Internet of Things—unlike the previous two prototypes, that have more classically computationally-based inspirations, the *Participation Scales* begin to imagine a new kind of computation that is invested in the social life of a community. The scales become a material representation of personal participation in broader cohousing, as well as representing and displaying overall participation levels within that community in real-time.

3.2. Interpreting Cohousing IoT: Community Design Workshops

To understand how these three prototypes might fit into cohousing residents' visions of their futures, design workshops were held that let groups of residents consider the possible role of the prototypes in their communities. These prototypes reflect the issues and concerns of cohousing and are meant to be used to help researchers learn more about how those concerns manifest in cohousing, rather than as a way to assess the success of the prototypes as such. In this way, the idea of "fit" is helpful to draw out what breakdowns exist or how they might be made useful to community life.

These workshops contained design activities involving the three prototypes, including an introduction using the scenarios above and a short demonstration of their capabilities. In the workshop, residents collaboratively constructed scenarios on a map using tokens that represented objects in everyday life to reveal the relationships and stories that emerge as different events taking place. This "landscape game" (after [54]) provides an opportunity for residents to generate a physical mapping of things and their environments, articulate the relationships between objects and social life, and document the emergent properties of cohousing while incorporating new prototypes designed to support cohousing life.

This workshop was held four times in three cohousing communities: twice at Eastlake Commons and once each at Eno Commons and Pacifica Cohousing. Between 3 and 10 residents attended at each event, for a total of 25 participants, representing a significant part of each community. Each of these workshops lasted approximately two hours, and the discussions that emerged from the workshop format were transcribed and coded using thematic analysis [58]. These codes come to the fore in Section 4. For each of these workshops, an overhead map of the community taken from Google Maps provided a backdrop for the landscape game. The workshop has three parts:

First, residents choose a time to develop a landscape game around. In cohousing, specific times are often associated with particular events or activities. Sunday at 6:00 p.m. is often when common meals take place, and in Figure 7 (left) residents are placing cooking and food-related tokens on their community's common house. Other times are less distinctive to cohousing. Weekday mornings mean that residents are preparing for a work or school day, regardless of the kind of home they live in. For whatever time they select, residents choose tokens representing common household and community objects and place them onto the map of their community. They explain how these things are related to

one another and annotate the map using post-it notes to describe what is going on in the community, where events are taking place, and what things are involved.

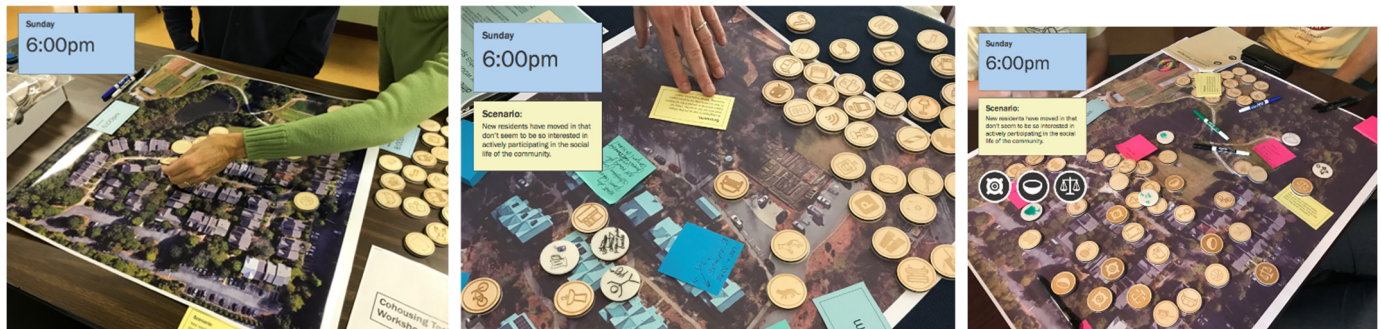


Figure 7. In the first phase of the device landscape game, left, residents have chosen Sunday at 6:00 p.m. In the second phase of the device landscape game, center, residents respond to a scenario and modify the device landscape to take that change into account. In the third and final stage of the device landscape game, right, cohousing residents imagine roles for the three prototypes as component parts of the device landscape for cohousing.

After producing a map of objects at a particular time, cohousing residents choose a scenario from a set of possible scenarios around community breakdown, natural disasters, surplus goods, and opportunities for mutual support. In Figure 7 (center), the scenario is “New residents have moved in that don’t seem to be as interested in actually participating in the social life of the community.” This scenario becomes the basis for a rethinking of the landscape. In this phase, residents rebuild their map, revealing connections between daily life, community goals, and the objects in the landscape.

In the last phase of the landscape game, residents are introduced to new tokens representing each of the prototypes. After some conversation about the devices and their uses, residents imagine how these prototypes could fit into the landscapes that they had created, and how the prototypes could relate to that situation (Figure 7, right).

These co-design workshops helped build an understanding of the design concepts’ relevance to cohousing by assessing how they “fit” with the communities. The workshops also tell us about cohousing, as the prototypes drive the discussion of particular issues in cohousing in concrete ways. The arguments made on behalf or against the prototypes can be seen as expressions of the qualities of the community itself, as mediated and supported by the activities in the workshop.

One way to consider the workshop results is to consider the conversations that came from it as taking place on three levels that build on top of one another (Figure 8). The top of the triangle has to do with whether the prototypes can help residents to reflect on the conditions and issues of cohousing. This relies on the middle level of the triangle, whether the prototypes can engage with the values of cohousing and what matters when living together. The prototypes’ fundamental fit with the community’s vision of itself is necessary for residents to engage with a prototype as something that relates to real cohousing practices in a meaningful way. If residents can engage with the prototypes and discover ways that the devices support cohousing values, it becomes possible to use the workshops and prototypes to reflect on how issues of cohousing can be explicitly designed for. These three layers are used here to present findings from the workshop in this section (Level I), as well as structure an analysis of the results of the workshop in the discussion (Levels II and III).

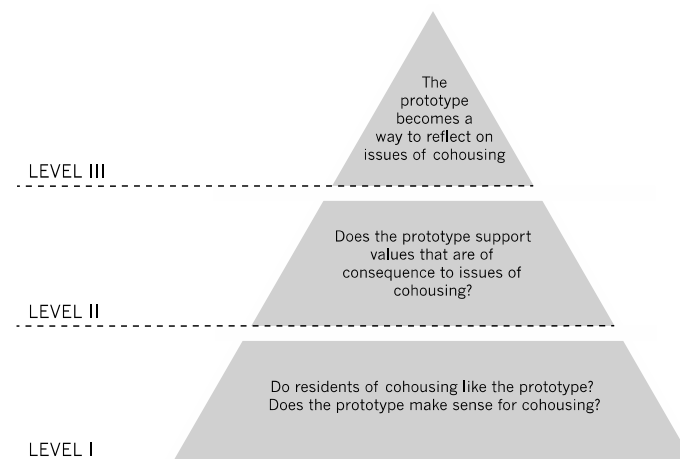


Figure 8. Three levels to consider the outcomes of the cohousing workshops with the prototypes.

3.2.1. Interpreting the Cohousing Radio

One of the communities had recently been experiencing petty thefts, and the *Cohousing Radio* was seen as a device that could support connecting and mobilizing residents in service of protection and security. Though this interpretation is not very closely related to the device's concept, ideas around security and monitoring are classic goals of IoT, and reflect these prototypes as acting in a legible technological role:

- *When you first brought this up, I was like "Oh my god, Susanna". We have an emergency calling post that nobody knows about, nobody uses. You can call it, record a message, hang up, but only on certain hours, and it will call everyone that's signed up for the emergency calling post ... we have no way to communicate with one another in an emergency. We get people running through the community, breaking into houses ... Well, the break-ins only recently happened. But yeah, stealing bikes, going into cars. I mean I've chased people off the property, several of us have chased people off the property. And to be able to go "Hey, 911, there's people here" or whatever. "Something's going down." That would be incredible.*

This quote illustrates how residents found the radio system appealing, but not necessarily as it was intended. While it was designed to provide a casual audio backchannel operating alongside other modes of social interaction within cohousing, residents understood the *Cohousing Radio* first as a means of creating an emergency contact system for residents. In conversation during the workshop, other possibilities for using the radio emerged. Beyond simple alerts or announcements, residents also came to understand it as a means of connecting people together that could supplant email for organizational purposes:

- *I think it'd be really great ... we have a participation problem, so if there's a way to just have people feel more plugged in, even if it is just socially, or by something beautiful—like, we have a recording artist who lives here, Jim. We have other artists. We have really interesting news [and] not everyone's on the listserv necessarily, or just doesn't check their email. But yeah, I mean if it can help get people plugged in. A lot of times like what Dale just did, somebody's going around, if there's a thing, someone will go around and be like 'Hey everybody, come out.'*

After some discussion of the intention behind the radio, residents found appealing aspects to consider, as well as ways of incorporating it into their daily routine:

- *[First listening to global news] and then listening to local news, and then listening to very local news.*
- *We have a very hyper local news.*
- *You get to hear like Dancing Water's poetry, and ... Susanna's meeting pitch and reminders and stuff.*
- *Yeah, it could just have tough, really clear guidelines.*
- *I would see, like maybe if it was an emergency post, you could get it to go right through.*

In the workshops, residents' concept of "tough, really clear guidelines" for radio content underscore a fear of giving unfettered access to creating sounds for sending into people's homes. That this could be abused was a concern as it could fragment a community. While the above comments illustrate a certain level of acceptance or enthusiasm around the possibilities that this radio holds for community life, residents were just as often found it unappealing:

- *This would be interesting, I'm just not sure how [the Radio] would ... I'm just not sure how that would go ... How useful that would be.*
- *I don't actually like the radio idea. Just because I think as a shared ... I don't know that anybody wants to hear my music.*

In this example, the resident wondered what the point of the radio was. As a speaker system, what could be shared was limited to audio, which was sometimes understood to restrict content to simply music. Beyond content, though, the idea of devices that build connection in a narrow-band way actually subverted the ideals of cohousing. The primary goal of cohousing is to support a sense of community through in-person, face-to-face interaction. Building connection between community members in an ambient way emphasized the difference between in-person sharing and a more faceless broadcast approach, especially one that requires production or curation:

- *Even with the creative stuff though, if Alex is gonna put his music on, or Jim is or something, I love the visual. You know if somebody's gonna post a clip of streaming of their actual playing. I love to see them playing, so, I'd be giving up something.*
- *It's more inviting to say, "Jim is playing at the common house, Alex is playing the common house." Or "The kids are putting on a show at the common house."*

While the radio distributes participation and could make participation in community life easier for some, it also was found to work in opposition to the norms and structures of cohousing. The most welcome interpretation of the radio prototype—as an emergency broadcast mechanism, was something that is already-understood as a job for technology. In this view, the radio is simply an extension of already-existing technologies like email listservs or emergency alerts.

3.2.2. Interpreting the Physical RSVP

The *Physical RSVP* was the prototype with the closest linkage between its design and needs of cohousing. The relatively simple form of the *Physical RSVP*—a bowl and tray that the bowl sits on—became a springboard to reimagining and reconfiguring the device's role in the community. One cohousing resident during an interview immediately extended the idea of a single bowl to schedule community dinners to a row of bowls, each with their own placards that indicate a different ongoing vote. In his vision, these tallies could take multiple forms for different kinds of events: the bowls could become a means of polling questions to the community (and through that polling, enacting community governance), sign-up sheets for cohousing events, a way to commit to doing particular work in the community, in addition to a means of simply letting the community know that you'll be at the common meal on Sunday evening.

At the workshops, this means that what the device had to offer residents was clear immediately—the prototype is meant to organize people together while relating their participation to a physical quality that it did not have before:

- *So, it would be like "Hey, are you coming to the movie night? Throw your ball in the popcorn bowl". That's cool.*
- *I like the idea of having a token that's me that I can put some place. That's fun... having one of these be me.*

This resident finds the idea of a ball representing their participation in a community event appealing to the point of scripting themselves into the device directly—that particular ball becomes them in the context of the event. Having this information in a central, highly

visible location in the community could add something useful for the residents, making information present to anyone passing by:

- *I like the idea that oh, we're in community, it'd be nice to come and have it in some common spot.*

However, a concern about the plausibility of people choosing to use new systems requiring new routines, reflects skepticism about whether residents would choose to engage:

- *I like that idea. I would ... Let's just say, you know, in a fantasy world, we could have something at the mailbox that would display kind of your same concept. But it wouldn't be ... I just don't see people taking something to the mailbox and putting it in.*

Beyond simply being a way to organize events, the cohousing residents at these workshops sometimes extended the concept of relating a person's physical presence to an internet-based articulation of existing cohousing practices. For example, at one community, the RSVP concept did not resonate. This community had been having issues with shared resources like tools being misplaced or stolen. This led to discomfort around investment in more expensive common goods like speaker systems or projectors. In the workshop there, the NFC-based RSVP system became a way to record tools or materials being "checked out" to a particular person through a similarly personalized object as the clay balls—totems for responsibility instead of intention to participate:

- *It would be nice to be able to keep ... Let's say I need the sledgehammer or stake driver or whatever, and I'm gonna use it for a whole week, to keep it at my house without having to worry about nobody knowing where it is.*
- *[Keeping an eye on] things that facilitate community gatherings. We're just on the minimal side for that, because who wants to put money into something that's going to disappear? The projector, music. I think like nicer ways to clean the floor. We could get it cleaner faster if we had a nice cleaning machine, but I'm not going to propose that on any budget because who knows how long it'll be here.*

For many cohousing communities, a key issue is the potential expense of these speculative systems, especially when contrasted to the kinds of training or skill-building that would be necessary to have residents become fluent enough to use the prototypes in their intended role:

- *I think the bowl is a cool idea, but you're competing against a piece of paper, which is what we do now.*
- *And that works pretty well. Paper is so easy. The other thing that communities, I think, technology, if it was very easy, could facilitate in sharing our resources. We have things that work for us, like the wonderful mulch pile, I think a dump truck comes. We just write down how many loads we use [to pay]. But there are other things that are more valuable. We might buy more food in bulk or who knows what, if we could distribute it in an easy way amongst the community. Nobody wants to do all the keeping track and the accountability of all that. If there was some way that it was more automated ...*

The need for any community investment to have a proximate use satisfying immediate needs in the lives of residents, underscores some of the issues that are at stake in cohousing. Residents share responsibility for living together, and they take that seriously.

3.2.3. Interpreting the Participation Scales

The *Participation Scales* manifest an anxiety that was common to cohousing community members in interviews, site visits and workshops. The scales visualize concerns around freeloading and equality in participating in the work of the community. Beyond a fear of what might come from representing community work and participation, though, was an acknowledgement that there are residents who do more, and that there could be a use for this sort of system to help community members who take too much community labor onto their own shoulders:

- *I don't want them to get burnt out. I don't want them to feel like they have to do everything they're doing all the time, or the place will fall apart. I don't want them to do so much that they just kind of suddenly fizzle and go "I am done". Cause that's happened, we have people like that. And it's really sad."*

Participation can be understood as the benchmark for community wellness—more people participating tends to make a community more vibrant. On the other hand, less participation, or participation that is primarily on the shoulders of one main “champion” means that the community is in danger of becoming just another housing development. The scales’ potential to prompt reflection on this point was provocative, but not unappealing:

- *There's something powerful about ... I mean, I wonder if that would change people's perceptions of community participation? I mean, at our house we would be short on ... We're tryin' to take care of ourselves, 'cause we give a lot to the community, and oftentimes too much in a lot of ways. Would that help us ... I don't know. But I like the visual. There's something happening that I like here.*

One resident—a software developer—immediately took to the idea and adapted it to become both more feasible and more workable for his community while thinking out loud how to build a real-world implementation for it. The scales prototype resonated with him enough to think through how these issues work in his everyday life, and prompted him to speculate about how it could work from an intrinsically collective standpoint:

- *Let's just say we had our scale, let's just say we had a participation scale next to everybody's name in the [online] directory. And let's just say it was all over the chart. But if on our home page there was a summary of that in a scale that says how are we doing with meeting it? Right? So, we have 75% of the people exceeding our goal. Then [a poor reading on] that individual scale wouldn't hurt as much.*

Tracking participation was often regarded being likely disruptive to a community, but possibly worth the tradeoff to build accountability and mutual understanding. Quantifying that abstract concern was too much for many residents, but the idea that there could be a way to track participation and build it into an accounting of living in community was not unimaginable.

- *I like the idea of here's the four hours, here's what you've done this far. Now, we did have for a while a system of logging your participation hours. And I did it for years. But I actually only recently stopped. 'Cause I just have no idea what anybody else is doing, I don't think anybody's doing anything with the data.*

3.3. Initial Workshop Results

Throughout the workshops, the ideas that these prototypes proposed were relevant to residents and prompted speculation about the capacities that “smart home” technology could offer to cohousing. Sometimes, an idea could be appealing, but the implementation was not quite right, as was the case with the *Cohousing Radio*. Other times, a prototype seemed relevant, but added a layer of complexity to everyday life, as with the *Physical RSVP*. Still other times, as was the case of the *Participation Scales*, a concept that seemed controversial proved to be intriguing and provocative for residents. The prototypes were understood by residents of cohousing in ways that reflected how the prototypes supported—and resisted—various goals that members of cohousing have in choosing to live together. While the prototypes presented to the community were expressly designed to support these values, how residents interpreted the prototypes as working in those ways was varied. Unpacking this distinction is important in that analyzing it provides a way to consider how the real issues of living together—and not the issues of cohousing as imagined by a design researcher—relate to these or future prototypes for cohousing communities. This unpacking becomes the content of the discussion section below.

4. Discussion

Interpreting the results of the co-design workshops from the middle level of the pyramid in Figure 8 helps lead to an understanding of how the design concepts could support—or hinder—values that matter to cohousing communities. Discussing how these values were taken up requires some analysis of how cohousing residents came to understand the prototypes. The process of cohousing residents getting to know the prototypes through the landscape game worked in three phases illustrated by Figure 9. First, residents are introduced to the prototype, and the intended use of the device is explained. This could be called a “received use” understanding of the prototype, as the designer’s thinking about what the prototype is for is the subject of discussion. After that, the residents try to fit the prototype’s use to their own experiences and structures of real-world cohousing life. This could be called “interpreted use,” as residents interpret the prototype based on their own knowledge. Finally, conversation about the prototype becomes more open-ended, and new applications or contexts for the prototypes emerge wholly different from any initial design concepts. This is “imagined use,” as cohousing residents take up the concept and make it their own by imagining novel uses embedded in the real-world practices of cohousing—speculating about possible applications that make sense to them.

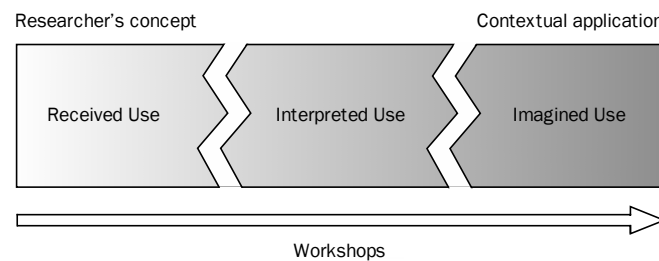


Figure 9. Prototypes move toward relevant uses through discussion in community workshops.

4.1. The Values That Matter to Cohousing

These distinctions are important in discussing how these prototypes were received, as it provides a way of considering how real issues of cohousing relate to the prototypes. Each step further away from the design as imagining cohousing by a designer gets closer to how these prototypes could reflect the values and goals of cohousing as it is lived. In [28], Jenkins describes a set of values that drive cohousing life and can be used to understand how the designs made sense in cohousing. To that end, some of those cohousing values are used here to frame how these design prototypes engage with the goals of living together in community.

In cohousing, *participation* means taking an active role as a resident in shaping the community that you want to live in and *caring* reflects the quality and depth of relationships between cohousing residents. In the workshops, residents immediately understood that the Participation Scales meant to represent participation in the community as well as the labor—both emotional and physical—that comes with community membership. We see above that some residents fear community champions overexerting themselves, leading to burnout and withdrawal. Others find the scales intriguing as a way to combat a lack of clarity around existing accountability practices. In both of these cases, the scales amplify social concerns that at stake in cohousing and make them extreme enough to become an explicit topic of conversation in the workshops, discussing issues of participation overtly.

The idea of “participating well” drove how these designs were interpreted. Rather than being a way to enhance or support broader participation in the community, some of these design concepts were interpreted as requiring a resident to do more work in order to participate fully. The Physical RSVP added substantial overhead to existing organizational structures—requiring residents to go to a place and drop a ball seemed impractical to residents already using sign-up sheets. Creating content for the community using the Cohousing Radio was also not very appealing. The playful aspects of the design were undercut by community values. In the discussions above, residents figured that the device

had no real application for their social sphere, and instead understand it as a device for security rather than for civics.

Responsibility is understanding your part and commitment to the cohousing community at large. Designing systems to take on issues of responsibility technologically led to conceptualizing responsibility through tracking traces of behavior [26]. This is especially clear in both the Physical RSVP as well as the Participation Scales. The RSVP device takes input from residents and places them in an event both physically and virtually by being on an online event's list of attendees as well as being represented by a ball in a bowl. This tracking of responsibility became the material for imagining alternative use cases for the RSVP device. Understanding the NFC-augmented balls as corresponding to intention lets residents extend the concept to voting on community issues. Residents are responsible for organizing their community and this different mapping of responsibility becomes part of a broader social space for the prototype to participate in. The Participation Scales perform tracking in the opposite direction. Instead of recording participation at the individual level, to be aggregated and reported to the whole community, they are designed to understand a resident's participation when compared to the aggregate and report it to an individual resident. This is a kind of self-tracking, as the scales assess individual participation as it relates to broader patterns of activity in community life.

Security means that every member should feel comfortable and safe in the community. For many, part of what makes a smart home appealing is that it can be monitored for security (for example, explored using design by [59]). As noted above, the radio prototype was intended to be primarily a social channel but was interpreted by cohousing residents as a way to send emergency messages to the community at large. Similarly, the RSVP system's shift from organizing social events to an imagined system that keeps track of tool checkout, or facilitating investment in more expensive shared equipment, reflects the paramount need in cohousing to not waste community investment. This imagined use of the Physical RSVP as an NFC-based check-in and check-out platform works in two ways. First, it flattens the system to something that is more legible as technology by falling in line with current expectations for smart homes and smart platforms. Second, it reflects how central issues of security are in cohousing—theft from the common house was a topic of conversation in workshops and preliminary interviews across field sites. Because the common house belongs to everyone and nobody, automating responsibility and security there is appealing for many residents of cohousing.

Collaboration is working with one another. One concept that drove the design of these prototypes was to create physical representations of the issues and practices that matter to cohousing and exploring these issues by imagining how the devices might support residents working together. These collaborations take place at different scales. The *Cohousing Radio* places devices in the homes that make up cohousing, while not really actively taking a part in it. The *Physical RSVP* interacts with cohousing physically and gesturally: by placing the ball in a bowl, a resident sends a particular signal that they will attend a community event. The *Participation Scales* do a similar kind of gesturing but act as a proxy for social life: they gesture to a resident who interprets that movement as representing their social participation. The scales shift contemporary ideas of domestic IoT away from monitoring conditions about your home to understanding the conditions of your participation in a community.

Finally, where the prototypes were imagined to be located influenced how they were conceptualized as collaborating in the social life of the community. This revealed differences between how the prototypes were received and understood by participants in the workshops. Where they were placed in the landscape game during the workshops was influenced by the different social spheres that they were understood to operate in. The radio operates at the private level of an individual's home; the RSVP system was meant to be fully public, and to be placed at a central common location like the common house; and the scales were initially thought to be private—although in conversation with residents

many though it could easily become public as well, reflecting the trust and acceptance that is necessary to living in community.

4.2. The Concerns of Living Together

Beyond reflecting on acceptability and the values of cohousing, the workshops served to reveal fundamental conditions that matter when choosing to live together. At the third, topmost level of Figure 8, the prototypes become a means to consider broader issues. These insights come from frictions or breakdowns that took place when discussing issues of fit or whether the prototypes were in keeping with the goals of cohousing in the previous section. That participants found the design concepts sometimes hard to relate to or not applicable to cohousing life, revealed the basic concerns that motivate their communities. These residents share responsibility for the community and its perpetuation, and the choices that they make can have strong effects on the viability of their community in the future. Rather than reflecting on cohousing values that could be manifested through technology in the future, residents discussed technologies serving cohousing in the present.

One way to consider this split is as the values of cohousing operating in contrast to the concerns of cohousing. These concerns are much more foundational to cohousing than the values and reflect more deeply how the community is organized. Being beholden to these concerns is what makes it possible for the higher-level values of cohousing to exist. These are *communication*, *governance*, and *fiduciary responsibility*.

As a concern, *Communication* is reflected in the way that the prototypes help to foster interaction among residents. The Cohousing Radio, for example, organizes people around content, and hopefully provides a new way for different content or more people to be able to have access to one another. Physical RSVP offered a way of organizing people around events in a clearer way. The concerns with these devices reflect opportunities for this concern to be subverted. In the radio, breakdowns include residents not wanting to share things that others do not like, or the possibilities for abuse. More subtly, the radio lacks personal qualities of communication. Being unable to see a resident perform, for example, creates a gulf between residents instead of building a richer social sphere. For the RSVP, the issue was one of access and possible lack of use, rendering the labor and training spent to get residents to use it wasted.

Fiduciary Responsibility as an idea of waste and cost was a constant concern in discussing prototypes in cohousing. In choosing to live together and pooling common resources, spending is and needs to be accountable to the community. Without an existing line item in a budget for technologies to support cohousing, it was hard to imagine these devices being possible. This often tempered any interest or appeal that the prototypes could have had for residents: for some participants, they felt unable to say whether a design concept was interesting if it seemed like a real-world installation would be expensive. The fundamental concern of a new shared expense meant that speculating about the idea was not possible.

The idea of *governance* builds on both organization and fiduciary responsibility to describe the overall structure of making collective decisions in communal life. Because cohousing uses a consensus model for decision-making, involving technologies in ways that could affect that decision-making is especially fraught. Governance concerns appear directly when the Physical RSVP is cast as a voting system, letting residents use clay balls to make community decisions. Beyond this, the responsibilities associated with a concern like governance are more than just how these tools could be used to organize residents to make decisions: these prototypes also have some barriers to entry. The radio requires knowledge of how to produce audio, for example. The scales lack a defined role in cohousing, and their possibility for misuse means that they could upend already-working structures. These barriers might lead to unequal access to cohousing infrastructure.

While there was interest in the prototypes, and strong enthusiasm for the workshops, cohousing residents resisted speculating towards possible cohousing futures. The design goal of probing values in cohousing was subverted by a reluctance to push past founda-

tional concerns. Being able to imagine what cohousing could be like if prototypes like these were used in the future, or what the current experiences of cohousing would be like now if these prototypes were “real” was not always a conversation that was on the table. The practical concerns that make cohousing work in day-to-day life was simply not congruent with the idea of speculation. One result from this research is a more concrete understanding of what makes cohousing work in practice. The ongoing labor that it takes to *do* the work of cohousing is both provisional and constrained. Inherently, maintaining community life is a conservative process that seeks to sustain the community first, and work towards broader social goals when possible. This makes sense from a practical perspective: in order to support social goals like sustainability or fellowship, the community itself first has to exist—and keep existing. In other words, the fundamental concerns of cohousing communities mean that future design work in this space be not just acceptable or legible to residents towards their values, but rather be in conversation with the foundational needs of living in community.

4.3. Designing for Community Life

With this understanding of the foundational concerns of cohousing, we can return to the prototypes, and imagine redesigning them to better support those concerns. Interacting with the *Cohousing Radio* was understood to separate people as much as bring them together, possibly inhibiting communication and thereby threatening governance. A redesign of the concept might be more direct, less asynchronous, and easier to take part in. Rather than building on a radio metaphor, it could perhaps exist somewhere between historical domestic technologies like the intercom or party line, offering an opt-in conversation channel for residents who wanted to join in when able. Another possible direction eschews content entirely, instead imagining ways to feel more embedded in the community. In that mode, it might let a resident “listen in” on common spaces in distorted or muffled ways that preserve privacy while building ambient connection between residents and their shared places. The *Physical RSVP* was interpreted as a tool for maintaining governance, whether as a voting system directly or as a way to track common goods. These reflect needs for securing common goods and building common goals in community. What was interesting about the *Physical RSVP* is that the RSVP capacities fell by the wayside in favor of tracking intention and state for both people and objects. Separating these again, perhaps with wearables on the one hand, or inventory systems on the other, might prove fruitful. The *Participation Scales*, as imagined by one participant, could be moved into software, and become a more mundane—but more useful-seeming—part of cohousing life. Software applications seem like they could sidestep some of the concerns about financial responsibility that make paying for bespoke physical solutions so unimaginable.

These design iterations take some of the feedback above into account to imagine how the cohousing IoT prototypes might better fit the concerns of cohousing. While these too would no doubt bring with them their own controversies, shifting the interaction elements or metaphors at play seem like one possible way to better design with community concerns. Finally, a key need for doing speculative design research with communities is to adequately scaffold conversations around what might be *preferable*, not just what is *plausible*. Stronger framing in the workshops that invited speculation about future technologies, with no strings attached, might help break participants out of the framings and commitments that while very necessary in everyday life, might inhibit more open-ended thinking about future possibilities.

5. Conclusions

This project set out to understand how ideas from the Internet of Things might be enacted in cohousing communities. Three prototypes were evaluated through a series of workshops with residents of cohousing communities across the American South. These prototypes were designed to support the community life of cohousing, and as such, the prototypes needed to be returned to real-world situations to get a sense of their accept-

ability. The workshops proved to be broadly successful in engaging with the ideas of cohousing through design, and the prototypes as instantiating imaginaries of community life. However, these workshops also revealed a kind of flawed success in the prototypes' ability to engage cohousing and broaden the frame of what a future smart home might be like for cohousing residents.

Despite some enthusiasm about possible applications and uses for the proposed devices, they were often seen as expensive or redundant, epitomized by a comment about the RSVP prototype that it was “competing with a piece of paper.” This reflects a pragmatic approach to the devices on the part of community members: understanding them as design research systems that exist outside of real-world constraints limits the possible conversation to what *already* works, rather than what *could work* in the future or *might work* in an alternative present. Ultimately, the pragmatism that is necessary to be both responsible to as well as to maintain a shared community means that the flexibility to reimagine the conditions of cohousing was limited.

What these workshops did lead to were deeper conversations about what it takes to maintain collaborative communities. From a public design perspective [2], the design prototypes became a way to foster rich conversations around issues that are common in the everyday lives of cohousing residents that are not often considered explicitly. In the workshops, the prototypes led to frank and thoughtful discussions of fundamental matters of concern for cohousing. One resident realized that conversations like these about the fundamental issues of cohousing never take place, even as they are constantly being negotiated implicitly:

- *You know, it's interesting, is when you stop to talk about this stuff, because we get so busy sometimes, we don't stop to even talk about all the challenges of cohousing, because we're in the midst of it.*

Residents of cohousing share responsibility for the community and its perpetuation, and the choices that they make can have strong effects on the viability of their community in the future. Rather than reflecting on issues inherent to cohousing that might be manifested through technology in the future, residents necessarily focused on how technologies could serve cohousing in the present, articulating what cohousing communities need to be responsive to in order to keep being successful.

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