# Spaces and Traces: Implications of Smart Technology in Public Housing

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## ABSTRACT

Smart home technologies are beginning to become more widespread and common, even as their deployment and implementation remain complex and spread across different competing commercial ecosystems. Looking beyond the middle-class, single-family home often at the center of the smart home narrative, we report on a series of participatory design workshops held with residents and building managers to better understand the role of smart home technologies in the context of public housing in the U.S. The design workshops enabled us to gather insight into the specific challenges and opportunities of deploying smart home technologies in a setting where issues of privacy, data collection and ownership, and autonomy collide with diverse living arrangements, where income, age, and the consequences of monitoring and data aggregation setup an expanding collection of design implications in the ecosystems of smart home technologies.

## CCS CONCEPTS

• **Human-centered computing → Empirical studies in interaction design**.

## KEYWORDS

Smart Homes, Public Housing, Participatory Design, Privacy, Design Research


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## 1 INTRODUCTION

Sensor-enabled data collection that supports automation, remote control, and proactive analytics to increase efficiency, comfort, and convenience are transforming the buildings in which we work and live. While large multi-user buildings have long had forms of automation around environmental control, building access, and security, these capabilities are reaching new consumers through smart home devices. At the intersection of these two applications of building and home technologies lies an issue for human-computer interaction (HCI): understanding and building for multi-family housing, where the assumptions and practices of automation to enable centralized control meet the individualized needs of the smart home. In this paper, we open the aperture of domestic HCI research to consider the specific challenges of multi-family smart home technologies. In particular, we focus on the implications for low-income residents in public housing where issues of surveillance, individual agency, and family opportunity take center stage.

In the Fall of 2017, we were approached by Atlanta Housing, the largest public housing agency in the southeast United States, to help them understand the opportunities and issues of smart technologies and services in a new multi-family and senior facility slated to open in 2019. In response to that request, we hosted a series of design workshops with key stakeholders through the spring and summer of 2018. The new facility was a large, multi-building site designed to address placemaking and community building through a focus on sustainability, life-long learning, and economic development. This setting is significant for HCI because it

eschews the smart home assumptions of the single-family (often wealthy) home. Further, the integration across suites of smart technologies designed for different contexts—from professionally managed multi-user buildings, to mass-market consumer smart home products, to personal smart devices—reveals how the assumptions around these different layers of infrastructure enable or impede the needs of residents, as well as facilities management.

Through the design workshops we hosted, we were seeking to understand, "How do we design smart systems and services for mixed-use public housing?" By staging a set of activities over three separate events, we were able to engage current residents in public housing, as well as property managers and maintenance staff in exploring this question. The output from these workshops provides insight into design considerations for how different technologies might integrate (and what that integration requires), as well as policy implications for managing technology integration given the landscape of third-party providers involved in data collection, aggregation, and resale. These insights, in turn, inform considerations around the role of smart technologies in mediating public and private space in a multi-family environment, as well as the consequences of monitoring and compliance for low-income residents enrolled in social services.

## 2 RELATED WORK

While there is limited HCI research specifically concerned with low-income housing, there is a rich history of work examining domestic settings, smart homes, community and placemaking.

### Smart Homes

The promise of smart technologies in the home has been framed in various conceptions of "smartness" which subsequently became the "smart home." The notion of a smart home signifies some redistribution of tasks between the inhabitants and the home, with the home taking more responsibility for tasks that previously required human involvement. However, as Harper has noted, research on smart homes has gradually shifted from the promise of an advanced intelligent environment towards a much simpler, but more ubiquitous ecosystem of sensors and devices [28]. The shift to a simplified notion of the smart home means that capabilities depend on the interactions of multiple systems which in turn has implications for how private and social life traverses this connected ecosystem.

An examination of home automation use in Orthodox Jewish households makes this challenge clear. Where smart systems are meant to administrate every facet of home life during the Sabbath, Woodruff *et al.* observe that HCI researchers often fail to recognize "broader considerations of how the pervasive influence of ICT-enabled networks and networking are blurring the lines between the private and the social, the domestic and the public" [61]. This point is particularly relevant to public housing communities because of the inherent political and social entanglements mentioned earlier. Consent to lose control of the administration of smart systems for a day each week in Jewish households, as Woodruff describes, is very different in public housing developments where consent does not necessarily come from the end user.

Rather than designing technology to replace human intelligence, the goal of the smart home should be "offering resources to act and think" [53]. After all, the way people organize their lives using various surfaces, spaces, and everyday objects means the home is already smart. And that smartness is actively configured by those same surfaces, spaces, and objects. Influenced by post-phenomenology, some scholars have turned away from conventional anthropocentric design and have begun to attend to the unique qualities, values, and morals of objects in themselves [42, 43, 58]. In line with this view, Desjardins *et al.* propose a material perspective to understanding the home [12]. Here attending to the way objects fit into and "experience" the home and its residents can help uncover novel insights, especially because the logic of smart devices is often hidden in the code. Questions such as "how does a camera know one's face?" or "what does it mean for smart thermostat to care for the environment?" offer us alternative ways to understand these technologies and their values. In public housing communities, attending to objects and materiality in this way can be illuminating given the complex relationships that interconnected devices in the home create among themselves and with humans.

### Domesticity and Public Policy

Domestic experience in HCI has a long history that includes the evaluation of domestic technologies [5, 9, 29], the consideration of spatial and social configurations in domestic settings [11, 54, 57, 62], and the transformation of everyday objects to enable social connection and ludic engagement [21, 23, 32, 48]. These perspectives demonstrate how technology can mediate social relations within the domestic environment by privatizing space [6], or by providing mutual support among inhabitants—including aging family members—within and outside the home [48].

In an extensive qualitative analysis of this literature, Desjardins *et al.* identified seven broad perspectives of domestic HCI research: *social routines, ongoing practices, home as testing ground, smart homes and automation, contested values, home as a site for interpretation,* and *speculative visions of the home* [12]. While the perspective of *smart homes and automation* has immediate resonance with our study, the perspective of *contested values* is most relevant because of the unique frictions and entanglements in public housing. Specifically,

questions about the boundaries of the home, assumptions about what the home means to its inhabitants, and expectations about practices within and outside the home take on a new meaning in public housing.

While existing work in HCI can be instructional for evaluating and designing smart systems for public housing communities, one perspective seems to be overlooked: public housing is an inherently political arrangement in ways that a typical single- or multi-family home is not. One could argue that all domestic arrangements are inherently political. For example, Taylor and Swan argue that domestic artifacts both classify information flows within the home and shape social relations among the inhabitants [54]. A key difference for public housing, however, is that the political and power arrangements extend beyond the boundaries of the family unit, involving social service providers and state authorities. The tight coupling between public housing and the external politics of their communities means that first and foremost, public housing is not about the home and its inhabitants, but is a policy tool with explicit national, state, and local policy goals directed at disadvantaged segments of the population.

To the extent that smart technologies become integrated into public housing, they are bound to entangle with the political and social factors of social welfare. This has two implications for the design of domestic smart technologies in this setting: first, smart home technologies in public housing become implicated in enacting and enforcing public policy—particularly through new facilities for tracking and compliance; and second, as a result, designing smart technologies for public housing communities means navigating more than just routines around automation. Instead, it demands attention to the contested values of what makes a home and the accountabilities and responsibilities of those who maintain it. Questions such as what devices are installed and where, who owns or funds them, what behaviors they are supposed to encourage or discourage, who benefits from the data collected, and most importantly, who has a say in all of the above are each relevant for smart homes of any kind, but have amplified force and consequence in public housing.

### Aging in Place

Senior residents are a critical stakeholder group in public housing communities. This is not only due to the fact that senior citizens tend to have unique needs, expectations and health conditions, but also because public housing for senior residents tends to be separate, with its own set of eligibility criteria and other policies.

There has been extensive research on the challenges of domestic life for the aging population and the role of computing in supporting daily health care practices [3], supporting awareness of their abilities through tracking and monitoring [37, 38], fostering intergenerational and interpersonal communication [48], and engaging the elderly population in the design and use of digital technology through participatory design and making [39, 47]. Given the changing physical or mental abilities of the elderly, smart technologies have the potential to provide new means of support in public housing. However, successful design will require re-contextualizing the recipients of these technologies in more nimble terms than just "the elderly", or "the patient" [3]. Similarly, the providers and other users of these technologies such as "the caregiver", "the property manager", "the vendor", "the adult child" or "the neighbor" may also call for inventive re-contextualization.

Attending to these identities and roles is important because the conditions of the elderly in public housing are very different from seniors who live in assisted living facilities or who have access to caregivers. White *et al.* suggest that devices such as passive health data monitors are often designed with the assumption that someone else is actively monitoring the device and data. Such monitoring may not be the case among low-income elderly [60]. Furthermore, White et al. suggest that helping residents build social networks among themselves to maximize mutual support is especially significant given the limited choices low-income residents have in their everyday life.

The issue of self-reliance and independence is of particular importance because it highlights a tension between the desire to live independently and the need to interact with others for assistance, comfort, or care [4, 48]. Public housing for senior citizens does not necessarily provide specialized caregivers. Thus, negotiating the daily realities of an aging population living in poverty and managing a variety of health conditions falls on the residents themselves, their families and social networks, and in some cases on the property management staff. Just as was the case with the notion of the home and domesticity, the notion of aging in place highlights the collision of values and commitments of various stakeholder groups, in this case between members of the household, technology vendors, and caregivers.

Drawing on these different perspectives of domesticity, the smart home, and applications of monitoring and sensing, we examined the various roles smart technology can play in public housing. These included shaping distinctions and boundaries within the home and the community, the socio-economic dynamic within and among various stakeholder groups, particularly public housing residents, and the political implications of adopting these technologies.

## 3 CONTEXT AND METHOD

Beginning in the 1990s, the city of Atlanta began systematically demolishing its public housing projects [33]—after having been the first to establish public housing in the US

[34]. Instead of maintaining these properties, the city transitioned toward new private-led models of providing low-income housing. The site of the development at the focus of our study, formerly known as Herndon Homes, was one of the last projects to be demolished and is in a gentrifying area adjacent to our home institution. This locale sits at a geographic and political intersection where race, economic mobility, and inaccessible higher education collide.

In 2017, Atlanta Housing underwent an expansion in its mission, moving beyond its original charter of providing housing to low-income seniors and families on public assistance, to developing multi-use and multi-income facilities as a core agency in leading the region's overaching redevelppment agenda. As part of this mission expansion, Atlanta Housing was in the process of finalizing requirements for the development at the Herndon Homes site. The development would include subsidized housing, a senior living facility, market-rate housing, as well as commercial and educational facilities. The site plan was developed to address one of the recognized challenges of placing low-income households amid middle-income communities: the disruption to social support networks and shifting of stigma [31, 41].

It is within this context that we conducted our design-based inquiry into the possibilities and challenges of smart technologies in public housing. Atlanta Housing approached us to develop a series of workshops as part of their stakeholder engagement efforts in the recognition that the changing landscape of smart technologies meant there were new opportunities for education, health care, economic participation, and security. Even as the purview of Atlanta Housing was expanding, its core mission, and its focus for this design-led investigation, was on the needs and considerations for its most vulnerable clients—the poor, and its senior population—both of whom were dependent on housing assistance and on a suite of social services that come in conjunction with that assistance. The initial goal for the agency was to help identify ways smart technologies could support wider educational and economic impact for their low-income families, as well as how they might improve the health and well-being for their senior residents.

We targeted each of three stakeholder groups in our workshops: families in subsidized housing, seniors, and facility management and maintenance. With the help of the Atlanta Housing administrators, we recruited participants to our workshops that included current and former residents, as well as people interested in the new development.

### Participatory Design Workshops

Our workshop design was rooted in participatory design and speculative futures [2, 14, 15, 17, 18]. We chose this approach as an effective way to investigate potential long-term impacts of smart technologies through making, storytelling, and the rehearsal of possible futures [18, 26, 49]. The methods and materials of the workshop were inspired by similar workshops done for co-housing research and with municipal employees and the constituents of their services [1, 10, 30].

We planned and hosted three workshops, each lasting about two hours. The workshops could build on each other, but it was not a requirement that participants attend each. Our goals across the three workshops were to introduce key concepts and examples of smart technology, to collaboratively explore the potential applications of these technologies in the context of a planned development, and to investigate possible long-term effects of smart technologies in the context of public and housing.

Atlanta Housing managed participant recruitment and their privacy policies prevent us from providing details concerning the participants. We can say that participants generally reflected the demographics of residents of Atlanta Housing, with the exception of gender mix. All of the participants were African American adults of varying ages. However, they were predominantly women. This reflects who tends to participate in such events rather than the overall gender mix among public housing residents. Participants were not compensated for their work, but we did provide food and childcare at the first and second workshops. The workshops were conducted in a semi-public setting where participants could come and go. The consequence of the open format is that we do not have exact number of participants, but can report we worked with at least 40 people (approximately 25 at the first workshop, 15 at the second workshop, which was a subset of the first, and 13 at the third). Finally, workshops with residents were separate from workshops with property managers in recognition of the authority dynamics and to facilitate uninhibited discussion.

*Workshop 1: Creating Sensors.* The goal of the first workshop was to introduce participants to smart technologies and begin a conversation about how these technologies might fit into their lives. Participants were seated at tables accommodating four to eight people, each table forming a small group. The workshop was conducted in a church community center located across the street from the new housing development. At the beginning of the meeting, a representative from Atlanta Housing provided a short update on the construction project and a brief time-line of major construction milestones over the next few years. The representative also introduced our research team and the purpose of the research. It was important to have the Atlanta Housing representative provide the context for our meeting because it was the agency who helped with outreach and recruit the participants.

Following this brief introduction, we gave a 20-minute presentation about smart technology. Topics included the


**Figure 1: From left to right A) smart device cards; B) design game sensor sheets; C) "what if" prompt cards.**

basics of sensors (*e.g.*, the concept of an input and an output), types of sensors, and how networked computing are used with sensors. Throughout the presentation, we showed examples of smart technologies for personal, domestic, and municipal use. We also showed a television advertisement clip for the Amazon Echo. The video clip helped break the ice and relate the introductory concepts of smart technology to an actual product in a familiar context.

We then gave each group a set of postcards that included a smart device from the presentation. On the reverse side of each card was a description of the device, and how one might use the device. At the bottom of the card was a question asking, "How can this device help my community?" We asked the participants to randomly pick one card, read the information and write down their answer. Next, within each small group, participants introduced themselves, and presented their card and their response. The primary purpose of this first activity was to initiate conversation among participants about these technologies and potential use in their communities (see Figure 1A).

For the second activity, we developed a design game [6]. The game helped participants imagine smart technologies of their own creation using the basic components described in the introductory presentation. The purpose of the game was to creatively experiment with the kinds of things smart technologies could do and to get participants thinking beyond commercial products. The game consisted of dice, stickers, and a worksheet with instructions. Participants played the game in pairs by rolling dice and selecting stickers corresponding to the values rolled. This would lead to a choice of sensor input (*e.g.*, humidity, motion, light, temperature) and a set of outputs (*e.g.*, sound, vibration, print, text message). Participants would then combine these inputs and outputs on a worksheet to create hypothetical smart devices for which they then wrote a description (see Figure 1B).

The third and final activity was a survey that asked participants to provide feedback about the imaginary devices they created. The survey was designed to be filled out by the participants individually, but also enabled discussion at the tables about how they understood and interpreted the different imaginary devices.

Overall, the first workshop was successful in introducing key concepts of smart technology and establishing rapport with the community. Despite some logistical challenges—including a last-minute change in venue and late arrivals and departures—we were able to engage the participants in the activities. Importantly, the workshop allowed us to gauge participants' comfort with the subject matter and with us as researcher collaborators. All of which helped us refine our approach for the subsequent workshops.

*Workshop 2: Uncertain Futures.* In the second design workshop we explored how smart technology could impact communities over time and how participants might respond to potentially complex interplay between the devices, the people who use them, Atlanta Housing, and the wider community. Most of the participants attended Workshop 1, so they were already familiar with key concepts. We explained the basic functionality of sensors to new participants using the introduction cards (see Figure 1A). We distributed participants around tables with four to five people. A facilitator sat at each table, leading the group through activities.

In the first activity, we asked participants about four different smart technologies discussed in the first workshop. The facilitator read a series of prompts aimed at provoking conversations about future uses of the technologies. The prompts consisted of a series of "what if" questions that encouraged participants to think through the consequences around privacy, data storage, access, and examples of malfunctions and misuses. For example, one of the prompts for a digital home assistant/speaker (*e.g.*, Amazon Echo) asked participants to consider what they would do, say, or think if

they found out that a child in their family used the device to do all their homework. This question stimulated the discussion about the proper and improper use of technology in a child's education, as well as parent involvement. The prompts we used were based on unexpected or unusual uses of technology that pushed participants to think critically about the technologies at hand.

In the second activity, we asked participants to project the issues they discussed into the future of their personal and community lives. To do this, we laid out all the answers respondents gave, and asked participants to discuss the consequences of their responses (see Figure 1C). This included weighing benefits and risks of these technologies, thinking about whether or not to use a given technology, and working through questions who gets to make different choices about how these technologies are implemented and used.

Compared to the first workshop, these activities were much better received by the participants. Since we concentrated on technologies already available, and a narrow subset of the technologies that we presented in the first workshop, it was easier for participants to imagine future scenarios and to respond to the "what if" prompts. This workshop helped provide more context and critical reflection on how residents might take up different smart technologies. The materials the residents created linked specific device features to desired outcomes (or undesired consequences) and provided reflections grounded in the everyday routines of living in public housing.

*Workshop 3: Seniors & Property Managers.* The third workshop used elements from the first two to engage with two remaining stakeholders: seniors living in Atlanta Housing's senior specific facilities, and property managers and maintenance staff. Engaging senior residents was important because, as mentioned earlier, they were a target population for Atlanta Housing and because the new development would include a senior living facility.

Property managers were also an important stakeholder group because they maintain the facilities, including the technologies used within. Furthermore, property managers mediate the relationship between Atlanta Housing and the residents by both enforcing rules and by providing services to the residents. As is the case with most properties, the property management staff work for a third-party vendor which adds another layer of accountability into the mix.

We involved these two groups at the same time because the workshop was held at an existing senior living property. We separated the participants into two groups, each lead by a facilitator: in the first group, the facilitator introduced the basics of smart technologies using the introductory activity from Workshop 1 and engaged with eight senior residents in a round-table format interview; in the second group, another facilitator worked with five apartment staff—three property managers and two maintenance professionals—to develop insight into their experiences of maintaining and working with building-level technologies to support operations and provide a comfortable living environment.

The goal of the discussion in the first group was to uncover the unique needs of elderly residents, how smart technologies might enhance their quality of life, and discuss concerns to senior living. The first activity from the first workshop was used as an icebreaker, and with support from the facilitator, the senior participants developed a rich discussion about impacts on their quality of life. In the second group, the facilitator led the facility staff through the introductory presentation of smart technologies, the smart sensor game, and a discussion about the future impact of these technologies. Although the staff were more technically savvy, we did not feel the need to modify the activities. Through the workshop, we were able to gain insight into the challenges and opportunities related to senior living and property management. This included the staff's experience in dealing with building-level technological issues such as maintenance, resident education, and the use of existing services.

The third workshop provided a much more concrete focus on actual issues. For the senior residents, this focus was on the technologies already in place, such as thermostats, smoke detectors, air conditioning units. For the facility staff, their focus was split between supporting building technologies, and handling medical emergencies. Taken together, the three workshops enabled a broad set of responses around concrete concerns for how existing and future smart technologies would impact individual and collective living arrangement in public housing.

## 4 WORKSHOP ANALYSIS AND OUTCOMES

We inductively analyzed the materials produced during the three workshops in order to cluster key concerns and shared issues within and across the stakeholders. These materials included the worksheets and game materials the participants filled out, as well as transcriptions of the discussion audio recorded at each of the tables.

In our analysis, we were specifically interested in the larger community effects of smart technologies as the participants envisioned or considered how their lives would change once living within an integrated ecosystem of smart devices. Because our residential participants were all (or had recently been) recipients of support from Atlanta Housing, there were a set of assumptions they were working under given the many regimes of control present for low-income families and seniors living on assistance. These ranged from income and work requirements where they were compelled to work

a minimum of 30 hours a week continuously, to requirements for on-going job and financial training, to criminal background checks and drug policies.

Smart technologies in public housing introduce new channels of high-fidelity data collection and behavioral analysis on the most vulnerable in society. The issues raised by these concerns reside at the level of the system, rather than the level of the specific interface. Through our findings, we attempt to characterize these systemic features and potential responses for how to implement smart technologies in the context of public housing, when the goal is to build solutions that aim toward improving self-determination.

### Tracking and Monitoring

The first key theme that developed from our analysis was how smart sensors would enable tracking and monitoring. Not surprisingly, the discussions about different applications of tracking and monitoring occurred at different valences. On one hand, workshop participants saw the value smart technologies offered in terms of security, health, and maintaining connections with family members; however, on the other hand, they had reservations about who had access to different kinds of data and where and when they might be leaving digital traces for others to follow.

Across the workshops, there were two main areas where tracking and monitoring were seen as viable applications of smart technologies. The first was in relation to health and wellness where personal devices could be used to help individuals manage their own chronic conditions. For example, when asked who they would give a health monitor to, one participant responded, *"I would give it to my oldest grand-daughter. She's 13 and she has asthma. And she keeps a pump with her and because the way the pollen is nowadays and everything. She might feel bad or something like that. A lot of time she's away from home. Doing activities and stuff like that."* – P1, Workshop 2. Here, the idea was both that such a device would be useful for her young granddaughter, and also that it would be a way for family members to know how she was doing while out of the house.

Monitoring others' health extended beyond immediate family. Particularly for seniors who live in public housing, tracking devices were seen as a way to manage mental and physical health vulnerabilities. This is best illustrated with a story shared by property management staff during the third workshop: *"And the reason why that [sensor] for dementia meant so much to me because that's what I see a lot. I just saw that last week. One of the residents was trying to go to the grocery store and she was getting turned around, because she's in early stages of dementia. So, one of the other residents had to take her and walk around with her to the store."* – P4, Workshop 3.

The second shared area for the use of tracking and monitoring was a concern for personal safety. Many of the workshop participants were women. Living in and navigating the neighborhood safely is not an abstract concern, but a practical reality. Returning to comments from P1, when discussing giving a health monitor to her granddaughter, she went on to say, *"I'd like it for safety... Because say for instance if you get lost or say for instance you get kid-napped or something, and you have your phone. Well, there is a tracking mechanism on my phone that can track where I am you know..."* – P1, Workshop 2.

This desire for a safer community also extended to smart technologies embedded in the environment. Smart street lamps and smart door locks were both legible and appealing as devices that addressed the needs and fears they currently had around physical safety. When discussing mobility and going out in the evening with her family, one senior participant said, *"They have to come and get me at least by 2 or 4. They have to get me back in the house before it's dark. That's just me..."* – P2, Workshop 2. Her unease at being out in the dark made the capabilities of smart street lamps appealing as they could track where she was and provide a better sense of security. Likewise, for in-building technologies like smart locks, one participant said, *"I'd kind of be OK with it because so that can track down who all is coming through the building, so in a way it would be a good thing that they can track that, so that they can have a record."* – P3, Workshop 2.

In these examples, the smart technologies discussed during the workshops moved between self-monitoring and monitoring by others; however, in both cases, the technologies were enabling new kinds of visibility for the residents in public housing. That visibility might be limited to family and immediate community members, or it might be extended to external providers or building management. Navigating that boundary was fraught and led to the next major theme.

### The Boundaries of Personal and Public Privacy

Although residents found good reason to use tracking and monitoring services as discussed above, that did not mean residents trusted these technologies. This lack of trust was especially (and appropriately) acute when residents themselves were not in control of what the device recorded and who had access to the data. The level of suspicion was especially high among senior residents who were already concerned about their independence. In some cases, this distrust undermined building safety: property managers shared stories of residents taping over smoke detectors because of a perceived invasion of privacy. Furthermore, public housing presents a distinct context and mode of domesticity. Residents do have individual units and within those units, there is a sense of personal space. However, public housing in general is a site of significant external of oversight. Some of this comes in

the structure of public housing itself: one has to qualify for public housing and then continue to be monitored in order to determine ongoing need and compliance with program requirements.

Unsurprisingly, participants' perception of when surveillance was appropriate depended on whether it was in a public or private space. Sensors and recording devices were welcome in public spaces, but unwelcome in private spaces. Distinctions become more complicated when surveillance was in semi-public spaces like hallways, common rooms, and gyms. This complexity was evident during Workshop 3 when we prompted the participants with a scenario built around the use of a smart speaker. In setting up the scenario, we explained that a smart speaker needs to always be recording sound in order to respond to verbal cues directed at it. As the conversation progressed, participants argued the merits of such surveillance and the differences in meaning depending on where the data is recorded, what data it records, and who has access to it. First, participants were very upset about such a violation of privacy. As one participant expressed: *"Oh I would have to contact whoever is at the complex that I live. And I would ask them why, and who is this information is sent to…Because you know, you're eavesdropping on everything that's going on in my household."* – P1, Workshop 3.

Some participants were able to recognize potential benefits of such pervasive recording in cases of a home break-in, but overall, recording private conversations in private spaces was not viewed as acceptable. This issue was also discussed later in the workshop when we discussed the presence of smart cameras. Initially, the reaction was very positive because participants associated surveillance cameras with security. However, once we explained how smart cameras could be applied to identify and track people's movement in and around the property, there was much more disagreement: *"You're talking about people coming and going in the neighborhood. But the first one that you asked us [about home speaker recording conversations] you were talking about the privacy of our home."* – P1, Workshop 2; *"No! That should not happen. For the simple reason that you don't know who could be out there waiting on you to get home."* – P2, Workshop 2; *"That's why you would want that beneficial because they could see, to be able to identify."* – P4, Workshop 2.

When we discussed the possibility of smart locks being monitored by the housing authority, participants wrestled with these tensions in a similar way, framing it as a tradeoff between security and privacy. One general solution the residents discussed was to allow them to control access to the recorded data. This came up during the discussion of the smart speaker: *"I would like to have it [the smart speaker], but then I'd like to be able to see what I have stored in there and erase it."* P3, Workshop 2.

These discussions reveal how residents struggled with the blurring of boundaries between private and public space, and how smart technologies contributed to that ambiguity. Placing tracking and monitoring technologies in spaces like hallways, gyms, common areas, and in the vicinity of the property can be as invasive as placing them in someone's apartment. Smart computational capabilities can recognize identities, deduce patterns in behavior, and classify people in different ways. Added to the already present forms of monitoring and program compliance, the potential presence of smart technologies created new expectations and new concerns in what was available and who had access.

### Shifting Baselines

The final theme that developed from our workshops centered around shifting baselines, and how changes born of smart technologies may lead to distrust. Whole new forms of interaction, enabled by sensors and responsive environments, add complexity. That complexity in turn amplifies distrust in the motivations of use and desired outcomes: managing energy efficiency might mean tracking occupancy, but that might also enable behavior monitoring. With the different visibilities that smart technologies enable about residents, there is also a need to provide visibilities for residents. It was along these lines that workshop participants noted that certain services were basic needs, as opposed to discretionary consumer services.

The observation that smart technologies needed to address residents' needs came through a desire for smart solutions to everyday tasks. In a discussion about mobility, one participant noted that it was often difficult to navigate the public transit system when going to new or non-routine locations: *"I had to find out the bus to come by [the workshop]. My daughter had to Google it for me. And it's the 26…I called [first], but I guess they were gone for the day."* – P8, Workshop 2. Another woman at the table pointed out that she *"should download the [transit] app on your phone,"* and went on to describe how it helped her navigate the city. The challenge that arose here was that one of the participants was fluent and comfortable with present technology solutions, while the other was not, underscoring that it is not about the availability of technology, but about the expectations around where and how to seek information.

In addition to smart phones and family, residents in Workshop 3 talked about a third access point for information: their TV. Cable TV, according the seniors in our workshop, trumped other technologies for the ubiquity and usefulness. TV serves as a critical source of entertainment, a source of news, and a connection to the community. When talking about TV in particular, our participants were quick to point out that negotiating and dealing with the costs of basic cable service was a source of stress—financial and emotional:

*"They're crazy if I'm going to pay more than $60 for TV."* – P6, Workshop 3. These costs become more burdensome when we expand the necessary baseline to include broadband or wireless data plans. All of this reinforces observations that we need to distinguish between access to endpoint (a mobile phone, or laptop—a fixed cost) and access to service (broadband, wireless data—an ongoing cost) [36, 44]. In the context of public housing, this represents a large shift in baseline expectations. To date, services like cable TV and broadband internet are assumed to be household responsibilities; however, in the connected home and connected community envisioned by Atlanta Housing, these services become infrastructure, necessary connective tissue that enable the ecosystem of devices and desired social, educational, and economic outcomes.

As new technologies are deployed into public housing communities, once they become embedded in the lives of individuals within those communities, their absence can be dangerously disruptive. The dependence on smart technology to mediate access to transit or the loss of a simple amenity like cable TV can have a significant impact. It may increase their experience and sense of isolation or prevent them from having access to information, in both cases, becoming an issue of independence and agency.

## 5 DISCUSSION

From an HCI design perspective, there are several specific ways to respond to the constraints when applying smart home technology to public housing. Part of this response comes from a re-framing of what a home is—away from the assumed single-family dwelling, and also away from the assumption (or illusion) of control propagated by the current smart home rhetoric. The framing of "offering resources to act and think" is correct [53], but it requires refinement around what those resources are, who is acting, and who is thinking.

### Accountabilities of Tracking

Technologies that enable tracking could improve residents' ability to support themselves. Use of tracking and monitoring by the residents themselves to help and support each other could be framed as a form of self-organization on a very small and local scale [13, 19]. However, this is only possible when data and the tools for their collection are accessible. Access to these data could support existing local practices that are already "smart," rather than attempting to replace human intelligence [53].

Supporting smart practices is not un-problematic. While residents themselves are keen on using monitoring and tracking to take care of themselves and others, the power-laden nature of sensing and tracking may damage, rather than improve, inter-personal and community relations [52]. For example, if an adult child has access to a device that can monitor her parent living in a senior facility, the parent could perceive this arrangement as a violation of privacy and a loss of independence. Atlanta Housing could exacerbate this situation further by requiring seniors with certain health conditions be monitored by someone else. Furthermore, smart surveillance technologies could exacerbate enduring social and racial segregation in mixed income communities [22, 35].

Because smart technologies create traces of use, location, and other sensitive information about the residents, their use in public housing also exposes an already vulnerable population to further regulation. For example, companies can exploit various decision heuristics to direct them towards certain behaviors and reveal even more information about themselves [24]. Furthermore, given access to such data, the housing provider might decide—or be compelled—to use them in ways that increase the burden on the resident (*e.g.*, cut access to existing services, or determine eligibility for services based on specific behaviors).

Thus, even when tracking and monitoring is aimed at empowering the residents, certain kinds of smart practices could be legitimized or delegitimized based on a housing agency's own priorities (e.g. lift residents out of poverty). These concerns fit within a larger landscape where shifting social services provision to data-driven and algorithmic decision making undermine liberty, equity, and inclusion because "it makes it difficult to understand how government bureaucracy works, who has access to your information, and how they use it" [20]. Finally, issues around tracking and monitoring capabilities in public housing demonstrate the need for accountability about whose and what kind of smartness these technologies are supposed to support, and how the benefits are distributed among the stakeholders involved.

### Self-determination in Data and Use

Smart technology endows the housing authority—as an organizational entity—with the ability to shift the boundaries, however blurry, between private and public space. For residents of public housing, this also includes social and legal boundaries [61]. Consequently, the deployment of such technologies in public housing is fraught with social and ethical questions. For administrators of public housing the challenge is two-fold: first, maximizing the benefit of smart technology, much of which comes from aggregating the data and acting upon it; and second, providing residents with sufficient choice to decide how much of their privacy to give up. For residents, the questions are how to establish and maintain boundaries between personal and public space in a world in which data flows freely.

In the built environment, the demarcation between these spaces is clear: there are walls and windows and doors. Those

architectural territories become porous with the introduction of smart technologies. This is further complicated by the fact that both the ownership of such devices and the living units themselves are hybrid affairs. Here, the contested values of a home in that hybridity, where property ownership, technology ownership, data ownership, and occupancy and use of each makes these contestations messier, more multi-dimensional and asymmetrical [12].

There is a need for robust systems for privacy jointly maintained [16, 40]. We should also recognize that some tactics, such as obfuscation, may be pursued and are, in some cases, warranted [7]. More recently, researches have raised concerns about the limitations of technical solutions to privacy, including privacy-enhancing technologies. One reason is that the very nature of smart technologies is that they are "always on," sensing the environment with the subjects (i.e. residents) having little control. Some have suggested alternative approaches such as Privacy by Design (PbD), where privacy is built in into organizational goals and are therefore addressed at the design stage [45]. Such an approach would require the housing authority to develop new technical and organizational capabilities to limit the collection and exposure of private data, especially in cases of high visibility of individual identity, location, and behavior patterns (e.g. smart thermostats, smart locks, facial recognition systems, custom smartphone apps, *etc.*). Consequently, the housing authority might have to take on the role of a system designer, rather than just a paying customer who delegates the resolution of these issues to the vendors.

### From Endpoint to Infrastructure

The tension between a persistent desire for "the new" and the practices of technology use occur at different paces [50]. The conversation about the smart home often focuses on the endpoint—the lock, thermostat, or camera—when in practice, substantial change comes from the enabling infrastructure. There are echoes of such perspectives in the domain of sustainable HCI, both in regards to simple living [25], and in terms of resisting obsolescence [46]. Looking at the role of basic amenities as part of a broader supportive ecosystem of public housing, rather than as a set of individual consumption behaviors, can provide alternative ways to assess the potential of smart technologies in public housing [8]. Furthermore, such an approach allows for a more flexible framing of both smart technology and its users in this setting [3]. For example, basic amenities could be framed as mental health maintenance and the elderly resident as a local partner for nurturing individual and community wellness. Lessons from sustainable HCI on how to support diverse orientations towards use and consumption could be valuable for framing approaches to smart technologies in public housing [51]. Supporting these diverse orientations will require developing alternatives to dominant design perspectives such as white-collar, educated, urban, *etc.* At the very least, this would encourage a critical evaluation of technologies and services that are being proposed for public housing by various technology vendors.

The example of the TV from above is so potent in part because it is a universal technology deeply embedded in contemporary life, and because it is so emblematic of dominant consumer culture with its dependence on advertisement revenue and consumer spending. The move to smart technologies in the home aims precisely at embedding a host of other services and capabilities in a similarly deep way. Yet, as that agenda advances, it shifts the baseline of expectation of both residents and of public housing. When access to sophisticated services and information sources is present, we expect people to make use of them and penalize them when they do not; likewise, when we direct people to use such services, we should expect them to be made available.

## 6 CONCLUSION

The outcome of our design workshops provides an initial understanding of the issues and opportunities of deploying smart technologies in public housing. By pushing the spatial and social boundaries of how smart devices are currently positioned, our work adds to an expansion of how we consider domestic life and the technologies meant to support it.

As shown in previous HCI research, excessive reliance on the benefits of technology without fully understanding the drawbacks may harm the users in unexpected ways [20]. Access to smart technologies does not always translate to adoption or active participation–particularly in low income communities where different relationships to public institutions shape how computing technologies are put to use [19].

As we move to an era of smartness—phones, cars, homes, and cities—we risk widening the digital and participation divide [27, 59]. Even though the goal of Atlanta Housing was to understand how they might bridge the digital divide by providing access to smart technologies in their properties, it quickly became clear during the workshops that merely adding smart devices into an environment fraught with regulation and precarity only create more anxiety. A chasm opened between a basic conceptualization about smart technologies and a robust understanding of how they operate and might be put to use. Fear and distrust about the consequences of these devices and systems rushed in to fill that void.

This distrust was in large part rooted in how the "smartness" of these new technologies rests in their ability to aggregate data across systems in order to tune use and experience. The home that responds to its inhabitants needs to know

something about them, and that knowledge comes by recording movement and preference and then storing that in a place and in a form that can be acted on. When the residents in our workshops were acting on those data, as in the discussions around monitoring family, the utility of these systems was embraced. However, when the data were being acted on by outsiders, even in the name of public safety, our participants had real concerns around the consequences those external judgments and actions would have.

The larger issue here is that as the smart technologies get moved into a wider range of environments, we need to attend to the kinds of participation we enable. For low-income communities, this often means working to empower their support networks to engender resilience [56]. But it also means recognizing the ways non-participation can expose individuals to negative outcomes [55]. Overcoming these challenges requires more than simple interfaces or transparency in data agreements. We need to approach with care the notion of agency and accountability, because a well-designed interface that explains where and how your data are being used is of no use if you cannot assert control over the spaces and traces of those data.

In this project we set out to understand the potential opportunities and issues of designing and deploying smart technologies in public housing. What we discovered were themes that are common to many of our contemporary concerns with technology, concerns about privacy, concerns about shifting boundaries, and along with that, shifting expectations and responsibilities. We also saw concerns about what the baseline is, not merely for access, but for participation. In the context of public housing, these concerns are amplified because residents are already subject to regimes of surveillance and at a disadvantage in terms of rights and opportunities. As HCI researchers, we have an opportunity to inform both the research and implementation of smart technologies in such contexts.

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