Socially-Aware Requirements for a Smart Home

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ABSTRACT
The majority of smart home research has focused on novel technical artifacts, but has overlooked the issues surrounding social relationships in the home. We argue in favor of research that is sensitive to and functions within the social constraints of dual income family homes. This paper describes our grounded contextual fieldwork with real families in their homes, and identifies socially-aware concepts smart home systems will need to address.

Author Keywords
Social identity, activity-centered design, context-aware computing, end user programming, control, ethnography.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Much smart home research has focused on the substantial technical challenges required to deliver ubiquitous [28] and/or context-aware [10] services, but avoided consideration of the wider social circumstances in which those services will ultimately reside. Our work seeks to explore this space, using grounded contextual fieldwork with real families in their homes to drive the development and evaluation of smart home systems.

In this paper, we briefly describe a field study of twelve dual income families (see [9] for a more complete description). We believe that this fieldwork might help identify valuable opportunities to introduce technology into the home, and, by providing a rich understanding of the social construction of the home, help designers to make informed decisions about the appropriate delivery of those services. By understanding the social space of the home, we hope to produce more pertinent, available and ultimately, valuable smart home technologies.

We report on six social characteristics of home life that *should but currently do not* influence the development of smart home services. We believe that an understanding of these social dimensions should be more tightly-coupled with the determination of what services should ultimately be developed, and how those services should be implemented. These characteristics include:

1. Families are *plural*. Most systems are singular.
2. Families perceive chores as activities, not procedures.
3. Many tasks are device- and/or location-independent.
4. Ownership of chores can be ambiguous.
5. The *thermostat predicament*: rules don't always agree.
6. The house plays a role in family and individual self-definition.

In this paper, we describe our fieldwork, elaborate the opportunities our work has uncovered, and define a research agenda that we are pursuing to explore those opportunities. We begin with our field study.

METHOD
Our work currently investigates the needs of dual income families. We define a dual income family as a family with both partners working full-time, and that have at least one child in school. Recent demographic trends reveal the particular timeliness of this selection. Dual-income families now comprise 43% of the population of the United States [17]. By moving away from the single-income model, these families are exposed to a surprising variety of external and internal stresses [8,17].

Fieldwork began with two-hour contextual interviews of 12 families that included directed storytelling, shadowing, and artifact walkthrough. As our pilot fieldwork identified the "wake up" and "arrive home" time as requiring the most potential support, we chose to focus our investigation on those time windows. Also seeking to gather inspired emotional input, we left families with a cultural probe package [15].

To discourage self-presentation bias, we chose to not record our interviews. Instead, we used paper notes, and followed each interview with an intense summarization session. We mapped each home, photographed objects and locations of interest, and recorded photo locations on our maps.

OPPORTUNITIES

By focusing on social dimensions of dual income families, our fieldwork has led us to identify six social characteristics of home life that we believe should occupy a central place in forming research questions. We address each point individually.

Families are plural. Most systems are singular

Most end-user programming systems for smart homes have been designed for one user to control the home, e.g. [6,14,20,21,24,28]. A one-on-one programming mentality dominates previous conceptions of the smart home, the services it can provide, the interaction techniques it affords, and the language to express control over the home. Bachelor pads aside, most homes have multiple occupants, and systems will need to account for multiple users and all the complexity this creates. Designing with social blinders greatly limits the interactions a smart home may be capable of delivering, the situations in which all users might want to exert control, and violates the core principles of user-centered design. A multi-user approach is especially relevant when a system needs to address household activities that are fundamentally collaborative.

People perceive chores as activities, not procedures

Most systems approach smart home services as a combination of operations performed on a confederation of devices, e.g. [6,20]. While people understand many activities this way [11], there are many tasks for which this concept is at best, inflexible, and at worst, incapable.

Our families described many chores as "do the laundry," or "make dinner." If we expect to design systems that conform to these mental models of housework, our systems will have to understand that "the laundry" refers to several devices (washing machine, dryer, iron), and the twenty steps required to describe the various sub-tasks with which people might want help. The activity of laundry also might extend to a wider set of activities that laundry depends on, including "having soap," and "separating whites from colors."

Additionally, many potential services that a smart home might offer are independent of specific procedures, locations, and devices. Control of a smart home will need to be evolve a language that can express control over the environment itself.

Many tasks are device- and/or location independent

While some tasks, such as cooking dinner or doing the laundry, revolve around specific (even multiple) locations, other activities in the home are not bound by any physical limitations. R. Reminding, communication, and other such activities may have temporary homes, but they are fundamentally ubiquitous. A home that reminds you to get your socks extends the concept of laundry beyond the machine and everywhere into the house. Doing laundry moves beyond the device level. When you program a house, what will users mental model of what is actually being programmed contain? In this sense, you are programming an environment, not any specific device contained within it.

Ownership of chores can be complex

Account of the social environment will need to reflect the more complex and often ambiguous disbursement of responsibility and accountability of many tasks in the home. Of primary importance, many tasks are by their very nature, collaborative. Some chores follow interesting culturally-programmed patterns [25], but across a large number of chores, our families evolved specialized preferences and patterns for assigning responsibility. Some of our families treated tasks such as food shopping or laundry as entirely collaborative activities, obfuscating the notion that any single person would or could exert exclusive control over information pertinent to the completion of those activities.

What would a smart home do when confronted with the social reality of even simple ambiguity of chore ownership? What should a smart home do if it reaches a decision point and the chore "owner" is absent or unavailable? Could a smart home assign responsibility to someone in their absence?

The thermostat predicament: rules don't always agree

Smart homes will have to accept input from multiple users and have a means of deciding what to do when inputs conflict. What happens when different family members express their conflicts through instructions they provide to the system? Field studies of smart temperature control systems [23] have empirically validated that technology can mediate such conflicts. We have very little understanding what will happen when social conflicts invade smart home systems with more complex capabilities. A smart house will need to participate in value decisions and in negotiating group goal setting.

The house plays a role in family and individual self-definition

People construct their social identity through their consumption and use of products [2,13,22]. And as the home is the single largest purchase most people ever make, the home is often the largest product through which people enact their social identity. Their investment deepens as people personalize their homes, and display them for others to comment on [2].

The smart home could potentially offer a limitless set of customizations. And through these customizations, people might come to define themselves in new and unexpected ways. More complex than "make my desktop blue," the way a house reminds you to wash your daughter's basketball jersey could become an extension of each family's personality as much as their dishes, their automobiles, or their holiday meals.

A smart home can also participate in the existing social dialog between members of a family. Parents often want

their children's rooms to reflect a certain look, while children want a room to reflect their emerging and sometime rebellious personality. Interaction and control of the smart home can become one of the places through which children express that growing individuality, and through which parents explore their sense of what defines their family.

RELATED WORK

This section positions our work within the large landscape of research on the smart home, and context-aware computing.

Bringing technology into the home represents a significant technical challenge. Naturally, much smart home work has addressed technical problems relevant to the development of a smart home. Other researchers [24,21] have developed dedicated "living laboratories," or industrial experiments [5] so that they might move their work from laboratory to hybrid field lab, allowing them access to more varied social input than a constrained lab can indulge.

Our investigation of the social environment in the home has identified six dimensions of home life that systems have largely avoided, but could help researchers take steps towards bridging the gap between smart home *concepts* and smart homes.

This approach has been gaining some momentum. Bellotti and Edwards [4], for example, provide a general framework that advocates human needs in the design of ubicomp systems. Though not addressing any particular domain, their framework provides heuristic guidelines that ubicomp developers should include in their design process. In [3], Bellotti *et al* focus their attention on the particular needs presented by sensing systems. Grinter and Edwards [16] describe challenges that ubicomp in the homes as particularly sensitive to social implications.

Calls for a deeper understanding of the home [16,27] have been shifting the work from technical artifacts to field studies. This changing focus is reflected in field studies, including studies of communication patterns in the home [7] and fridge magnets [26].

CONCLUSION

We see two major tasks that fall out of our fieldwork. The first task is to define services that deliver value [19], and that are both cognizant of and conforming to the embedded social constraints we identify. A second task will be to create an expressive and flexible language that allows families to customize those services to match the wide variability between homes in their customs and cultures. We address each point in turn.

Develop valuable services

By augmenting the core capabilities of the home, a smart home might allow families to develop a different and potentially deeper relationship with the home itself. This relationship can be manifested through the choice of services offered, and the manner through which those services are delivered.

Research valuing efficiency, for example, might want to suggest applications that would help remind people of their pending tasks as they walked in the door. Between tasks is known as the most precipitous and non-interruptive time to provide reminders. But our fieldwork shows that people's entry to the house is a highly-valued moment, and services valuing efficiency might violate the great relief brought about during that moment of entry.

Most importantly, our fieldwork has revealed the particular susceptibility dual income families have towards cascade coordination failures. Our fieldwork brings to light the need for a system that could support this pressing user need. Interestingly, our fieldwork also suggests a way to deliver those services. Most research exploring reminder services describe them in a way you might receive advice from servant [14,28]. But other metaphors might accommodate a wider vocabulary of service design and delivery. For example, our research shows an opportunity for the smart environment to take on some of the duties formerly provided exclusively by the "stay-at-home mom." This vision extends the house's mission beyond its role as shelter, into a more proactive position, managing and coordinating information and needs between individuals, anticipating and alerting individuals about hidden or impending dependency failures, and ultimately, occupying a position of "social" support.

Also, our fieldwork suggests that reminder services might pay close attention to the economy of motion, and to the chain of dependency of activities. Regarding economy of motion, reminder provided at places where individuals are unlikely to expend energy would be wasting valuable user patience. But a system with an understanding of existing traffic patterns might know when people were more likely to cross boundaries, and provide a reminder during that critical moment when individuals are more likely to make directional decisions. Also, reminders that involve basketball practice, for example, need to account for a chain of dependency of other activities. A reminder that includes a note about laundry delivered at game time would not provide sufficient time for the needed dependent activities to take place. This also suggests a need for an interaction technique that allows people to easily identify and describe unique dependencies in the activities in which they participate, so that a system might be cognizant of them, and include them in its reminding functions.

Customization = control

Because dual income families depend so substantially on their homes, maintaining a sense of control over an augmented environment presents an important and challenging contribution.

In [1], Dey and Barkhuus note that users experience control when they can customize context-aware applications. But

this control depends on a language that allows families to express what we have seen to be a wild variety of preferences. The creation of such a language forms a central part of our research interests.

Our long-term vision requires that we create an assortment of application concepts, examine the elements they have in common, and see if these common elements could find expression in a language allowing families to programming their smart home.

The challenge presented here will consist of identifying activities that occupy a sweet spot of flexibility, where end-user programming could provide the kind of services that would be valuable.

Some services (*e.g.* a hot water heater) are so totally predictable, that customization would provide little value. Conversely, some events that are so variable such as what do people want to eat for dinner, that they would defy expression in a language – every event might likely be an exception. But we hope to find a sweet spot where custom services might provide enough value so that families would invest in the customization process.

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