

Socially-Aware Requirements for a Smart Home

Scott Davidoff, Min Kyung Lee, John Zimmerman, Anind Dey
Human-Computer Interaction Institute + School of Design
Carnegie Mellon University

|| scott.davidoff | mklee | johnz | anind || @ cmu.edu

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.

Categories and Subject Descriptors

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

General Terms

Design, Experimentation, Human Factors.

Keywords

Social identity, activity-centered design, control, flexibility, context-aware computing, end user programming, ethnography dual income family.

1. INTRODUCTION

Much smart home research has focused on the substantial technical challenges required to deliver ubiquitous [31] 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.

2. 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 [20]. By moving away from the single-income model, these families are exposed to a surprising variety of external and internal stresses [8][20].

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 [17].

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.

3. 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.

3.1. 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][16],[23],[24],[27] and [31]. 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.

3.2. 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],[23]. 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 evolve a language that can express control over the environment itself.

3.3. 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. 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.

3.4. 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 [28], 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?

3.5. 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 [26] 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.

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

People construct their social identity through their consumption and use of products [3][13][25]. 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 [3].

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.

4. RELATED WORK

While substantial progress has been made towards developing the complex suite of complementary technologies required to implement a robust smart home, e.g. [6][16][23][24][27] and [31], surprisingly little progress has been made towards moving from smart home *concepts* to smart homes.

A series of research efforts are beginning to explore this curious absence, seeking both to explain and overcome this deficit. Our work sits within this tradition. Hindus [21], for example, cautions against too directly porting the techniques for design of office into the home. She describes that the home does not value efficiency in the same way that business does, and this misalignment of

values could lead to the development of inappropriate technologies. Tolmie *et al* [30] extend this argument, suggesting a fundamental difference between the language of the workplace, which councils “tasks, processes, productivity and functionality” and that of the home, which favors “lifestyle, aspirations, emotions and aesthetics.” Harper [19] observes that the computer’s form factor, designed for a business setting, prevents its seamless integration into many aspects of the home environment, including “home work” spaces like the kitchen.

This more socially-aware approach has been gaining some momentum. Some researchers have looked for more sophisticated understanding of home activity by developing hybrid field-laboratory environments. Dedicated “living laboratories” [24] have allowed access to more varied social input than highly-controlled environments can indulge.

Calls for a deeper understanding of the home [18][30] have also generated a series of detailed field studies of home life, including studies of communication patterns in the home [7], use of refrigerator magnets [29], adoption of communication technology [15], and general use of domestic technology [32]. Field studies have covered a broad spectrum of families, including families with both stay-at-home moms [7], and, like our study, dual-income families [2][8][9].

This recent focus on a more nuanced and socially-aware understanding of home life have produced a series of high-level design guidelines. Bellotti and Edwards [5] 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 [4], Bellotti *et al* focus their attention on the particular needs presented by sensing systems. Grinter and Edwards [18] describe challenges that ubicomp in the homes as particularly sensitive to social implications.

Despite a growing body of work arguing for more subtle approach to smart home research, little tangible progress has been made suggesting how to operationalize the social data gleaned from these field studies. Our work seeks to continue this agenda, pushing towards observations that can provide sufficient traction to move from theory to design.

The generally slow progression from field to practice suggests that the problem of developing a socially-aware smart home is both extensive and complex, and that field observations lack the rich detail required to implement designs capable supporting either of the rich human-human or human-computer interaction envisioned by the architects of intelligent environments. Whatever the root cause, armed with detailed field knowledge, researchers now face the challenge of designing services and artifacts that leverage the knowledge social scientists are providing.

5. CONCLUSION

We see two major steps researchers will need to take in order to take on this agenda. The first task is to define services that deliver value, 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.

5.1. Develop valuable services

Detailed field studies can serve to both generate knowledge about family practice, and use that knowledge to develop smart home systems that match the needs of families as observed.

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 [16],[31]. 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.

5.2. 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 program 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.

6. ACKNOWLEDGMENTS

Our thanks to our colleagues at Carnegie Mellon's Human-Computer Interaction Institute, Dan Siewiorek, Jodi Forlizzi, Ian Li and Charles Chung Man Yiu.

7. REFERENCES

- [1] Barkhuus, L., & Dey, A.K. (2003) Is context-aware computing taking control away from the user? Three levels of interactivity examined, in *Proceedings of Ubicomp 2003*, 159-166.
- [2] Beech, S., Geelhoed, E., Murphy, R., Parker, J., Sellen, A. & Shaw, K. (2004) Lifestyles of working parents: Implications and opportunities for new technologies, *HP Tech report HPL-2003-88 (R.1)*.
- [3] Belk, R.W. (1988) Possessions and the extended self, *Journal of Consumer Research*, 15(2): 139-168.
- [4] Bellotti, V., Back, M., Edwards, W.K., Grinter, R.E., Henderson, A., & Lopes, C. (2002) Making sense of sensing systems: five questions for designers and researchers, in *Proceedings of CHI 2002*, 415-422.
- [5] Bellotti, V. & Edwards, W. K. (2001) Intelligibility and accountability: Human considerations in context-aware systems, *Human-Computer Interaction*, 16(2-4), 193-212.
- [6] Cook, D.J., Youngblood, M., Heierman, E., Gopalratnam, K., Rao, S., Litvin, A., & Khawaja, F. (2003) MavHome: An agent-based smart home, in *Proceedings of PerCom 2003*, 521-524.
- [7] Crabtree, A., Rodden, T., Hemmings, T. & Benford, S. (2003): Finding a place for ubicomp in the home, in *Proceedings of Ubicomp 2003*, 208-226.
- [8] Darrah, C. N., English-Lueck, J. & Freeman, J. (2001) Families at work: An ethnography of dual career families, *Report for the Sloane Foundation* (Grant Number 98-6-21).
- [9] Davidoff, S., Lee, M.K., Yiu, C.C.M., Zimmerman, J. & Dey, A.K. (in submission) Principles of smart home control, submitted to *UbiComp 2006*.
- [10] Dey, A., Abowd, G., & Salber, D. (2001) A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications, *Human-Computer Interaction*, 16(2-4).
- [11] Dey, A.K., Newberger, A.N., & Chau, E. (2005) Support for context monitoring and control. In submission.
- [12] Dourish, P. (2004) What we talk about when we talk about context, *Personal and Ubiquitous Computing*, 8(1), 19-30.
- [13] Dittmar, H. (1989) Gender identity-related meanings of personal possessions, in *British Journal of Social Psychology*, 28(6):159-171.
- [14] Elliot, K., Neustaedter, C., and Greenberg, S. (2005) Time, Ownership and Awareness: The Value of Contextual Locations in the Home, in *Proceedings of Ubicomp 2005*.
- [15] Frissen, V.A.J. (2000) ICTs in the rush hour of life, *The Information Society*, 16: 65-75
- [16] Gajos, K., Fox, H., & Shrobe, H. (2002) End user empowerment in human centered pervasive computing, in *Proceedings of Pervasive 2002*, 1-7.
- [17] Gaver, B., Dunne, T., & Pacenti, E. (1999) Design: Cultural probes, *interactions*, 6(1): 21-29.
- [18] Grinter, R.E. & Edwards, W.K. (2001) At Home with ubiquitous computing: Seven challenges, In *Proceedings of Ubicomp 2001*, 256-272.
- [19] Harper, R. (2003) Inside the smart home: Ideas, possibilities and methods. in Richard Harper (Ed.) *Inside the smart home*, Springer, New York, 1-14.
- [20] Hayghe, H. V. (1989) Children in 2 worker families and real family income, in *Bureau of Labor and Statistics' Monthly Labor Review*, 112(12): 48-52.
- [21] Hindus, D. (1999) The importance of homes in technology research, in *Proceedings of CoBuild '99*, 199-207.
- [22] Horvitz, E. (1999) Principles of mixed-initiative user interfaces, in *Proceedings of CHI 1999*, 159-166.
- [23] Jahnke, J.H., d'Entremont, M., and Stier, J. (2002) Facilitating the programming of the smart home, *IEEE Wireless Communications*, 9(6): 70-76.
- [24] Kidd, C., Orr, R.J., Abowd, G.D., Atkeson, C., Essa, I., MacIntyre, B., Mynatt, E., Starner, T., and Newstetter, W. (1999) The Aware Home: A living laboratory for ubiquitous computing research, in *Proceedings of CoBuild 1999*, 191-198.
- [25] Kleine, R.E., Kleine, S.S., & Kernan, J.B. (1993) Mundane consumption and the self: A social identity perspective, in *Journal of Consumer Research*, 2(3): 209-235.
- [26] McCalley, L. T., Midden, C. J. H. & Haagdoorens, K. (2005) Computing systems for household energy conservation: Consumer response and social ecological considerations, in *Proceedings of CHI 2005 Workshop on Social Implications of Ubiquitous Computing*.
- [27] Mozer, M. (1998) The neural network house, in *Proceedings of AAAI Symposium on Intelligent Environments*, 110-114.
- [28] Rode, J.A., Toye, E.F. & Blackwell, A.F. (2005) The domestic economy: A broader unit of analysis for end user programming, in *Proceedings of CHI 2005*, 1757-1760.
- [29] Taylor, A.S. & Swan, L. (2005) Artful systems in the home, in *Proceedings of CHI 2005*, 641-650.
- [30] Tolmie, P., Pycock, J., Diggins, T., MacLean, A. & Karsenty, A. (2002) Unremarkable computing, in *Proceedings of CHI 2002*, 399-406.
- [31] Truong, K. N., Huang, E. M., & Abowd, G. D. (2004) CAMP: A magnetic poetry interface for end-user programming of capture applications for the home, in *Proceedings of Ubicomp 2004*, 143-160.
- [32] Venkatesh, A., Chuan-Fong E.S. & Stolzoff, N.C. (2000) A Longitudinal analysis of computing in the home based on census data 1984-1997, in *Proceedings of HOIT 2000*, 205-215.
- [33] Weiser, M. (1991) The computer for the 21st Century, *Scientific American*, 265(3): 94-104.