# Lessons for the Future: Experiences with the Installation and Use of Today's Domestic Sensors & Technologies

authors

address

**Abstract.** Domestic environments are receiving increasing attention as sites of deployment for pervasive technologies, as evidenced by the growing number of studies of homes and by the maturing of technologies in prototype aware/smart homes. The challenge now is to move technologies out of purpose built homes into everyday environments in ways that will fit with existing buildings and the people who live in them. In this paper we describe our findings from fieldwork designed to gain an understanding of current experiences with technologies in the home that bear similarities with emerging applications: sensors and sophisticated home automation/entertainment systems.

## 1 Introduction

The home is gaining increasing attention as a possible site for deployment of pervasive computing technologies [11]. Prototype 'aware/smart homes' such as the Georgia Tech Aware Home [1] and MIT PlaceLab [13] demonstrate the possibilities for sensor and network technologies in home environments. In parallel to, and preceding, this work, there has also been considerable interest in the home as a site of study in its own right, both to understand the how the home is experienced and made home, and also to identify opportunities for design. O'Brien, for example, has looked at the role of different technologies in the home and how they modulate the social life of the home [16]. Crabtree et al. explored the flow of information through a home, highlighting activity centres with a view to how these could be supported by technology [5].

An implicit notion in much of this work is that there is a gap between the vision of some possible future with an aware/smart home making use of various sensors and complex infrastructures and technologies, and the reality of lived-in homes today with their everyday technologies and patterns of social life that are far removed from this vision (as evidenced by the need to build purpose built homes as demonstrators).

Our recent studies of some everyday homes, however show that many aspects of this vision are already a part of many homes. The contribution of this paper is to explore some of the experiences of living with current sensors and technologies and draw out implications for design of future pervasive technologies for the home.

The studies to be reported in this paper are part of a larger project concerned with the design, prototyping, and in-situ evaluation of pervasive technologies in domestic

settings. Because our approach is to try to design for real homes and involve users as participants in the design process, we undertook a set of initial in-home studies to serve as a baseline understanding of each particular home and family so that we could better tailor our co-design sessions with them.

These studies gave rise to surprising findings. One was the ways in which "everyday" sensors in the home are often broken or require various workarounds to be used. Another was the multiple factors beyond just functionality that determine what technologies are in the home and the ways in which these too are often problematic or poorly understood. This led us to triangulate our findings through a survey about everyday sensors and through interviews with smart home installers to explore experiences with more advanced technological arrangements in the home.

In this paper we first review some of the background work around studies of domestic environments and pervasive technologies for domestic settings; we then describe three studies we have undertaken exploring current experiences of technology in the home. Finally we discuss our findings and their implications for future efforts to design applications of pervasive computing for domestic settings.

## 2 Background

Weiser's [22] dream of a future of ubiquitous and pervasive computing was just as much a vision of technology in the home as it was one of technology in the office. A sociological thrust in the research has sought to understand through ethnographic methods the current nature of the home and, having gained that understanding to suggest sites and artifacts within the home that might be possible targets for technical augmentation in the manner envisioned by Weiser. Secondly, a more technological thrust has focused on realizing possible future technologies in a purpose-built environment.

The ethnographies of the domestic environment have found a strong focus on the presence of routines in the home [21, 18, 5] and artifacts that support routines have been highlighted as candidates for technological enhancement, for example: calendars, family notice-boards, wall-planners [5]; and, shopping lists and the kinds of notes that are attached with magnets on a fridge [20, 19]. Other work has highlighted the importance of everyday technologies in supporting the maintenance of routines, such as using episode length of children's videos as a timing device [17]. We take such findings as sensitizing starting points in our in-home studies.

In parallel there have been significant technological advances to the point where we are now seeing relatively stable prototype developments and some initial in-home deployments. Sensor networks are being developed in conjunction with sophisticated inferencing processes to make higher-order sense of continuous sensor data [18,13]. Component applications are being developed such as SMS messaging in the home [19]. There are increasing efforts to develop toolkits that minimize the time and effort to build pervasive applications [8].

High profile examples include the Aware Home Research Initiative at Georgia Tech, creating created a "living laboratory" with various technologies including location sensing technologies, large-screen projected displays and camera-based eye-

tracking [1]; and the "The Place Lab" at MIT that has its Home-n augmented with over a hundred sensors, including sensors of temperature, humidity, light, barometric pressure, electric current and water flow, "where the routine activities and interactions of everyday home life can be observed, recorded for later analysis, and experimentally manipulated" [13]. These developments have resulted in important advances but at a loss of the authenticity of everyday settings, e.g., Place Lab is optimized for the observation of a single volunteer individual for limited periods of time.

Other research has sought to deploy technologies into existing homes, as with Beckmann et al's sensor installation kit [2]. Others have used in-home deployments as a form of technology probe to elicit interesting responses to new technologies which may act as inspiration for future design [12]. More provocative installations of technology such as a weight-sensitive 'drift table' have been undertaken by Gaver et al. [7] as part of their curious home project. Such provocative, unusual and strange interventions in the home can serve to highlight design possibilities by making the familiar strange, the importance of which is highlighted by Bell at al [3].

Given the substantial amount of work that currently exists, both in understanding domestic life and in developing technologies, it is timely to think more seriously about how to move from purpose-built 'aware/smart' homes to augmenting everyday domestic environments. While the potential vision points to homes that could be very different to experiences today, there are nonetheless lessons we can take from current homes to inform the more pragmatic design and deployment of technologies in the home. Grinter et al [9], for example, highlight the experiences of skilled computer people in maintaining their home networks. This paper seeks to make a similar contribution by looking at both what we call 'everyday' homes and at high-end "smart" homes to find lessons that can be built upon.

## 3 Overview of Studies

To explore people's experiences with existing technologies in the home, we used a mix of qualitative and quantitative methods: in-home interviews and 'tours' with participants in their own homes; an online survey of sensor technology experiences; and interviews with professionals who install "state of the art" technologies into the homes of the wealthy. We will report each study in turn.

### 3.1 Study1: In-home Interviews & Tours

As stated previously, the initial intention of the in-home interviews was to have a baseline understanding of our participants and their homes in order to inform future design work with them.

**Participants and Methods.** 12 people from 7 UK households participated in this study (see Table 1 for an overview of the households). They were recruited via email lists and were given £25 in remuneration. All the interviewees were "middle class" by

English standards – they were professionals or worked in clerical professions in support of professionals and had a university education.

**Table 1**. Profile of participant households (Pseudonyms used)

| Household | Occupants (Ages) | Adult professions | Type of home |
|---|---|---|---|
| 1.(Chloe & Jack) | Parents mid 30's, children 6 and 8 | Teacher, director of technology company | Detached, brick, early 1900s |
| 2 (Emily & Thomas) | Couple late 20's | Admin assistant, software developer | 2-bedroom terraced house |
| 3 (Megan & James) | Couple, late 50's | Admin assistant, Teacher | Detached, late 19th century |
| 4 (Charlotte & Joshua) | Couple, mid-30's, children 5, 10, 12 | Human Rights consultant, homemaker | Detached, early 1900s |
| 5 (Sophie & Daniel) | Couple, mid 60's | Retired Astronomer, homemaker | Detached, early 1900s |
| 6 (Lauren & Harry) | Couple, late 30's, children 8, 10, 14 | Director of technology company, homemaker | Detached, early 1900s |
| 7 (Lucy & Sam) | Couple in 60's | Retired telephone engineer, homemaker | New detached, brick bungalow |

A study session with each household consisted of an in-home tour and interview with one or two of the adult family members. Each session lasted approximately 90 minutes and was conducted by two researchers, one playing the role of interviewer and the other capturing the session on video. A study protocol was developed focusing especially on their current relationship of participants to the technology in their homes. Participants were asked to give the interviewer a tour of the house and all of the technology that was visible was discussed. The participants were asked how each piece of technology came to be there, what it was used for, when it was last used and if there were any problems or issues with it. If the technology under discussion had been bought by the participants they were asked where they bought it and what criteria were used to decide on the purchase. Interviews were informed by previous ethnographic work on the home and so questions were also asked about areas of the home and activities and artifacts that had been identified as potential candidates for digital augmentation, e.g., as in [5, 10, 20]. Analysis of the videos was conducted through repeated viewing and coding to identify themes and issues.

**Findings: In-home technologies.** We saw many of the same things that others have noted in studies of home settings. For example the fridge and other notice boards were commonly used as spaces in which information was displayed and through which family life was coordinated [5]. Women were the primary timekeepers and maintainers of calendars, and controllers of flow of physically instantiated information (paper mail) around the house [10].

All of the households owned a diverse array of technologies: every house had at least one computer, at least one mobile phone, and at least one TV, DVD system, and audio system; two homes had burglar alarms; six had broadband internet connections

(although one of those had never worked); three had wireless connectivity; and every home had a thermostat and a smoke detector. Other technologies observed included: mp3 players, illegal mp3 transmitters, video cameras, digital cameras, solar panels, thermostatic sewing machines, face spa, handheld and console video game players, Personal Digital Assistants (PDAs) laptops and retro gramophones. What was surprising though was the extent to which these sensors and technologies already made up the home, the stories around those technologies, and the issues that people experienced living with these. For the purposes of this paper, we will focus on the following: sensor experiences, general technology experiences, technology choices, gendered relationships to technology, and information requirements.

*Sensor Experiences – Work Arounds.* The future of pervasive computing within built spaces is often oriented around sensing technologies, e.g., see [14]. All of the households had at least one of the following sensors: thermostat, burglar alarm, smoke detector. Three of the seven homes had problems with these, despite them being commonplace and "mature" technologies.

Three households stated that they thought their thermostat was not triggered at the correct temperature, for example: *"That's the underfloor heating, but it only works if you turn it up to 35 degrees centigrade – that's not the temperature that it gets to in here, that's the temperature that the mice enjoy under the floorboards."[Joshua, House 4]*

Burglar alarms also proved problematic. One couple, who did use their burglar alarm extensively, referred to the burglar alarm being falsely triggered during power cuts. Another couple no longer used their burglar alarm after the alarm went off falsely when there was a power cut. It was also difficult to use even if they had wanted to because the control panel had been installed in an under-the-stairs cupboard with no lighting: *"It's a bit difficult to turn that thing on and then get out of the door with two kids in 30 seconds."[Chloe, House 1]*

These pointed to issues people had with not understanding and/or not trusting the ways in which their sensors worked, as well as the practical realities of location and timing and false alarms that render them less useful. As the work done at Georgia Tech, MIT and other places shows many ubiquitous computing applications, especially those targeted at the home, envisage a house which has many sensors acting in concert. It is therefore a serious concern that a substantial number of the "everyday" sensors that are found in real homes either do not work properly or, equally importantly, are not regarded by their users as working properly.

*General Technology Experiences - Not Working, Not Understood.* A recurring theme across the households was the number of *technologies that did not work properly*. A striking thing about the discussions was the poor strategies people had for fixing their non-working technologies.

Networking was a case in point. In house 3 the ADSL broadband internet connection had not worked in the six-months since it was installed. The participants were unable to give any real explanation for why it didn't work, and their only suggested strategy for getting the broadband to work was to buy a new laptop and hope that it would mysteriously work better than existing computers in the house. Another inter-

viewee [Jack, House 1] was having problems with his second attempt at wireless networking. His first wireless router had "just packed up for no apparent reason" and because he felt that his second was becoming unreliable, he was intending to buy a third wireless networking box. He seemed to be unaware of two of the three main problems that might be affecting his wireless connectivity – using WEP data encryption and interference from other wireless networks in surrounding houses and seemed to think that the solution would be to buy a "stronger" base station. .

Further, many homes had a large number of *technologies that were not used*. These included sewing machines, exercise machines, cappuccino machines, food processors, solar panels, radios and video cameras which were either left to languish in a cupboard or put into a 'back room' to be dealt with at some later unspecified time.

While there was no scarcity of technology in evidence in most houses of the houses that we visited, there was often a serious *lack of understanding of and know-how about the technology*. This seemed to be a strong contributing factor to why various pieces of technology remained broken or unused. Sometimes family members trade knowledge e.g., in how to program the video recorder in exchange for some other household task, as also found by Rode [17]. Sometimes the know-how was problematic. Charlotte and Joshua (House 4) had a 12 year old daughter who had set up her own website. Her parents decided to take down the website because they felt that the pictures were inappropriate and the content was unwise for the web but could only do so with the help of their 10-year-old daughter.

*"We're just starting to learn about this stuff, because she's our eldest and she doesn't have any older brothers and sisters. But her friends have elder brothers and sisters and they show them how to do it."[Charlotte, House 4]*

We also found evidence of cases where the know-how required to fix a problem was not present in the household. In these cases, external help was often sought, but with mixed success. Some accessed informal networks of friends and work colleagues. Others sought help from one of a number of advertised PC Repair/Support services. In one case however, this was a fragile solution since it is in the nature of computer networks to change.

*"I got a man in and he set up all the networking, and that was fine until this laptop got filled up with shareware and other junk and I had to re-install it and now the networking doesn't work."[Joshua, House 4]*

Only one couple had attended computer courses to help them with their lack of knowledge but the class had not helped them fix their webcam: *"It used to work until we got broadband, but it hasn't worked since. I asked my brother and he couldn't fix it. I was thinking, maybe we'd just give it one more try."[Sam, House 7]*

*Technology Choices: How technology gets into the home.* In purpose-built aware/smart homes, technology configurations are pre-determined as part of some configurable package, largely by the researcher in an academic context or the provider/installer in a commercial context, albeit modified by consumer choice. In the 'everyday' homes that we looked at, there were much more diverse and complex reasons for how technologies arrived there. People received technologies as (possibly unwanted) gifts from relatives and they felt a social obligation to keep them or at least

bring them out for display when those relatives visited (as did Chloe & Jack with a face spa and sewing machine). Parents gave their financially struggling children hand-me-down technology (as was the case with Megan & James' television). Children gave their less-technology-savvy parents hand-me-down mobile phones or computers (as with Chloe and Jack).

Of course people also bought new technology but when they did, performance and technical features were not necessarily the primary reasons for purchase:

*"Has it got the couple of features I know I want? Does it look nice because I'm going to be looking at it all of the time? And is it within my price range? And I just get fed-up with everything else because you could spend hours, months choosing things"[Megan, House 3]*

Technology choices were also often driven by a strong sense of values. Many of the interviewees saw their choice of technology as a fundamental expression of their beliefs but wanted the technology to fit in with, rather than transform, those beliefs.

*"I want to live in a yurt with internet access"[Emily, House 2]*

For the 'yurt' couple, Emily and Thomas, almost all their technology choices were influenced by their desire to live an ecologically responsible lifestyle, and they spent considerable time researching products on internet sites that specialized in selling technologies for ecological living. These products included energy-saving thermostatic air-mixing taps, electricity generating solar panels and a fibre-optic "light-pipe". Interestingly, picking up on our 'not-working and not-used' theme, the solar panels had never been installed and were languishing in the spare bedroom and the light pipe, although it was installed, was missing a part and not working.

The very choice of these technologies serves to explicitly convey to visitors in the home what values are held there or what impressions they want to project. *"I printed that out [tide tables] because I wanted people to think that we're the kind of family that goes boating. We're not."[Joshua, House 4]*

Technologies were also chosen for reasons of form and aesthetics over function (as also found when we talked to smart home installers (detailed below)). In house 7, Lucy said she was unhappy with the interface to her microwave because it was difficult to use. When asked how she'd come to choose it she said it was because it would be the same shade of white as her conventional oven. Another of our participants had asked her husband to buy a "little radio" so that she could listen to Radio 4 in the kitchen while she was cooking and washing up but instead her husband bought a very large radio that we found in the spare room covered in dust because the woman didn't like the look of it in the kitchen.

*Gendered relationships with technology.* As can be seen above, in almost all of the households, women played a key role in deciding what technology came into the home where purchases were made. As has been seen in other studies [10], the women also played a large part in the construction and maintenance of domestic routines, handling mail, doing the filing, and managing the family diary/calendar. Calendar management/display has frequently been discussed as one possible application of ubiquitous computing [5]. It is therefore perhaps interesting to note that in many homes the family calendar was either "in the head" of the woman of the house or in a

small personal diary, that was carried by the woman in her handbag. For one woman, this control was also explicitly associated with a particular location in the house:

*"This is my chair and no-one else is allowed to sit here. And that's my work basket, the radio and I always have you can see, the Ikea catalogue [laughs] and my cross-word. I sit here and I can see the cooker and I can hear the front door and I can answer the phone and I'm near the back door and I can see the sink. My poor husband has nothing like this, but then he doesn't do anything like that. I organise the house I run the house, I do all the paperwork."[Megan, House 3]*

We saw other examples of men similarly exerting control over different domains in the home. In two houses there was some kind of restriction by the husband on the wife's use of central heating controls. In house 7 Lucy was 'forbidden' from touching the central heating controls: *"I don't touch that [Central heating control], it's more than my life's worth"[Lucy, House 7]* In house 2, Thomas had stuck a cardboard flap over the button which altered the thermostat temperature *"…because Emily is always tempted to just put the temperature up when she wants the central heating to come on and that flap is to sort of remind her not to."[Thomas, House 2]* In house 1 the idea of using the fridge as a coordination space would not be well received. *"We never stick things on the fridge, I hate clutter" [Jack, House 1]*

*Information Requirements.* We were surprised then that amongst our interviewees there were no problems or dissatisfaction with the current (mainly paper) solutions that were used to manage information. Participants did mention other kinds of information which they would like technology to provide. Emily and Thomas (House 2), who were very keen on environmental issues said they would like to know how windy and sunny it was on their roof. Megan (House 3) said that she would like to know more about the history of her Victorian-period house and about the people who had lived in it before her. Lucy and Sam (House 7) who live in a nearly-new home wished that they had all the documentation (guarantees, instruction manuals, etc) that came with the pre-fitted appliances and a circuit diagram of the burglar alarm.

*In summary*. Though it would be hard to generalize from these few households, to the whole of the United Kingdom, let alone to other countries, they do provide us with some evidence of use and experience of a wide variety of sensors and technologies and raise interesting questions around the issues of everyday troubles with technologies, technical know-how and support, the multiplicity of ways technologies get into a home and gendered relationships with technology.

### 3.2 Study 2: Household Sensor Questionnaire

The surprising lack of understanding of current sensor technologies and the number of supposedly mature sensors that didn't work well led us to question whether or not these were common experiences. To explore this we developed a simple on-line questionnaire that asked about sensors that are commonly found in the domestic environment: respondents were asked if they had a thermostat, smoke detector or burglar alarm and, if they did, whether it worked properly. They were asked to detail any

problems they had and also to give details of occasions when smoke detectors or burglar alarms had produced false alarm situations. Subjects were recruited via an email that was circulated within the department and to acquaintances of the authors who were asked in turn to pass it on to other friends. 20 people responded to the questionnaire, 11 men and 9 women with an average age of 37. 5 of the 20 respondents (25%) were tenants in rented accommodation and 15 of the 20 respondents (75%) were home owners.

**Findings: Domestic Sensors.** 14 (70%) of the respondents had a thermostat in their house. 1 of the respondents (=7%) reported that their thermostat didn't work properly. All of the respondents reported that they had a smoke alarm in their house, of which 14 (70%) reported that their smoke alarm worked properly. However, when asked if their smoke alarm had ever gone off when there wasn't a fire, 17 of the 20 (85%) respondents said that it had at some time gone off when there wasn't a fire. In many cases the detailed explanation of when the smoke alarm was triggered falsely indicated that this was a regular occurrence. *"Alarm continually going off when cooking", "The toaster causes them to go off.", "They go off when the room is too hot regardless of there being no smoke."*

6 of 20 respondents had burglar alarms. Of these, 4 said that their burglar alarms worked correctly. When asked if there burglar alarm had gone off falsely 3 of the six respondents said that it had: *"Mistakes entering code", "Detector went of when intruder not present", "It briefly goes off when power is restored after a power cut"*.

Hence, while not universal, these results suggest that alarm-based sensors were often experienced as problematic but that this was not necessarily perceived as problematic (as with 70% saying that the smoke alarm worked properly yet 85% had had issues with false alarms). Thermostats seem to be less problematic in use but we did not test what people's underlying models were of how the thermostat worked.

### 3.3 Study 3: Smart Home Installer Interviews

Apart from 'everyday' issues with sensors, our in-home studies also highlighted how much technology people already have in their homes, even very 'average' middle class households, though the technologies are largely 'simple' standalone systems or devices. This led us to think about other homes at the higher end of the market and their experiences with more complex infrastructures and technological arrangements. These were of interest because they represent the current state of the commercialization of aware/smart home technologies and represent possible early adopter experiences with more emergent pervasive technologies for the home. As highlighted by Edwards and Grinter [6] the history of technology adoption may in some ways be a useful guide to the way in which technology is adopted in the future. As was the case with television, the technologies that wealthy people can afford to have professionally installed one day may well be the technologies that the rest of us will be able to buy as an of-the-shelf solution the next.

**Participants and Methods:** Ideally, we would want to interview the householders themselves about their 'smart home' installations. However, the demographics of the people who are in this category make it difficult to access them as participants – on the characterization of the people who do the installations, they are normally very wealthy people with high pressured jobs, often involving travel, who would not prioritize time for study participation. Instead, we chose to conduct interviews with companies that install "smart home" technologies in the houses of wealthy customers.

We interviewed two people who worked in customer-facing technical roles at two different companies, referred to here as Smith Ltd and Jones Ltd. Jones Ltd is a company with approximately 20 members of staff. It began as an audio equipment stall at record collectors' fair 30 years ago and now offers integrated home entertainment and automation systems solutions. Smith Ltd is a similar company, with 3 full-time staff members. It has been in business for approximately 5 years and was formed by two programmer/engineers who had previously run a company providing technical support services to industry. An example of a recent installation they delivered into a 16th century house was of a video/music server which could be accessed from any room in the house, networked plasma and projection screens, a complex lighting control system, in room web-cams and CCTV monitoring of the grounds.

Interviews with the company representatives lasted approximately 2 hours. The interviewees were asked to discuss the requirements of a typical customer, perceived trends in the industry, which features were popular or unpopular and the common causes of support calls. Again an interview protocol was developed and used as background preparation while leaving the actual conduct of the interview free to follow leads as they emerged. A content analysis was conducted on the interview notes to identify common themes.

**Findings: Smart Home Installers.** In both companies, participants described very similar pictures of the customers they served, the systems they installed and the experiences reported back to them from customers via their service centres or representatives. One very important difference from the 'everyday homes' just discussed is that most 'smart home' installations begin with an empty shell of the house, or with discussions with the architect before the house is even built. None of the everyday houses that we visited – even the one that was newly built had acquired their technology as the result of one monolithic installation.

*Technology Choices: What was or was not in demand.* How people choose to prioritize and allocate their money in designing these installations is an important indicator of the technologies they at least think they want to live with. Both companies reported that one of the most commonly requested 'smart home' components were motion-sensitive lights in hallways to allow night-time navigation to the bathroom. Other components that were popular included an "Occupancy Simulation" – turning the lights on and off in a pattern that might deter burglars – and a bedside switch which allows all the lights in the house to be turned off at once.

Television and entertainment systems, particularly distributed or networked solutions, were also high on people's purchase lists: *"People are really into telly."[Smith Ltd]*. A feature which allows the user to pause a TV show in the living room and

resume watching it from another room (typically the bedroom) was a popular request, as was waterproof TVs fitted in bathrooms.

There were also a number of technologies that the installers noted little demand for or that fell low on people's priority lists. Interestingly, these tended to be the ones with more advanced or automated features. In the category of technologies which might seem like a good idea, but in fact are little used in practice Smith Ltd cited voice activation as a technology that they no longer recommended: "*Voice recognition stuff, kind of works, it's fun for about five minutes, but it drives you up the wall after two days."[Smith Ltd]*

Other seemingly archetypal home automation features became a low priority, even to the most wealthy of customers, when they discovered how much they cost. "*People like the idea of automatically opening and closing curtains until they find out that it costs about £1600 per large window."[Smith Ltd]*

While talking to these people, we also asked them about their opinion about potential for user-configurable solutions. This is because there has been a current research towards the production of ubicomp toolkits that would allow the user to reconfigure aspects of their digital infrastructure and conduct some forms of end-user programming [8, 4]. Neither company felt that there was a strong demand for this: *"They can't even plug the right cable into the right socket at the back of their DVD recorder to get the best signal for their plasma screens. Reconfiguration will probably happen but only in the IT-savvy/early adopter community."[Smith Ltd]*

Both companies reported a strong gender divide in attitude and approach to the technologies chosen and installed. Men were largely drawn to the technology and wanted it on display but women were much more concerned with the aesthetics of the installations and that they fitted in with the interior décor: *"Boys want all the toys – wives want everything to be out of the way and have the minimum number of remote controls." [Smith Ltd] "This installation has a wall-mounted display and in-ceiling speakers. The woman was wearing the trousers, she wanted nothing on display."[Jones Ltd]*

Smith Ltd reported that on many installations as much as 50% of the cost of the project was spent on cabinet-making and carpentry to ensure that the technology was aesthetically concealed.

*Complex systems, complex infrastructures and controls.* Complex integrated solutions require complex infrastructures to support them. However these infrastructures tend to be hard-wired because of practical concerns with current wireless solutions including insufficient data rates for the transport of high quality video. As such, one of the most important services that smart home installation companies provide is designing the layout of cables around the home and laying the cable around the home. Thus installations, once designed and installed, remain relatively inflexible.

These more complex systems also require more complex interactions to manage and control them relative to the more stand-alone technologies of the 'everyday' homes reported earlier. A typical home cinema system installed by Smith or Jones Ltd involves at the very least a control for the projection screen, the screen projector, the DVD player, and also possibly for the lights, the curtains and the sound. The options offered by the companies include: individual controls for each of the boxes

(the problems with which have well-documented [15]); a single remote control from which all of the commands can be sent by infra-red as a macro; and, the most expensive option, an LCD panel to control all the devices via RF to a controlling system.

None of these solutions is perfect. The use of individual remote controls means that the user has to identify several remote controls and press the right button while pointing at the right device:*"The [infra red] remote doesn't know what state appliances are in when it sends the signal. If a remote has to send out a whole string of commands the user has to stand there while all the commands are sent."[Smith Ltd]*. The interfaces for the LCD displays are currently only programmable using proprietary applications and a large amount of systems programming to the proprietary API is required to interface a new appliance.

It is no surprise then that one of the most commonly reported causes of support calls to the companies' service centres were problems with remote controls. The most common problem was that the battery had gone flat but this was often only able to be diagnosed after a time-consuming support call, or even a visit.

There were several hints in the discussion of these smart home controls being a source of dispute, especially where one person, often the woman, found it difficult to perform everyday tasks: *"Hubby [the husband] gets all the kit installed and then he goes off on a business trip and the wife's left alone, sitting on the sofa with all the remotes and she can't put the telly on or turn off the lights."[Jones Ltd]*

## 4 Discussion

While the full realisation of the aware/smart home is still some way off as the norm for everyday household living (if that is even the sort of home we want to live in, a discussion for another time), there are many aspects of this vision that people 'live' with right now. We argue that understanding these current experiences can provide valuable lessons and insights for the types of issues and troubles people might have with even more sophisticated and complex sensor and technical networks in the home of the future and so shape future design directions. Others have also drawn out lessons for designers of pervasive technologies for the home. Edwards and Grinter [6] present them as seven challenges, covering a range of technical, social and pragmatic concerns. Beckmann et al [2] draw out five principles for end user sensor installation, based on in-home deployments of sensor kits in 15 existing homes.

The in-home studies point to the routine experiences and troubles, that people have with the sensors, infrastructures and technologies available today. It should be of interest to the constructors of future homes that involve hundreds of sensors that many of the everyday stand-alone sensors that are already in homes are reported as not working properly and, curiously, other sensors are reported as working properly yet regularly produce false positive results.

A principle from Beckmann et al is to "make appropriate use of user conceptual models for familiar technologies" [2] but the findings here suggest that often people do not have well-developed models in the first place, as evidenced by the poor understanding of how sensors worked, nor do they have the skills and know-how as evidenced by the poor strategies people had for problem solving. The fact that so many

of the technologies and sensors were either broken or required work-arounds to make use of reinforces the critical importance of Edwards and Grinter's call for the technologies to be reliable [6]. Yet many technologies that are regarded as unproblematic commodities by the research community (ADSL broadband, wireless networking) are still causing huge problems in peoples' homes. Design for reliability may be part of the solution, but it may be that pervasive computing has to recognize and incorporate into its design, not only the social capital of providing technical support and know-how to friends and family, but also access to a wider community of support. It may be that, as with personal computing, pervasive computing in the home will have to go through a "hobbyist phase".

Another of Edwards and Grinter's challenges is to support system inferencing in the presence of ambiguity [6]. The findings here, both of everyday homes and the smart homes, is that the reverse is also required: users need to be supported to make inferences in the face of system uncertainty as they seek to trouble shoot problems. Even something as simple as turning a device on or off can become much more difficult with the smart homes, pointing to a need for intuitive easy to use controls and reflective support for trouble shooting (which as discussed is not straightforward the more complex the installation gets).

Functionality is only one of many considerations in making technology choices, as also identified the themes of "balance installation usability with domestic concerns" [2] and "design for domestic use" [6]. As we saw in both everyday and smart homes, technologies need to need to fit in: to the power structure; to the physical space; to the values; and to the aesthetics of the home. In this arena, technology choices are often contended along gender lines and/or are highly value-laden. The management of the home and its routines was often the domain of the woman; applications which interfere with this power structure or simply make it more difficult to do the things that she already does may not find favour. Similarly we saw evidence of other aspects of running the home – control of the heating – that might be a male domain. Values played out in terms of where people were prepared to direct their effort and budget.

There are still multiple routes of entry for technologies into the home. Not only are people incrementally evolving their own homes with new technology purchases, but they receive gifts, are given hand-me-downs. How technology comes into the home also needs to be recognized, as per the "accidentally smart home" challenge [6] and their design should acknowledge, perhaps encourage, these alternative routes of entry into the home and coexistence with older-generations of technology (see also the "impromptu interoperability" challenge [6]).

Ultimately people will need to be persuaded to purchase these new technologies for the home; seeing where people currently allocate their spending power is instructive for directing attention to what might be more acceptable. In the smart homes especially, people were prioritizing safety (in sensor-based lighting choices) and entertainment/leisure (in high-end home entertainment system choices). In neither smart homes nor everyday homes did we see evidence of demand for many, what might be called "typical", smart home features, such as curtain openers, voice control and kitchen automation). Such automation, where deployed, was often experienced initially as a novelty then as annoying.

## 5 Conclusion

Significant technical advances are being made that mean that the vision of pervasive computing in the home is closer to becoming a reality. In this paper we have reported on three complementary studies that explore people's current experiences with technologies already in homes, albeit in a UK context. These are interesting because the technologies and sensors in everyday homes and more complex smart home technologies share many of the same components that will be used to realize these future visions. Our findings and the general sensitivities drawn for design suggest that the issues to be addressed to realize the vision will be much more about the human, social, cultural and marketing issues than the technical issues.

## 6 ACKNOWLEDGMENTS

<removed for anonymity>

## REFERENCES


1. Abowd, G., Bobick, A., Essa I., Mynatt, E., and Rogers, W. The aware home: Developing technologies for successful aging. In Proc AAAI Workshop Automation as a Care Giver. Alberta, Canada (July 2002) 185 - 192
2. Beckmann, C., Consolvo, S. and LaMarca, A. Some assembly required: Supporting end-user sensor installation in domestic ubiquitous computing environments Proc Ubicomp 2004. Nottingham, UK. (6-10 September 2004) Springer-Verlag. 107-124
3. Bell, G., Blythe, M., and Sengers, P. Making by making strange: Defamiliarization and the design of domestic technologies. ACM Trans. Comput.-Hum. Interact. 12, 2 (Jun. 2005), 149-173.
4. Blackwell, A.F. and Hague, R. AutoHAN: An Architecture for Program-ming the Home. In Proc IEEE Symposia on Human-Centric Computing Languages and Environments, (2001) 150-157.
5. Crabtree A, Rodden T, Hemmings T and Benford, S.: Finding a Place for UbiComp in the Home. Proc Ubicomp 2003, Seatle WA, Springer-Verlag, 208-226
6. Edwards, W. K., Grinter, R. E.:At home with ubiquitous computing: seven challenges. Proc Ubicomp 2001: Ubiquitous Computing International Conference; Atlanta, GA. Springer Verlag; 2001, 256-272
7. Gaver, W. W., Bowers, J., Boucher, A., Gellerson, H., Pennington, S., Schmidt, A., Steed, A., Villars, N., and Walker, B. 2004. The drift table: designing for ludic engagement. In CHI '04 Extended Abstracts. ACM Press, (Vienna, Austria, April 24 - 29, 2004). 885-900.
8. Greenhalgh C., Izadi S., Mathrick J., Humble J. and I. Taylor: ECT: A Toolkit to Support Rapid Construction of Ubicomp Environments. In Proc Ubicomp 2004, , Nottingham, UK, (2004), 207-234
9. Grinter R. E., Edwards W. K., Newman M., Ducheneaut N.: The work to make the home network work. In Proc ECSCW'05. Paris, Springer-Verlag. (2005) 97-119.

10. Harper, R., Evergeti, V., Hamill, L., and Strain,J.: Paper-mail in the 21st century: an analysis of the future of paper-mail and implications for the design of electronic alternatives by presented at the Oikos 2001 workshop, Denmark, 2001: http://www.surrey.ac.uk/dwrc/Publications/okios.pdf (last accessed 3rd October 3, 2005)
11. Hindus, D.,Mainwaring, S.,Hagstrom, A. E., Leduc, N., AND Bayley, O. Casablanca: Designing social communication devices for the home. In Proc CHI'01. ACM Press. (2001) 209-216
12. Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B. B., Druin, A., Plai-sant, C., Beaudouin-Lafon, M., Conversy, S., Evans, H., Hansen, H., Roussel, N., and Eiderbäck, B. Technology probes: inspiring design for and with families. In Proc CHI'03. Florida, USA, ACM Press, New York, NY, (2003) 17-24.
13. Intille, S. S., Larson, K., Beaudin, J. S., Nawyn, J., Tapia, E. M., and Kaushik, P: A living laboratory for the design and evaluation of ubiquitous computing technologies. CHI '05 Extended Abstracts (Portland, OR ). ACM Press, (2005) 1941-1944.
14. LaMarca, A., Chawathe, Y., Consolvo, S., Hightower, J., Smith, I., Scott, J., Sohn, T., Howard, J., Hughes, J., Potter, F., Tabert, J., Powledge, P., Borriello, G. and Schilit, B.. Place Lab: Device Positioning Using Radio Beacons in the Wild. In Pervasive 2005, Munich, Germany, LNCS Vol 3468, (2005) Springer-Verlag, 421 - 486.
15. Norman, Donald A., "Home Theater: Not Ready for Prime Time," IEEE Computer, Volume 35, Number 6, (2002) 100-102.
16. O'Brien, J., Rodden, T., Rouncefield, M., and Hughes, J. 1999. At home with the technology: an ethnographic study of a set-top-box trial. ACM Trans. Comput.-Hum. Interact. 6, 3 (1999), 282-308.
17. Rode, J.A., Toye, E.F. and Blackwell, A.F. (2005). The Domestic Economy: a Broader Unit of Analysis for End User Programming. Proc CHI'2005, ACM Press, (2005) 1757 – 1760.
18. Schilit B, LaMarca A, Borriello G, Griswold W, McDonald D, Lazowska E, Balachandran A, Hong J and Iverson V.Challenge: Ubiquitous Location-Aware Computing and the Place Lab Ini-tiative. In Proc ACM Int Workshop on Wireless Mobile Applications & Services on WLAN (WMASH 2003), San Diego, CA. (2003) 29-35.
19. Swan, L. and Taylor, A. S.: Notes on fridge surfaces. In CHI '05 Extended Abstracts (Portland, OR, USA, April 2005). ACM Press, New York, NY, 1813-1816.
20. Taylor, A. S., & Swan, L. List making in the home. Proc CSCW '04. Chicago, IL, ACM Press, (2004) 542-545.
21. Venkatesh, A., E. Kruse, and E. C.-F. Shih: The Networked Home: An Analysis of Current Developments and Future Trends, Cognition, Technology and Work, vol. 5, no. 1, (2003) 23-32.
22. Weiser, M. The computer for the 21st century. Scientific American, 265(3): (1991) 66-75.