Smart Homes: Past, Present and Future

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2.1 Introduction

A "smart home" can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond.

The full-blown concept of the smart home is the acme of domestic technology we can envisage at present. The concept, at one time only encountered in science fiction, has moved closer to realisation over the last ten years. Although the gap between reality and fantasy is still wide, it is important that we start to give proper consideration to the implications this technology holds for the way we will live in our homes in the future.

To date, the limited amount of research into smart home that has been carried out has been primarily focused on the technical possibilities. As a social scientist myself, I am concerned that the personal and social consequences of smart home technology are largely being overlooked. (A notable exception is the work of Mynatt and colleagues at the Everyday Computing Lab at the Georgia Institute of Technology, e.g. Mynatt et al., 2001; Siio et al., 2002; Voida and Mynatt, 2002.) The home is a quintessential "human" place, with all the intricacies that entails. As I hope to persuade you in this chapter, the smart home is far too sensitive and important a sphere for social scientists to ignore any longer. If we take up the challenge which the smart home presents, we can make a significant contribution – the evolution of the technology itself will be shaped by our discussion and research.

With this chapter I am aiming to provide the motivation and the background for social scientists to become involved with the emerging phenomenon of the smart home. The chapter is divided into three sections looking at the past, the present and the future of the smart home – at the historical context which brought about the emergence of the

"smart home" concept; its present status in terms of consumer take-up, current research projects and academic literature; and its future prospects, both commercially and as a potential area for social science research. The field of smart home research (and domestic technology in general) is in its infancy and relevant literature is sparse. I have therefore drawn together information from a range of disciplines and speculated where necessary, particularly regarding the future.

Finally, I should declare my own position – the social science of domestic technology is an area I find fascinating and I hope that I can communicate some of my enthusiasm in this chapter. Domestic technology has been referred to aptly as the "Cinderella" technology (Cockburn, 1997) – it simply does not get the creative urges of the male technology designers going (though hopefully the smart home may change that). Homes are still maintained largely by women's unpaid work but women have long been disenfranchised from the development of the domestic technology they use, playing little or no part in the design process which generally views them as passive consumers. It would be an oversimplification to see the whole neglect of domestic technology in male versus female terms but there is an element of truth in that view which, for me, adds to the drama and interest of this field of study. In fact, of course, research into domestic technology provides a greater opportunity to affect people's lifestyle and quality of life than research into many other technologies. In the developed world we are nearly all stakeholders in domestic technology and, to most of us, the home is a very important place.

2.2 Past History of the Smart Home

2.2.1 20th Century Domestic Technology: Seedbed of the Smart Home

The 20th century saw a dramatic revolution in domestic technology, a revolution which culminated at the close of the century with the emergence of the previously unimaginable concept of the "smart home".

At the beginning of the 20th century most of the available domestic technology would have been easily recognised and used by people from a hundred years earlier. By the end of the 20th century, however, domestic technology had changed beyond recognition. The first major impetus for change was the introduction of electricity into homes in the first quarter of the century. This provided a new source of clean, convenient power for appliances and spurred the introduction of novel equipment for the home. The second major impetus was the introduction of information technology in the last quarter of the century. This opened up possibilities for exchanging information between people, appliances, systems and networks in and beyond the home, possibilities which are still being explored.

In the following brief historical review (with due acknowledgement to Gann et al., 1999), I have attempted to capture the escalating pace and dramatic nature of developments in domestic technology across the 20th century – changes which prepared the "seedbed" for the emergence of the smart home.

- *1915–20:* During the early part of the century the emerging middle-classes were experiencing a shortage of domestic servants (Forty, 1986). In line with this labour shortage, electrically powered machines such as vacuum cleaners, food processors, and sewing machines were introduced into the home for the first time. The advertising angle was that with the help of technology, one person alone (inevitably a woman) could manage all the household chores and still have time for leisure activities (Hardyment, 1988). Advertisements used phrases such as "spring cleaning with electricity", "no longer tied down by housework", and "automatically gives you time to do those things you want to do" (Gann et al., 1999). Mains electricity was not yet widespread, however, and so for most housewives such images remained a high-tech fantasy.
- *1920–40:* By 1940 the proportion of households in UK with mains electricity had risen to around 65 per cent. Many homes still only had electricity for lighting, however, while others had just one 5 amp socket. People sometimes declined to pay the additional cost to have a socket fitted as they were unable to envisage any use for one. Within the home the emphasis switched from production to consumption, with advertisers attempting to understand and appeal to the psychology of the housewife, "Mrs Consumer" (Frederick, 1929). It is an irony that the introduction of new domestic technology actually resulted in women spending more time on housework than ever before, because standards rose – washing machines led to clothes being washed more often (Cowan, 1983), and vacuum cleaners led to floors being cleaned more frequently (Hardyment, 1988).
- *1940–45:* During the Second World War, government propaganda portrayed women as technically competent and stressed the valuable role they could play in taking over traditionally male jobs in manufacturing and industry, freeing men to go into the armed forces. Women grew accustomed to working outside the home and (as illustrated by the well-known film *Rosie the Riveter*) many became technically proficient and enjoyed these new roles. Through working in these comparatively well-paid jobs women also came to value their labour in financial terms. These factors helped to pave the way for the uptake of domestic technology after the war.
- *1945–1959:* After the Second World War, in order to free jobs for men returning to civilian life, government propaganda switched to persuading women that their place now was back in the home. Advertisements of the time show women in the home, waving husbands and children off for the day, and then turning their attention to the daily

domestic fight with "germs rather than Germans", as it has been expressed. Home design started to reflect new ways of living alongside modern technology. For example new styles of kitchen emerged to accommodate the refrigerators, electric cookers, and washing machines that were starting to penetrate the domestic market. The concept of the "television lounge" was introduced, the sale of televisions having increased massively prior to the Coronation.

- *1960s/70s:* The 1950s ideal of the stay-at-home-housewife was overturned during the "swinging 60s". With the contraceptive pill and greater choice about whether and when to have children, more women started to go out to work. Numerous labour-saving devices became common in the home, including kettles, toasters, cookers, coffee and tea makers, food processors, hair dryers, electric razors, washing machines, sewing machines, vacuum cleaners, and irons. Other technology became commonplace in the home, for example central heating and thermostats.
- *1980s/90s:* By the beginning of the 1980s, almost three-quarters of households in England and Wales had colour television, and by the end of the 80s half also had video recorders (Bowden and Offer, 1994). Microwave ovens, freezers and tumble dryers also became increasingly common during this period which, in addition, saw the introduction of cordless and mobile phones for domestic use. A host of new home entertainment technologies became available and started to penetrate the domestic market – cable TV, DVD, the playstation, and the multimedia PC. The migration of the PC from workplace to home is particularly significant because it opened up the possibility of teleworking, blurring the distinction between home and work. Furthermore, by allowing access to the Internet, the PC connected the home to a host of new services such as banking, shopping and information, services which are still evolving.

From this brief review it is apparent that different forms of domestic technology have been adopted at different rates. As this may have implications for the uptake of smart home technology in the future, it is worth considering an important distinction known to have influenced diffusion rates in the past – the distinction between "time-saving" goods and "time-using" goods (Bowden and Offer, 1994). "Time-saving" goods are those which can potentially increase discretionary time by reducing the time needed to carry out a task, for example washing machines. "Time-using" goods are those which occupy discretionary time and improve its perceived quality, for example television. The diffusion of "time-saving" goods such as the vacuum cleaner, refrigerator and washing machine took several decades and was clearly related to household income. In contrast, radio, television and video (all "time-using" goods) reached equivalent levels of diffusion within a few years and showed much less relationship to household income.

A further point worth noting with regard to future smart home technologies is that "time-saving" and "time-using" goods may compete for the amount of time allocated to their use. The increasing amount of time people spent watching television was found by reducing time spent on housework, which had previously risen steadily for years as standards of hygiene became higher (Bowden and Offer, 1994). There may be a historical lesson to learn here.

In summary then, the 20th century saw an increasing pace of change in domestic technology, a readiness to adopt "time-using" technologies in particular and, by the end of the century, many homes linked via the PC to information and services beyond the home. This then was the seedbed in which the concept of the smart home developed.

2.2.2 Emergence of the "Smart Home" Concept

> Advanced home control systems go by several names, including smart home, home automation and integrated home systems. By any name, these systems conveniently control home electronics and appliances including audio/video, home office, telecommunications, intercom, security, lighting, HVAC, and lawn sprinklers. Control systems can also provide information – residents can find out how much electricity they've used on specific appliances or systems, and utilities can read meters remotely. The systems can be accessed from remote locations by phone or computer, allowing residents to turn on the heat, for example, on their way home from work (*Home Energy Magazine Online* May/June 1998).

Interest in "wiring" homes for increased functionality, as described above, dates back at least to the 1960s. At this time it was largely the province of home hobbyists, however, and most other people would have considered the description above to be science fiction.

By 1984, however, commercial interest in home automation had grown sufficiently for the National Association of Home Builders in the USA to form a special interest group called "Smart House" to push for the inclusion of the necessary technology into the design of new homes. Interest came principally from the fields of building, electronics, architecture, energy conservation, and telecommunications. Social scientists showed no real interest in the smart home concept.

Since the 1980s, manufacturers of consumer electronics and electrical equipment have been developing digital systems and components suitable for use in domestic buildings. Important developments have included the replacement of electromechanical switching with digital switching, and of traditional twisted pair and coaxial cables by optical fibres. Other enabling developments are new communication networks (e.g. ISDN, Internet) which allow two-way communication, and new end devices (e.g. web TV, video phones) (Barlow and Gann 1998).

During the 1990s the concept of the smart home entered popular culture for the first time. No longer the province solely of sci-fi buffs and

electronics hobbyists, smart home articles began to appear in life-style magazines such as *Boys' Life*, *Vanity Fair* and *House Beautiful.* The BBC recently ran a television documentary series entitled *DreamHouse*, which followed a family living in an experimental smart home for six weeks, giving viewers some idea of what it might be like to live in such a house. However, despite greater public awareness of the smart home concept, the extent to which people at the end of the 20th century were ready to welcome such technology into their own homes was uncertain. Popular media suggested some apprehension, particularly over issues of retaining control over the technology. Although this was not a new concern (see, for example, the film *Demon Seed* released in 1977), it remained a relevant theme as indicated by the film *Dream House* (1998) in which a malevolent smart home takes control over its occupants. The enduring unease about smart home technology has been neatly expressed by Gold (quoted by Gibbs, 2000), with his question "How smart does the bed in your house have to be before you are afraid to go to sleep at night?"

2.3 Present Status of the Smart Home

2.3.1 Consumer Take-up

Although the concept of the "smart house" was well established by the end of the 1990s, to date only a small number of expensive "smart homes" have been built and sold on the commercial market, in contrast to the rapid diffusion envisaged.

Gann et al. (1999) suggest a number of reasons for the slow uptake of smart home technology. The principal barriers to uptake they identify are that:

- The initial investment required from the consumer is high, restricting the market to the middle and upper income brackets, and potential buyers must first be convinced of the benefits they will derive.
- In Europe, dependence on old housing stock means manufacturers must find solutions for "retrofitting" existing housing, which is more expensive than networking a home at the time it is built (Barlow and Gann, 1998).
- Because of the lack of a common protocol, the smart homes industry in Europe has tended to focus on simple on-off switching systems (e.g. remote control switching) for single applications, which require no additional network installation.
- Suppliers have adopted a narrow "technology push" approach and paid too little attention to understanding the needs of users. Consumers want systems which will help them with managing everyday tasks, offer labour saving and task simplification, ease of operation, remote control and cost reduction (Meyer and Schulze, 1996). There is a gap

between consumer requirements and the products currently available. In particular, Meyer and Schulze suggest, suppliers need to win the acceptance of women, who still remain responsible for the bulk of domestic tasks.

- Suppliers have done little to evaluate the usability of their products. Barlow (1997) points out that this is not a simple task, however, because of the diversity of the user population, variation in the context of use, prior training necessary, and the challenge of investigating products not yet in existence.

The smart homes industry must satisfy a number of criteria before consumers will be motivated to buy its products, Barlow and Gann (1998) suggest. First, the industry must develop solutions which meet real user needs. Secondly, the solutions must operate at three levels – as *generic technologies,* providing basic, compatible "building blocks" for *context-specific systems* (which can be adapted to a wide variety of dwellings) and for *personalised systems* (tailored to the requirements of specific individuals and households). Thirdly, the solutions must offer functionality; ease of use; affordability; reliability and maintainability; flexibility, adaptability and upgradability; and replicability and ease of installation.

Interestingly, Gann et al. (1999) have pointed out a number of parallels between the present market for smart home systems and the early market for electrical appliances. Before demand for electrical appliances took off, a number of preconditions had to be met, including a cheap supply of electricity, cheap and reliable appliances, and the installation of a distribution and wiring system. Initially, most homes with electricity had only one 5 amp socket and people were not convinced of the value of having more – those homes which had more than two sockets were usually newly built houses in the upper price range (Forty, 1986). In a further parallel with smart homes, potential consumers showed apprehension about the risks of electricity; fears had to be allayed and acceptance gained by demonstrating its advantages.

2.3.2 Experimental Projects

Despite the fact that consumer uptake has disappointed the pundits, there are now quite a few demonstration smart homes in existence. Many of these are simply commercial showcases with no research agenda. However, there are also a number of commercial projects actively exploring the possibilities offered by technology associated with the smart home, for example utility companies seeking to control domestic energy consumption remotely. These investigations are interesting because they can be regarded as experiments in the "real world". Their drawback is that, where they are not academia-led and involve no social scientists, evaluation from a user-centred perspective may not be thorough. Furthermore, the findings may never enter the public domain.

For these reasons I will limit the review of experimental smart homes below to academic projects exploring the implications of the technology. This leaves a small field in which the following projects are most notable:

The Adaptive House (University of Colorado)

The aim of the Adaptive House experiment is to explore the concept of a home which programs itself, freeing the inhabitants from the need to carry out this task. The researchers point out that the software for an automated home must be programmed for a particular family and home, and updated in line with changes in their lifestyle. Given that many people find it difficult enough to program their video recorders, programming a smart home will be beyond their interest and capability, and hiring a professional to do the job would be costly and inconvenient.

The prototype system is installed in the home of one of the researchers and controls room temperature, water heat, ventilation and lighting. The home is equipped with sensors which monitor temperature, light levels, sound, the opening of windows and so on, as well as control devices for heating, lighting, fans, etc. The system monitors actions taken by the residents, such as turning on a certain configuration of lights, or turning up the thermostat, and looks for patterns in the environment which reliably predict these actions. A neural network learns these patterns and the system then performs the learned actions automatically. (See Mozer, 1998; and http://www.cs.colorado.edu/~mozer/house/)

ComHOME (The Interactive Institute, Sweden)

The ComHOME project is described by the researchers as "a full-scale model constructed of a number of scenario-like room set-ups" (Junestrand and Tollmar, 1999). The apartment is equipped with technologies such as sensors, voice control and voice-mediated communication. In this context researchers are investigating different spheres of home-based activity, for example communication, distance work and social activities, and exploring the impact which technology may have on them. (See Junestrand and Tollmar, 1999; also http://cid.nada.kth.se/pdf/cid_61.pdf).

House_n (Massachusetts Institute of Technology)

House_*n* is a collaborative, multi-disciplinary project led by the Department of Architecture. The overall aims include creating environments which suit people of all ages; creating customisable environments; developing algorithms to interpret sensor data to detect what people are doing; exploring the impact of technology on traditional learning environments; inventing interfaces and components that conserve resources; and exploring the impact of home delivery of products and services. There

are plans for a "living lab" house but in the meantime a large workshop room is being equipped as a prototype.

In the workshop it will be possible to display digital information on almost any surface, with other surfaces allowing easy user input via touch or special devices. A partition allows division of the floor space for living and sleeping, and provides a "medical nook" for the receipt and analysis of medical information. It is planned to explore a variety of home activities within this context, using an "active counter" that can be used for kitchen tasks, work tasks, and eating; an "active table" with digital surface that can be moved around within the environment; "video walls"; and floors that can have video projected onto them.

Researchers in the Media Lab at MIT are meanwhile exploring a vision of the kitchen of the future as a digitally connected, self-aware environment with memory of its actions. Concepts and prototypes include a variety of intelligent appliances as well as an intelligent work surface.

(For House_*n* see http://architecture.mit.edu/house_n/. For the Media Lab kitchen projects – e.g. Counter Intelligence, CounterActive and Kitchen Sync – see http://gn.www.media.mit.edu/pia/Research/index.html).

The Aware Home (Georgia Institute of Technology)

Most of the research by the Aware Home Research Initiative takes place in the Broadband Institute's Residential Lab – a suburban house equipped with high-speed internal and external connections, cameras and microphones, a house-wide wireless net allowing communication between cordless devices, and a radio-locating system for tracking tagged objects. At the time of writing the house had not been lived in. The Aware Home project is arguably the most well-advanced of the smart home research projects, involving researchers from the Broadband Institute, the Everyday Computing Lab, and the Future Computing Environments Group.

The over-arching theme which has been adopted is to use the technology to help maintain older people in their own homes for as long as possible. There are two focuses to the research: first, issues and possibilities concerned with making the house aware of the whereabouts and activities of its occupants at all times; and secondly, the implications of maintaining continuous connectivity to the electronic world, particularly as a means to "reunite the nuclear family of the 21st century". There are a wide variety of concepts and projects associated with the Aware Home and in different stages of development. Examples include: software which automatically constructs family albums from video pictures collected in the house; an intercom system which uses voice recognition to allow people to speak to one another by saying their name; software that telephones a person when their photograph is spoken to (after first checking they are awake); electronic tagging of easily mislaid items such as keys

and remote controls; reminders from the house about appointments, medication, etc., through subtle images and sounds; a "smart floor" system which identifies and tracks people by their footsteps; digital portraits incorporating iconic data representing the physical and social well-being of the Aware Home occupant; and a smart environment (the kitchen in particular is mentioned) that records contextual information alongside a record of everyday activities to help people resume interrupted activities. (See Kidd et al., 1999; Gibbs, 2000; http://www.cc.gatech.edu/fce/ahri/ and http://www.broadband.gatech.edu/facilities/resident/resident.htm).

Summary

It is important to emphasise that among the experimental smart homes reviewed above only the Adaptive Home is occupied. This obviously limits the scope of the conclusions which can be drawn from the current research – much of the complexity of the home environment only emerges in the interplay of activities and relationships between household residents.

2.3.3 Academic Literature

Although the concept of the smart home is now well established and a number of research projects are underway, as a field of academic research the smart home is still in its infancy. This is perhaps not surprising because, as we saw earlier, domestic technology in general has been neglected by academics, despite the enormous changes seen over the last century. Reasons for this neglect have been examined by an established body of feminist research (see, for example, Wajcman, 1991). Chief among the reasons identified are lack of financial motivation to increase productivity in domestic work; little involvement of the technology users in the design process; product designers' view of domestic technology as unexciting; and a continued focus on stand-alone appliances, often for marketing reasons.

In what will hopefully become a landmark paper, "The Importance of Homes in Technology Research", Hindus (1999) calls for more academic interest in domestic technology on the grounds that it is too economically important to ignore and that research has the potential to improve everyday life for millions of users. She points out that although information technology may have migrated from the workplace to the home, research specific to the home is still needed because workplace findings cannot easily be generalised to the home context. She points out three reasons for this. First, "*homes are not workplaces*" – unlike workplaces they are not designed to accommodate technology, they are not networked, nor do they have the benefit of professional planning, installation and maintenance of technology and infrastructure. Households also include elderly people, children, babies and pets, as well as working age adults. Secondly,

"*consumers are not knowledge workers*" – motivations, concerns, resources and decisions are different in the home. Whereas workplace purchasing decisions are determined by concern with productivity, householders are interested in aesthetics, fashion and self-image. Thirdly, "*families are not organisations*" – they are not structured in the way that corporate organisations are structured, and decision-making and value-setting are quite different.

A few papers on smart homes are now beginning to emerge, however, generally in association with one of the experimental projects outlined earlier. However, these usually approach smart homes from the technical point of view (e.g. Mozer, 1998). A paper which is unusual in approaching smart homes from the perspective of social science is that by Berg (1994). In her paper she argues that the smart home is a "gendered socio-technical construction" developed in line with the interests of its male designers. She focuses on housework which she describes as "mainly women's unpaid work, compris[ing] the most repetitious and time-consuming tasks in the household – cooking, washing, cleaning, tidying, mending". She interviewed the designers of a number of experimental smart homes, asking how they thought technology might help and found that the designers "manifest[ed] neither interest in nor knowledge of housework. The home is acknowledged as an important area of everyday life, yet the work that sustains it is rendered invisible." She observed that

> the men (and it is men) producing prototypes of the intelligent house of the future and designing its key technologies have failed to visualise in any detail the user/consumer of their innovation. In so far as they have one in mind, it is someone in their own image. They have ignored the fact that the home is a place of work (women's housework) and overlook women, whose domain they are in effect transforming, as a target consumer group (p. 176).

She concludes by criticising the smart home as a typical case of "technology push" rather than "consumer pull", motivated principally by what is technically possible rather than what is desirable.

Publications of relevance to smart homes, and to domestic technology generally, are currently dispersed across a wide range of academic disciplines. Those looking to the literature for guidance must pick their way across a fragmented area, gleaning what they can where they can. This is an unsatisfactory situation as the potential offered by smart home technology can only be realised through a proper understanding of the complex social context in which it will be used. Like Hindus (1999) and others, I hope technology in the home will receive more serious attention in the 21st century.

2.4 Future Prospects for the Smart Home

The commercial outlook for smart homes is still a matter for speculation. A recent report by Barlow and Venables (2001) discusses this topic

in some detail, and from a more technical standpoint than would be appropriate here. Barlow and Venables also consider the issue in Chapter 13 of this book. However, the present chapter would be incomplete without some discussion of the smart home's commercial future, and particularly the scope for social scientists to influence the course of developments. We shall therefore look briefly at likely changes to the markets, main players and barriers to take-up.

2.4.1 Markets

The distinction between the "niche market" and "generic market" looks set to continue.

The niche market caters for the needs of special groups such as elderly and disabled people. By definition, therefore, it is a smaller market but one with the potential to take off rapidly if the cost-saving benefits of providing health care and practical support through home technology can be established. Attempts to do this are underway (e.g. Tang et al., 2000).

The generic market refers to the population as a whole and is therefore potentially a huge market in comparison. However, as yet no smart home technology has had the "must have" quality which led to the rapid diffusion of television, for example, with take-up largely independent of household income. As we saw earlier, "time-using" technology has been adopted more swiftly than "time-saving" technology in the past. This suggests that inroads into the generic smart house market are most likely to be made by those technologies which add to the perceived quality of discretionary time.

Social scientists have an important role to play in developing a better understanding of the niche and generic markets for smart home technology. Through sensitive exploration of user needs and values, we can help to ensure that technological developments will offer genuine benefits, in contrast to the "push" technology which dominates the market at present.

2.4.2 Main Players

There is some indication that the main players in the commercial market for smart home technology are changing. Historically, it has been the electrical equipment suppliers – manufacturers of switches, sockets and distribution boards for example – who have played the leading role in developing the market. Now, however, there is established interest from consumer electronics manufacturers such as Nokia, Sony and National Panasonic, and ranges of so-called "smart" appliances are being marketed directly to the household consumer.

Service providers are also taking an increasing lead in exploring the market for smart home technology. A number of electricity companies in Europe and the States are looking into the provision of services which allow householders to control their heating, lighting, security equipment and other appliances remotely, by telephone or computer, with signals sent over the existing electrical wiring in their homes (Handford, 2002). These companies also have an interest in using the same technology for energy conservation and management of demand.

Again social scientists have an important role to play. The possibility exists for the service companies themselves to take some control over the technology within people's homes. Will this be acceptable to people? Will the gains in terms of savings outweigh the costs in terms of loss of privacy and autonomy? Commercial companies are already starting to explore whether consumers are prepared to have this kind of relationship.

2.4.3 Obstacles to Consumer Take-up

Earlier on we looked at a number of current obstacles to consumer take-up of smart home technology. We will review these now and consider whether they are likely to change in the near future:

- *Dependence on old housing stock* – there is no prospect that this will change in Europe and manufacturers must continue to look for ways of equipping houses retrospectively.
- *Lack of a common protocol* – this is becoming less of an obstacle than previously because there are now home boxes which can cope with different protocols.
- *High initial investment from the consumer* – cost remains relatively high and potential buyers are yet to be convinced of the benefits. A likely development is the evolution of a more modular system of smart home technology which people can acquire in stages.
- *Little usability evaluation by suppliers* – it remains the case that insufficient attention is paid to usability of smart home technology and it seems unlikely that attitudes are about to change.
- *"Technology push" by suppliers* – suppliers are still paying too little attention to the needs of users and trying to market products and services for which there is no demand.

Some of these obstacles look set to remain while others are beginning to shift. The skills of social scientists are particularly needed to overcome the last two obstacles on the list. First, whether or not social scientists choose to become involved in the evaluation of usability themselves, they should make their voices heard in pushing for it to happen – it is a vital part of the design process if the technology is to become

acceptable to the user. Secondly, social scientists are well placed to play a major part in developing a proper understanding of user needs and it is this which will overcome the present "push" of unwanted technology to uninterested consumers.

2.4.4 Academic Literature: What to Watch

So few papers on smart home technology are available in the academic literature, one can only speculate which fields to watch for future developments. The obvious usability issues in the design of appliances, interfaces and systems for the smart home invite the involvement of human factor researchers. However, the context of use which the home provides is complex, social and cultural, suggesting the need for sociologists, anthropologists, ethnographers and social psychologists to contribute too. A number of people have pointed to multidisciplinarity as the way forward for the design of information technologies in general. For example, Norman (1998) identified the following sets of skills as important within the ideal research and design team: anthropology, sociology, cognitive science, experimental psychology, human-computer interaction, architecture, industrial design and art.

For the time being we can expect to see publications of some relevance to the smart home scattered across the literature of a number of academic disciplines. However, there are signs of growing interest in the home as a context of use of interactive technology (e.g., O'Brien et al., 1996; Scholtz et al., 1996; Tollmar and Junestrand, 1998; and this volume) and it is realistic to hope that a dedicated journal may emerge as a focus for this interest within the next decade.

Until then, it is important not to overlook the World Wide Web as a means of keeping abreast of developments concerning the smart home – a means which offers the advantage of providing some information about commercial research ventures as well.

2.4.5 Foundations for Future Research: Relevant Categories and Constructs

A number of categories and constructs concerning smart homes, and domestic technology in general, have emerged from the literature so far. The distinctions concern both the technology and its users, and range in level of analysis from classifying homes as a whole to considering occupants' behaviour at a minute-by-minute level. These categories and concepts are valuable because they prompt one to shift perspective, so gaining different insights into homes and the use of technology within them. They may well provide the foundations for future research, so I

review them here under the following headings: smart homes, households, activities, and technologies.

Smart Homes

There are various ways of conceptualising the organisation of elements which make up a smart home. These range from focusing closely on the technology, to a looser biological metaphor for the management of information. Five examples from the literature are given below and later I propose a sixth.

- Dard (1996) focuses on the flow of information about activities and resources within the home. He classifies three information flows: *human flows* (e.g. supervising private and shared spaces); *energy flows* (e.g. monitoring energy consumption); and *information flows* (e.g. managing transmission and reception of messages).
- Barlow and Gann (1998) focus on the technology. They distinguish three levels of technology: *generic technologies* which provide compatible building blocks for more elaborate systems; *context-specific systems* adapted to a variety of dwellings; and *personalised systems* tailored to individual and household requirements. The authors also consider the level of automation which the technology permits, distinguishing between *fixed* applications, *programmable* applications, and *automated* applications.
- Jedamzik (2001) focuses on both the control and the information which is available to the user, and proposes that a smart house has four components: *user interface*; *technical field* (controlling light, heat, climate, water); *field of information* (where the house serves as a knowledge base, e.g. health, household accounting, scheduling); and *service field* (connecting to external services, e.g. financial, legal, commercial, educational).
- Gann et al. (1999) also focus on the functionality available to the user, distinguishing two forms of smart home. In the first, the emphasis is on *intelligent appliances* . This is the more traditional approach to home automation. The other involves *interactive computing within and beyond the home* which has come to the fore more recently.
- Another approach, focusing on control of the home environment, adopts the biological metaphor of the sympathetic and para-sympathetic nervous system in animals. This approach highlights that while certain aspects of home control require the user to exercise conscious thought and deliberate action, it may be desirable to monitor and control other aspects automatically (e.g. lighting and temperature), freeing the user for other tasks.

This variety of perspectives is useful for the different ways it gives us of looking at the smart home, its technology, and its users.

Households

As well as considering the smart home as a technological entity, it may be useful to categorise the residents along a number of dimensions, with the aim of understanding how various family set-ups or household types make different use of technology available for the home.

Meyer and Schulze (1996) have already made an attempt to do this for the purpose of predicting uptake of smart home technology. They suggested that uptake will depend in particular on size and composition of the household, the division of labour, and stage in the family lifecycle. They proposed that the households with the most to gain from adopting smart home systems are those in which both partners are working; highly mobile single-person households; and households with elderly or disabled people.

Of course there may be other dimensions of relevance, for example the geographical spread of family and friends, and whether the household is located in a rural, suburban or urban setting.

Activities

Analysing the activities which take place within a home may also be a productive means of considering the use of domestic technology. There are several possible frameworks to use in conducting such an analysis:

- *Spatial framework* – the home may be considered in terms of spatial "zones" within the home, which may or may not map onto particular rooms, but which are differentiated by the type of activity that is carried out in that location. For example, an ethnographic study by Mateas et al. (1996) showed space in the home is not of equal significance but shows behavioural clusters such as "Work space" and "Hang-out space" (often the kitchen, where families spend much of their time).
- *Temporal framework* – the activity within a home may also be considered from a time perspective. For example Mateas et al. (1996) looked at the way time was structured during the day and found the idea of large blocks of free time was a myth. Instead the day consisted of many small blocks of time, each constrained to varying degrees by a variety of factors. An alternative to the "time blocks" approach is to look for temporal patterns in activities, an approach already well established in the study of conversation where it is referred to as "sequential organisation", e.g. Sacks (1992).
- *Goal-oriented framework* – some activities may not be captured effectively within either a spatial or temporal framework. These are complex sequences of activity which are neither spatially nor temporally contiguous. An example is packing to go on holiday, which might involve planning what to take; washing and ironing clothes; ordering foreign currency; finding a suitcase; buying a novel for the journey,

etc. – tasks which may take place over several days and across several locations, not all of them within the home. A complex sequence of activity like this could be broken down into a series of shorter component activities which do fit into a spatial or temporal framework. However, it is important to maintain a sense of the overarching purpose of the component activities, so any framework should incorporate goal-orientation.

- *Communication framework* – finally it is worth mentioning that in deriving a model of household activity from their ethnographic data, Mateas et al. (1996) gave a special status to communicative activities and considered these separately. They found, for example, that most communicative activity took place between family members in the same location (supplemented by contact with remote family and friends), and was highly valued within the family system.

Technologies

In addition to investigating types of households and activities, it may be helpful to categorise the technology itself with a view to looking for patterns of behaviour and technology use which map onto these categories.

Let us consider the well-established distinction between "white goods" and "brown goods" as an example (e.g. Cockburn and Ormrod, 1993). These two categories of domestic technology are contrasted in Table 2.1, illustrating some of the patterns in behaviour and technology use that emerge from this approach.

Summary

The categories and constructs we have reviewed above (relating to types of home, household, activity and technology) are valuable for the different insights each provides. This is useful groundwork but we need much more research if we are to gain a proper understanding of the way technology is and might be used in the home.

2.4.6 When is a "Smart Home" not a Smart Home?

When is a "smart home" not a smart home? Or, put another way, when *is* a "smart home" a smart home? These questions may sound trite but I raise them with serious intent and suggest that attempting to answer them will pay dividends in terms of improving the clarity of thought and vision surrounding the smart home concept.

As yet there are no industry standards governing use of the term "smart home" and it is applied very loosely – to anything from a home with a closed-circuit television security system to a ground-breaking

Table 2.1. White goods and brown goods

	White goods	Brown goods
Example	Washing machine, cooker, vacuum cleaner, microwave	Hi-fi, TV, VCR, PC, camcorder, cable, games console, Internet
Function	Domestic work	Leisure
Effect on time use	Time-saving	Time-using
Underlying technology	Mechanical Electrical	Electronic Computer
Orientation	Self-contained	Bring "outside in"
Designers' attitude	"Pedestrian"	"Leading-edge"
Exposure in home	Behind the scenes	On show
Consumer uptake	Push	Pull
Gender stereotype	Female	Male
Workplace findings	Not relevant	Some limited relevance where technology "domesticated"

demonstration house. Back in 1989, Forester sounded this cautionary note: "a combination of home computers, consumer electrical goods, videotext services, and home security systems, even in a 'smart house', wired with heating and lighting sensors . . . hardly adds up to a revolution in ways of living". I agree; even now much of what is presented as radical and new proves to be unexciting on close scrutiny.

My personal view is that the smart home does hold the potential for a paradigmatic shift in the way people live with technology at home. As things stand, however, it is hard to analyse that potential. None of the distinctions between smart homes reviewed above seems to capture it, and the frequently exaggerated claims for so-called "smart homes" simply muddy the waters. Trying to analyse what is genuinely new and different in the opportunities offered by smart home technology would be a good starting point for more insightful design and further breakthroughs in the future. Technologists can only take things so far – social scientists have an important role to play too.

To start the ball rolling I present a classification between smart homes which is finer-grained than those reviewed above. My aim is to capture the scope for a paradigmatic shift in the way we live with domestic technology, although the reality is not yet with us. My starting point is the distinction drawn by Gann et al. (1999) between homes which simply contain smart appliances, and those which allow interactive computing in and beyond the home. Maintaining this focus on the functionality available to the user, I propose five hierarchical classes of smart home:

1. *Homes which contain intelligent objects* – homes contain single, standalone appliances and objects which function in an intelligent manner.

2. *Homes which contain intelligent, communicating objects* – homes contain appliances and objects which function intelligently in their own right and which also exchange information between one another to increase functionality.
3. *Connected homes* – homes have internal and external networks, allowing interactive and remote control of systems, as well as access to services and information, both from within and beyond the home.
4. *Learning homes* – patterns of activity in the homes are recorded and the accumulated data are used to anticipate users' needs and to control the technology accordingly. (See, for example, the Adaptive House which learns heating and lighting usage patterns, Mozer, 1998.)
5. *Attentive homes* – the activity and location of people and objects within the homes are constantly registered, and this information is used to control technology in anticipation of the occupants' needs. (See, for example, the Aware Home, Kidd et al., 1999.)

This classification of smart homes highlights different levels of communication of information within and beyond the home; distinguishes systems which can learn from those which cannot; and differentiates homes which maintain constant awareness of occupants and objects from those which do not. The classification is also hierarchical: from the users' perspective, each level promises some increase in functionality; from the technical perspective, each level generally depends on the systems for the previous level being in place.[1]

Within this classification of smart homes, the issue of control over appliances and systems in the home emerges as a strong underlying theme. Moving up the hierarchical classification, the control systems involved range from the simplest switching mechanisms (which respond only to direct on-off signals) to highly complex systems (capable of interpreting and responding to complex external stimuli such as people and their activities). The opportunity for occupants to delegate control to the technology increases correspondingly. It is this handing over of control that increases potential functionality in the smart home – the house itself can be empowered to perform a greater range of tasks relating to the occupants' comfort, convenience, security and entertainment.

If a paradigmatic shift in the way we live with domestic technology is going to occur, I suggest that it is the implementation of the fifth level of smart home, the Attentive Home, which will bring the shift about. The Attentive Home, with its potential for flexibility, proactivity and responsiveness to the user, appears to offer the possibility of a home environment qualitatively different to any we have seen before.

[1] The order of the last two categories is debatable; however, I argue that monitoring household activity and anticipating needs in real-time is a technically more demanding task than learning general patterns of use across time, and that meeting this challenge would offer greater functionality for the user.

2.5 Conclusion

To summarise, we looked at the emergence of the smart home concept towards the end of the 20th century, placing it in historical context by reviewing the rapid developments in domestic technology brought about first by electricity, and secondly by information technology.

We examined current obstacles to smart home technology diffusion, reviewed the principal academic projects investigating smart home issues, and considered what the available academic literature has to offer and reasons for its paucity.

We looked at possible future developments in terms of commercial players and markets, and likely academic stakeholders. We also considered categories and constructs relating to homes, households, activities and technology which may provide a useful foundation for future research in this area. Finally we considered the question "When is a 'smart home' not a smart home?", the reasons for asking this question, and an extended classification of smart homes which starts to address the issue.

Considering this and other issues related to technology in the home is undoubtedly made harder by the lack of a body of evidence on the design and use of technology in the home setting. It is necessary to draw on literature from across a range of disciplines to piece together a more complete picture, and many gaps remain. As Hindus (1999) pointed out, there is not yet a "critical mass" of interest in this area from academic researchers, or for that matter, industry. Hopefully her paper will mark a turning point and domestic technology will become established as a field of study in its own right.

In smart home research in the meantime, issues for investigation, methodologies, research paradigms, and frameworks for analysis must all be decided on with little guidance from the literature. Research must necessarily be pioneering in approach and holds the potential for considerable impact, not only shaping the course of future research, but determining the nature of the very homes we will live in. This is an interesting field of research for social scientists and an exciting time to become involved.

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