Who uses smart home technologies? Representations of users by the smart home industry

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Abstract

Through ambient intelligence and automated control systems, smart homes have been presented as a key means by which households can optimize their use of energy-consuming appliances in order to save energy and money.

Whilst the adoption of smart home technologies and their appropriation within everyday domestic lives is critical to the overall success of smart homes, to date visions of smart homes have been strongly driven by technology push and have not been based on a clear understanding of user-centric benefits, nor have users been engaged with in any clear or systematic way. There is thus an important need to understand how smart home users are being represented and understood within these technology-driven visions.

The paper presents the results of a content analysis of industry-produced smart home marketing materials that focussed on representations of the technology itself, its users, and of technology-user interactions. The content analysis was based on a coding template derived from a systematic review of the academic literature on smart homes and their users. Key findings from the content analysis include:

- differences in opinion around whether user practices are predominantly stable, routine and predictable or involve substantial variability and unpredictability;
- consensus around the modular development of smart homes within existing homes through additional and integrated (rather than replacement) technologies;
- a widespread lack of attention to within household interactions and the possibility of multiple users with divergent technology preferences;
- an implicit assumption that user decision-making is mainly rational, centred on information-processing;
- strong consensus on the design of user interfaces as mobile, familiar, intuitive, and visible devices;
- ambiguity regarding the potential tension between control and empowerment as opposed to automation.

The paper concludes that industry visions of smart homes are more convergent than academic research suggests, particularly around issues of user decisions and interaction, trust and confidentiality, and control and automation.

Introduction

Through the ongoing development of forms of ambient intelligence and automated control systems, 'smart homes' are increasingly becoming a reality. As Cook states, "the idea [of smart homes] is that computer software playing the role of an intelligent agent perceives the state of the physical environment and residents using sensors, reasons about this state using artificial intelligence techniques, and then takes actions to achieve specified goals, such as maximizing comfort of the residents, minimizing the consumption of resources, and maintaining the health and safety of the home and residents" (Cook 2012, 1579). The smart home concept involves three core characteristics: i) monitoring through sensor networks to gather information about the state of the domestic context and its residents,

ii) control mechanisms using communication between devices to enable automation and remote access, and iii) user interfaces – via in-home displays, personal computers, tablets and smart phones to enable users to set preferences/goals as well as to provide information and feedback to residents about these preferences/goals. As Cook (2012) makes clear, smart homes promise a wide range potential benefits including improved safety and security, leisure services, health care provision and home energy management. With respect to energy management specifically, which is the core focus of our research, smart homes herald a number of perceived benefits to both householders and utility companies. These include the provision of real-time data on energy use, automated home energy management systems, individualised customer management and improved load management (particularly as part of smart grids).

To date, however, visions of smart homes have been driven by a strong technology push from industry service providers (hereafter 'industry') and have not been based on any clear vision of user-centric benefits nor on any sustained or systematic engagement with potential users (Haines *et al* 2007). Given that the uptake and adoption of smart home technologies by these users is critical to the success or otherwise of smart home innovations (e.g. Haines *et al* 2007; Taylor *et al* 2007), there is thus an important need to develop a better understanding of who these users are, and how they might use smart home technologies in their everyday lives. To begin to address this challenge, this paper analyses existing representations of 'users' through a review of the academic literature on smart homes and through a content analysis of industry-produced smart home marketing materials.

At the time of writing, both the literature review and the content analysis are ongoing. As such, the analysis presented here should be seen as preliminary and as a work in progress. Nonetheless, even at the early stages of this work a number of key themes appear to be emerging that are worthy of further reflection and research. The next section outlines the initial results of a systematic literature review on smart homes and their users, focussing on the distinct representations provided by the engineering and technical sciences, the medical and health sciences and the social sciences. The section after that provides details of how this literature review was used to generate a content analysis coding template focussed on smart homes and their users and how this was applied to a sample of industry-produced smart home marketing materials. The section after that presents the initial and preliminary findings of the content analysis, before the last section concludes the paper by focussing on key points of consensus, dissensus and ambiguity within the marketing materials and between the marketing materials and academic literature.

Systematic Literature Review: Smart Homes and Users

The Scopus database was used to identify academic literature for inclusion in the systematic literature review. Based on the search string 'Smart AND Home AND User AND Technology' as well as synonyms and variants thereof, and limiting this to articles published since 1990, the initial search yielded 12,310 articles. By reviewing titles and abstracts to exclude irrelevant hits, this was eventually reduced to 150 articles that had a clear focus on smart home technologies and were concerned to some extent with smart home users. These 150 articles derived from a range of different academic disciplines, but can be broadly categorised into three areas: engineering and technical sciences, medical and health sciences, and social sciences. Across these disciplinary areas, however, the disciplinary origins of these articles was overwhelmingly based in the engineering and technical sciences (67 % of all articles) with medical and health sciences (20 %) and social sciences (13 %) much less common.

The dominant focus of most articles was on the technology development processes relevant for smart homes. With the exception of some of the social science articles, papers were rarely focussed explicitly on users and were rarely based on any formal engagement with users. Instead, in the majority of articles, users received only incidental treatment and this was often based seemingly on assumptions rather than on formal research or engagement. Nonetheless, across these three broad areas, users were represented in very distinct ways. These different disciplinary user-representations form the basis of the next three sub-sections.

SMART HOME USERS IN THE ENGINEERING AND TECHNICAL SCIENCES LITERATURE

The engineering and technical sciences literature was strongly focussed on smart home technologies themselves and their development and evolution. Here, Ricquebourg *et al* (2006) observe that the smart home concept has gradually evolved from being about controlling lighting and heating to being a more general concept covering almost all domestic electrical items. Furthermore, Ricquebourg *et al* observe that as the concept has extended, the focus of attention has shifted towards monitoring to generate 'contextual awareness' and, based on this, towards developing software languages to enable interoperability between and automation of appliances.

Within this broad focus, users are assumed to have a stable set of service demands and expectations based around comfort, security, safety and cost that are understood to be pursued through essentially regular and fixed patterns of behaviour (e.g. Das *et al* 2002). Users are understood to engage with smart home technologies by selecting various options and pre-sets that communicate their particular preferences. In addition to these settings, the smart home technology itself is then designed to gather 'contextual information' about both the domestic environment (e.g. thermal properties of the home, appliance characteristics) and/or its users (e.g. charting regular routines and patterns of action) through a range of sensors and monitors. With this information collected, the challenge then becomes using it to enable the technologies to automatically make decisions on behalf of users with the aim of optimisation against particular user preferences (e.g. comfort levels, energy efficiency, money saving etc.). As Park *et al* put it, smart homes are premised on "intelligent home appliances that can provide an awareness of users needs, providing them with a better home life experience" (Park *et al* 2003, 189).

Once their initial preferences have been selected users are essentially seen as passive agents within this literature, and decision-making is undertaken automatically by the smart home technology. For Das *et al* the aim is "to create a home that acts as a rational agent. The agent seeks to maximise inhabitant comfort and minimise operation cost" (Das *et al* 2002, 77). Within this body of literature, intelligence and smartness

is seen to reside firmly within the technology itself as it gathers information about user behaviour and uses this to reach rational and optimal decisions. Users are engaged in only two ways: through having their behavioural patterns automatically monitored through a network of sensors, or through a user interface which, as Park *et al* put it, must be user-friendly to avoid 'overpowering them with complex technologies' (Park *et al* 2003, 189).

In summary, this body of literature focuses very little on users. Where it does, they are seen as passive agents who, once they have entered their initial preferences through user-friendly interface, become the recipients of automated decisions undertaken by intelligent technologies to optimise against their preferences.

SMART HOME USERS IN THE MEDICAL AND HEALTH SCIENCES LITERATURE

Although not directly related to energy efficiency, it is instructive to consider understandings of smart home users in the medical/health sciences literature for the insights it provides about smart home users and how they may engage with emerging smart home technologies – whether these are designed to promote energy efficiency or not. Within this literature, there is a much stronger focus on users than in the engineering and technical science literature because, within this field, the principal benefit of smart home technology is seen as being able to assist users that suffer from particular medical conditions. Indeed, Demiris *et al* suggest that the whole concept of smart homes should be defined in this way: "A smart home is a residence equipped with technology that enhances the safety of patients at home and monitors their health conditions" (Demiris *et al* 2004, p88). Whilst there is much greater engagement with users in this literature, therefore, this engagement is with very particular groups of users, such as dementia sufferers (Orpwood *et al* 2005), those vulnerable to falls (Tabar *et al* 2006), or those who require physiological monitoring and potentially emergency help (Demiris *et al* 2004).

Often drawing on formal research on and engagement with these specific user groups, this literature is based centrally on the idea that these users exhibit specific characteristics, such as unpredictability (e.g. due to falls) forgetfulness, learning difficulties, anxiety, mistrust of new technologies etc. for which they require particular kinds of assistance. Smart home technology is therefore seen as 'assistive technology' (e.g. Orpwood *et al* 2005) that can enable these users to continue to live independently for longer (Demiris *et al* 2004, 2008).

This literature therefore emphasises the need to understand users' lives in considerable depth so as to design smart home technology that can best meet their needs. This includes designing technologies to be familiar and unobtrusive so as not to alarm users who may be wary of new gadgets, to be intuitive to use to help those with learning difficulties, and to be responsive and reliable so as not to act in unexpected ways even in unpredictable situations. For Orpwood *et al*, in a study based on designing smart homes to assist dementia sufferers, this may demand forms of co-design that involve working alongside carers to generate a detailed understanding of users needs: "It is … important to get an understanding of the reality within which the person with dementia is living, rather than assume that the designers view of reality is the correct one" (Orpwood *et al* 2005, 159).

Based on this detailed understanding of users the medical and health sciences literature, like the engineering and technical sciences literature, then focuses on the creation of smart home systems that automate decision-making processes in order to make (potentially life-saving) decisions on behalf of users. At the same time, given the detailed understanding of users that is built-in to the technology design process, there is a very strong recognition in this literature that this automation can be very difficult to achieve: "Any monitoring of human behaviour in order to make judgements is not going to be straightforward. The judgements made are always going to be probabilistic, and the designed has to incorporate means of dealing with errors" (Orpwood *et al* 2005, 162)

In summary, whilst users are therefore understood and researched in some detail within this literature, and whilst they have a strong influence on the design and technology development process, they are represented as essentially passive agents with decision-making capabilities delegated to smart home technologies.

SMART HOME USERS IN THE SOCIAL SCIENCE LITERATURE

The social science literature engages in much greater depth with users whilst giving less attention to smart home technologies. Although not universally the case, this literature appears to begin from the understanding that users lives are immensely complex and that this is poorly recognised in most existing smart home research. As Haines *et al* put it "visions of what [smart home] technology can do for people are rarely based on any comprehensive understanding of needs and in some cases are blatant technology push" (Haines *et al* 2007, 350).

Across this literature, the complexity of users everyday lives is recognised and represented along a number of dimensions. It is recognised that users have emotional as well as functional needs and that decision-making is informed by emotions as much as by processes of rational and logical thought (Haines *et al* 2007). Far from being predictable and routine, users everyday lives are seen as messy and regularly involving non-routine and unplanned actions that lead to the 'break down' of routines (Davidoff *et al* 2006). In addition, far from being fixed and stable, users lives (as well as their wants, needs and service expectations) are dynamic and change over time, particularly when they are disrupted through the introduction of new technologies (Edwards and Grinter 2001). Finally, this literature recognises that users do not live in a social vacuum, but co-exist and co-habit with others meaning that there may be multiple users with different and potentially conflicting preferences sharing the same domestic space at the same time (e.g. Friedewald *et al* 2005).

In identifying this complexity and unpredictability, the social sciences literature on smart homes calls into the question extent to which smart homes can be truly 'smart' as it suggests that technology may never be able adequately to capture and respond to the diversity, dynamism, reflexivity and emergence inherent to everyday social life. At the same time, this body of literature recognises that the technological visions underlying and pushing the development of smart homes are compelling and therefore that "smart home technology looks set to become a feature or people's lives whether it's wanted or not" (Haines *et al* 2007, 358).

As a result, perhaps the central focus of this literature relates to concern about the balance between user and technology ex-

pressed in terms of control versus domination. To counter the strong technological push detected within the smart homes field generally, a key aim of the social science literature has been to render users more active and give them more control over smart home technologies. Koskela and Väänänen-Vainio-Mattila express this most succinctly when they suggest that "computers should not make choices for users, but the other way around" (Koskela and Väänänen-Vainio-Mattila 2004, 240; see also Hamill 2006). To give control to users rather than to technologies, aspects of this body of literature also seek to engage users more firmly in the design of smart homes (e.g. Rohracher 2003). Through these means, this literature seeks to redefine the concept of 'smart', seeing it not as residing in technology itself, but rather as distributed between and an emergent property of how people's everyday lives and various technologies are intertwined (Taylor *et al* 2007). Accordingly, this literature calls for less attention to be paid to making novel 'smart technologies' and more to be paid to how these technologies are taken up within pre-existing and complex everyday lives.

In summary, the social science literature on smart homes and their users calls into question the very notion, as well as the location, of 'smartness'. Rather than developing smart technologies which automate decision-making for essentially passive users, and rather than developing technologies that automatically support users with very particular needs, as in the engineering sciences and medical sciences literatures respectively, the social science literature seeks to render users as active agents and to place them firmly in control of smart home technologies.

Methodology

DESIGNING THE CODING TEMPLATE

Drawing on the literature review, we designed a content analysis coding template that aimed to capture the principal issues identified. This was based around three core themes: i) the design and function of smart home technologies; ii) users of smart home technologies; and iii) user interaction with smart home technologies.

Each theme was comprised of multiple categories capturing more specific and discrete topics identified in the literature review. For example, the design and function of smart home technology theme included categories on the services provide by smart home technologies, the adaptability of smart home technologies to user practices, and on the conspicuousness of smart home technology components. The users of smart home technologies theme included categories on the types of user targeted, the implied nature of user-decision making and on the assumed benefits to users. Finally, the user interaction with smart home technologies theme included categories on the points of interaction between users and smart home technologies, user control of smart home technologies and on the forms and types of user interfaces.

Each category was in turn made up of a range of codes that sought to capture the various poles and potential spectrum of alternatives exhibited for each category. Although they go into considerable detail, we do not claim that these codes are exhaustive of all potential possibilities. Further, the codes were not necessarily mutually exclusive in order to allow for ambiguity and uncertainty within the marketing materials[1]. To further capture this uncertainty and ambiguity, we also collected qualitative notes on the marketing materials during the analysis.

PURPOSIVE SAMPLING OF SMART HOME MARKETING MATERIAL

The coding template was then applied to a sample of industry-produced smart home marketing materials. To identify companies actively targeting the emerging smart home market, we began by testing and refining the coding template on the marketing materials of the 10 corporate partners on the REFIT[2] project as part of which this research is being undertaken. Subsequently we compiled a list of all of the companies participating in the 2012 Smart Homes Europe conference hosted in Amsterdam from 9–11 October 2012 (see: http://smarthomes2012.com/ for further details). In total this generated a list of 268 different companies. A detailed web-search is still in the process of being conducted to identify marketing materials that are clearly focussed on smart home development. At the time of writing, this search has covered 77 different companies from this list and resulted (in addition to the REFIT project partners) in the identification of 31 different sets of smart home marketing materials to which the coding template has now been applied. These materials have taken various forms including website text, brochures and leaflets, as well as a number of short promotional videos.

Within this initial sample of 31 companies, three broad kinds of company have been identified each exhibiting a different level of proximity to smart home users. These are technology operators and installers who have direct interaction with users, technology manufacturers and designers who indirectly interact with users (e.g. through research and development) and companies offering supporting technologies, services and infrastructure who do not interact with users but rather with other businesses in the smart home industry.

With a sample of 31 sets of marketing materials analysed so far, the results presented in the following section should be seen as a work in progress. Any inferences drawn from the data should be recognised as preliminary and subject to change.

Results: Analysis of industry-produced smart home marketing materials

This section describes the preliminary results of the content analysis so far conducted. As there is insufficient space to detail all of the emerging findings, the section focuses specifically on those areas that highlight particular points of consensus or dissensus within the coded materials. Following the three core themes that comprised the coding template, the following three sub-sections present our emerging results relating to representations of smart home technologies, representations of smart home users, and representations of technology-user interactions.

1. There is not space to provide a comprehensive description of the coding template which eventually comprised 31 categories and over 125 separate codes, however, we would be happy to provide full details on request.

2. For further information on the REFIT project, visit: www.refitsmarthomes.org/.

REPRESENTATIONS OF SMART HOME TECHNOLOGIES

This theme emphasises the design, purpose, and functionality of the smart home technologies, encompassing both hardware (e.g., devices) and software (e.g., settings). The functionality of smart home technologies is inseparable from the domestic practices that the technologies respond to, facilitate, or shape. This functionality in turn makes clear the intended purpose of the smart home technologies from the users' perspective. This can be framed in terms of novel or improved services provided to households. Design considerations include the conspicuousness of the smart technologies within the home, both physically and functionally. Design, form, function and purpose are strongly intertwined.

Services provided

The purpose of smart home technologies from the users' perspective is described by the useful services they provide. These services can be categorised under broad headings, including energy management, security and safety, and entertainment and convenience. The attractiveness of these services to households will underwrite the successful uptake of smart home technologies.

As Figure 1 shows, the clearly dominant service provided by smart home technologies, within the marketing materials analysed, relates to energy management ('Energy' n=26). Only 5 of the 31 materials coded did not mention energy in some form. Security and safety related services include intruder detection, occupancy simulation (when household is away), automated lockdown, or open window/door alerts ('Security' n=16). Services related to entertainment and convenience range from easier access to media, control of home 'moods' (e.g., lighting and music), scheduling and so on ('Leisure' n=14). Other more niche services relate to health protection, fault detection, or water use monitoring ('Health' n=7, 'Other' n=6).

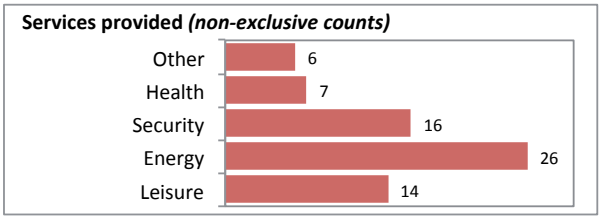

Figure 1. Services provided by smart homes.

Nature of relevant practices

Smart home technologies are of clearer relevance to certain domestic practices. Identifying the nature of these practices helps clarify the purpose and function of the technologies. Relevant practices may be understood as regular, patterned features of domestic life, or they may be seen as exceptional events or deviations from routine.

As Figure 2 shows, the predominant focus in the marketing materials was on enabling users to set 'scenes' or 'preferences' (e.g. for what lights or other electrical appliances should be on/off) that can then be activated when particular routines are performed – e.g. having breakfast, arriving home from work, going to bed etc. ('Routine' n=7). In many cases, however, the materials emphasised the capability of over-riding these pre-set preferences in the case of particular exceptions or deviations from routines. Such over-rides are often performed through smart phones/PCs and could therefore be enacted remotely ('Routine + Exception' n=12).

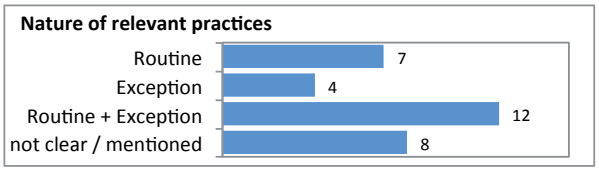

Figure 2. Nature of relevant practices.

Adaptability of technology to practices

The ability of smart home technologies to adapt or respond to variability and anomaly in domestic practices may vary. Technologies may allow only for pre-set patterns corresponding to typical or 'average' practices, or they may be able to adapt or learn about variability and exceptionality within users daily practices.

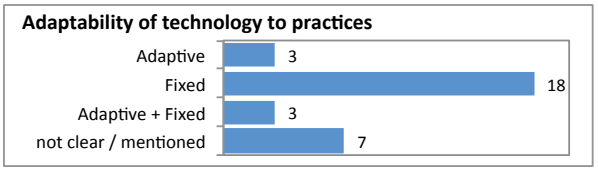

Figure 3. Adaptability of technology to user practices.

As Figure 3 illustrates, the marketing materials strongly emphasise a 'set and forget' approach based around pre-set or fixed scenes and preferences ('Fixed' n=18). As KNX put it in their marketing brochure: "Tell the system what you want to monitor and control, and the intelligent home system will do the rest, and will inform you automatically of the results". Across the marketing materials generally, smart homes are relativel rarely highlighted as able to 'adapt' to practices or 'learn' from or about user behaviour ('Adaptive' n=3). However, different kinds of 'adaptation' are mentioned in the materials. In some instances, for example, the technology is marketed as able to learn about the thermal properties of the home (e.g., in order to know exactly when the heating needs to be switched on to achieve a certain temperature at a given time), and in some instances the technologies may also automatically respond based on movement sensors. Further, in a few instances, they can 'mimic' user behaviour if, for security purposes, a user wants to give the impression of someone being at home. In general, however, the marketing materials describe smart home technology that is fixed in relation to user practices via pre-defined user scenes and preferences.

Type of home targeted

Smart home technologies may be designed for specific types of home in terms of occupancy (e.g., families with children), structure (e.g., detached houses), vintage (e.g., pre-war), and so on. However, the principal distinction within the marketing materials is between newly-built homes with smart home

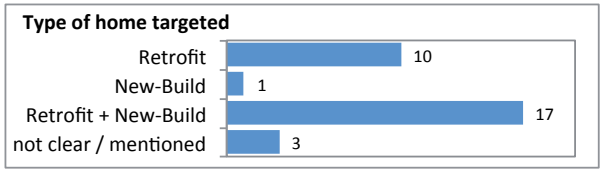

Figure 4. Type of home targeted.

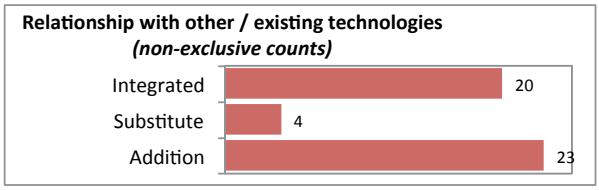

Figure 5. Relationship with existing technologies.

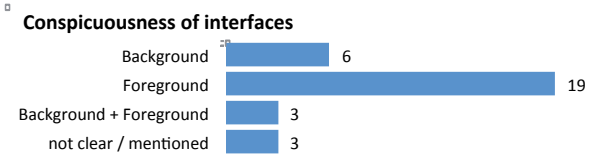

Figure 6. Conspicuousness of user interfaces.

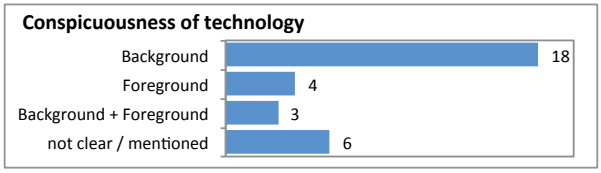

Figure 7. Conspicuousness of technology.

technologies integrated into the design, or existing homes into which smart home technologies would be retrofitted.

As Figure 4 shows, the emphasis in the marketing materials is strongly on the modular development of smart homes, either one room or one technology at a time. The materials suggest that the principal benefit of a modular approach is that it is cheaper than installing a whole system in one go meaning that smart homes may be more affordable to a wider audience. This inherently points to the emphasis on retrofitting smart home technologies into existing homes ('Retrofit' n=10 and 'Retrofit + New Build' n=17). Indeed, there is only one instance of the technology being seemingly designed solely for newly-built homes ('New-Build' n=1).

Interestingly, despite this focus on the incremental, modular development of smart homes, the marketing imagery included in the materials invariably shows new-looking houses that appear barely 'lived-in' or lack any distinguishable human trace. Across the materials analysed so far there is no literal 'vision' of a retrofitted smart home, even though the text within the materials suggests this is the dominant approach being adopted.

Relationship with existing technologies

There are a variety of different ways in which smart home technologies may relate to other technologies in terms of their design and physical presence. At the two extremes, they may be wholly new or additional technologies, or direct substitutes for existing technologies (e.g., a thermostat replaced by a 'smart' thermostat). Between these extremes is the possibility for smart functionality to be integrated into existing technologies.

As illustrated by Figure 5, the coded materials clearly show a strong emphasis on either new, additional smart technologies ('Additional' n=23) or on the integration of smart technologies or functionality within existing technologies ('Integrated' n=20). Very few materials suggest smart technologies substituting for existing, familiar technologies in the home ('Substitute' n=4). The new, additional technology generally takes the form of monitors and sensors (not currently part of a home's technological fabric), and also control hubs or interfaces and remote controls. Smart technologies integrated into existing technologies are often achieved through smart phones, PCs, smart plugs or even by embedding micro-chips in, for example, existing household appliances. To the extent substitute technologies are cited in the materials, these tend to relate to replacing existing appliances, e.g. replacing a 'dumb' TV with a Smart TV.

Conspicuousness of technology and interfaces

The technologies that make up smart homes can vary in their conspicuousness or visibility to the user. A distinction can be drawn between technological components that are in the background of domestic life, designed not to be seen, heard or interacted with, and those which are designed to be visible and foreground features and therefore invite user engagement.

As Figure 6 shows, the vast majority of interfaces are designed to be seen and interacted with by users ('Foreground' n=19). As Intel state, their smart home technology has "sleek user interfaces and compelling graphics. It can draw in consumers and appeal to them in the long-term." In contrast, a smaller number of interfaces are designed to blend into the background ('Background' n=6). For example, Siemens announce that their interface "harmoniously blends-in to any surroundings." This blending-in is often characteristic of devices that are wall-mounted. Conspicuousness *and* invisibility can be achieved simultaneously through multiple interfaces ('Background + Foreground' n=3). In some cases, there may be a dominant foreground interface, in the kitchen for example, in addition to a less conspicuous smart phone application that allows remote interaction.

By contrast to the user interfaces, and as Figure 7 shows, in the large majority of cases other elements of smart home technologies, (e.g., sensors, monitors, switches, smart plugs) are backgrounded ('Background' n=18). For example, IBM emphasise that all of its technology is "in the cloud", the Z-Wave Alliance emphasise "no new wires [and] no messy installation" and Siemens advertise that their smart fridges and washing machines are "whisper quiet". These devices are often white, designed to blend-in with their surroundings. In accompanying images, smart home technologies often have to be highlighted or specifically identified to make them visible.

Summary: the design and function of smart home technologies

In summary, regarding the design and function of smart home technologies, the marketing materials we have analysed so far illustrate a predominant focus on providing energy management services to users with some secondary focus on security, leisure and health services. In general, these services are to be delivered by allowing users to define a wide variety of pre-set 'scenes', for example to illustrate which lights, appliances and/or media services should be on or off when particular routines are being undertaken (e.g. getting up, getting home, having dinner etc.). The materials thus suggest that users have predominantly stable and regular routines, although they also often emphasise that users possess the capability to over-ride these pre-sets should their regular routines change for whatever reason. By attending predominantly to routines through pre-sets, the marketing materials suggest that smart home technologies will be largely 'fixed' in relation to user practices and will not automatically learn about (e.g. through contextual awareness) or adapt to them over time.

With regards to the design of smart home technologies, there is a fairly large amount of consensus within the materials that smart homes will be built-up gradually through modular development within existing homes. In so doing, they will generally serve to enhance or be integrated to existing domestic technologies and appliances rather than substituting for them. In turn, the new user interfaces introduced will be highly visible to users, offering new forms of information and control, whilst the rest of the smart home technology (sensors, monitors, control hubs etc.) will be largely invisible. Thus, aside from the introduction of new user-interfaces, the marketing materials we analysed imply that smart homes will look broadly similar to users existing homes.

REPRESENTATIONS OF SMART HOME USERS

This theme emphasises the characteristics and roles of smart home users. While an integral part of the smart home concept, users are not always depicted or represented explicitly in industry material. Typically, however, it is possible to infer some of the features of anticipated or targeted users, both from the text and from accompanying imagery. These range from household composition (or the age and gender of specific household members) to the ways important decisions about the home are made. Other features of targeted users are largely omitted. An example is the issue of how multiple member households all interact with smart home systems. The clarity of the 'value proposition' or perceived attractiveness of smart home technologies to users also varies.

Type of user targeted

Certain socio-demographic characteristics of smart home users may be explicitly identified in industry material. The most common characteristic is age and/or stage of the household lifecycle proxied by the presence of children, adults, elderly adults, or household members with specific health issues.

As Figure 8 demonstrates, the material reviewed strongly emphasises the appropriateness of smart home technologies for any profile of user ('All Purpose' n=28). Interestingly, however, associated imagery typically shows a young to middle-age white couple, often with a single young child. In a small number of cases, more specific user categories are either mentioned explicitly or implied. Children can be mentioned through references to games, through photos of toys, or through discussion of parental controls ('Children' n=1 + 'Parents' n=3). Elderly users can also be targeted ('Elderly' n=4). For example Accenture's 'vision of Intelligent Home Services' emphasises that elderly people need not learn to use new and potentially difficult technologies. The focus on elderly users is often linked to an emphasis on 'ease of use' to cope with users who are not familiar with new technologies. For example, Intel's 'Home Energy Dashboard' is marketed as so easy to use that "even my Dad – the technophobe – can use it!" Although in fewer cases, users with disabilities or health problems are also highlighted in relation to technologies that offer specific healthcare services ('Disabled' n=5).

Implied nature of user decisions

User interactions with smart home technologies require a certain amount of deliberation and decision making, even if this is limited to an initial, one-off process to establish default settings or pre-set user profiles. This decision-making may be purposive and broadly rational, or decisions may be characterised by more narrowly pragmatic concerns. Conversely, decisions may be emotional or affective responses to the technologies, or guided by the hedonic pursuit of domestic well-being.

Within the coded materials, and as Figure 9 shows clearly, decisions are depicted as overwhelmingly rational, designed to plan for and produce optimal outcomes based on available information and using pre-sets, timers, and so on ('Rational' n=29). Relevant outcomes include minimising energy use and/or maximising convenience. Decisions can also be characterised as emotional ('Emotional' n=10). For example, several materials emphasise using the technology to reflect the users mood or emotional state (e.g., 'adjust the lighting to suit your mood' – Philips) or to create particular emotional and aesthetic moods (e.g., a 'party atmosphere' – Philips). In materials targeted to disabled or elderly users, there may also be an emphasis on emotional well-being and social interaction (e.g., "technology that will discern and react to non-physical changes including emotional issues such as anxiety, depression, anger, loneliness and fear" – Accenture). Some materials emphasise specific pragmatic or practical decisions to save time, multi-task, organise chaotic lives, and so on ('Pragmatic' n=4).

Benefits to users

The value proposition, 'selling features', or perceived attractiveness of smart homes to their potential users should be expected to be an integral part of industry marketing material. This value proposition may focus on singular benefits, or on a host of either related or disparate benefits. These range from saving time, money or energy, to improving domestic productivity, fun, security or health.

As Figure 10 shows, the dominant value propositions mentioned in the materials reviewed focus on saving energy ('Save Energy' n=26) or saving money ('Save Money' n=16), with both clearly being inter-related. These benefits are achieved either through the efficient or optimal use of energy, or through the system being cheap to purchase and/or install. Next come the time saving benefits of smart homes ('Save Time' n=15)

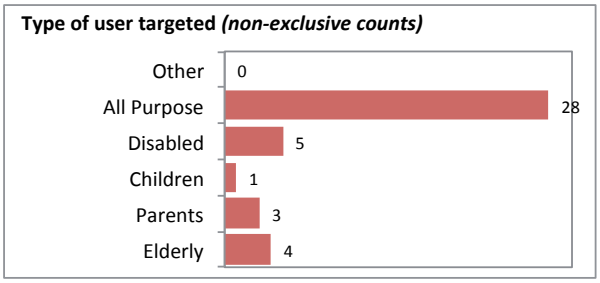

Figure 8. Type of user targeted.

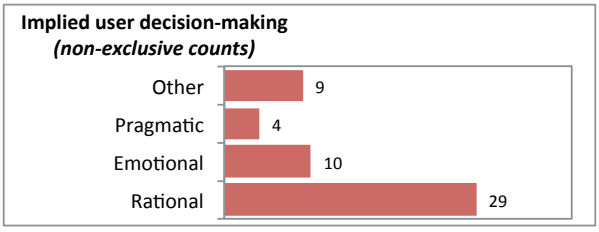

Figure 9. Implied user decision-making.

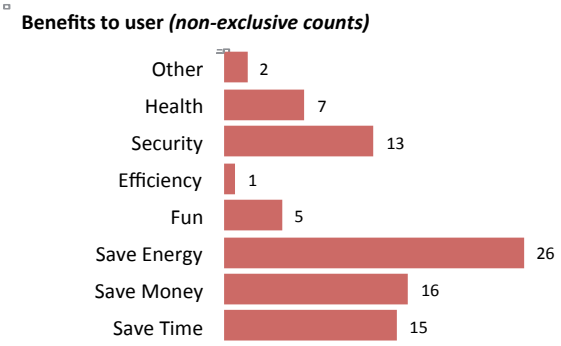

Figure 10. Benefits to user.

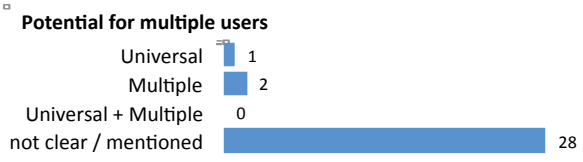

Figure 11. Potential for multiple users.

often through the control of multiple appliances 'at the touch of a button' (Z-Wave Alliance). Security is also regularly mentioned ('Security' n=13). Health benefits are too, although in more specific instances, for example, linked to elderly adults or household members with disabilities ('Health' n=7). A miscellany of other benefits appear in the materials occasionally, including the ability to control things remotely, the compatibility of the technologies with existing lifestyles, the lack of disruption and mess at installation, relative affordability, or ease of use.

Potential for multiple users

The majority of households have more than one member. In such households, who controls or interacts with smart home technologies? And what happens when their needs or preferences are not aligned? Smart home technologies may be designed to allow for the possibility for multiple users; or they may assume a single user.

As Figure 11 illustrates very clearly, despite its importance in the social science literature, the potential for multiple users to share access to and control of smart home technologies very rarely comes up in the material reviewed so far. In a few instances, the possibility for distinct 'individual profiles' is mentioned, however what happens when these potentially conflict is left unexplained ('Multiple' n=2). Conversely, the material rarely states definitively that the required user should input a singular 'universal' profile ('Universal' n=1).

Summary: users of smart home technologies

To summarise this theme, there is quite strong consensus that smart homes are designed for a general-purpose audience. In turn, it is assumed that this audience will make predominantly rational decisions based on forms of information processing (facilitated by smart home technologies) to achieve benefits such as saving energy, money or time. In some instances, the materials target specific user groups, such as elderly or disabled users, and, when so doing, they tend to emphasise precise and task-specific benefits that smart home technologies may offer. Less attention is given in the materials to how smart home technologies should cope with interactions and negotiations between users who share the same domestic space or, for example, to how different forms of decision-making (e.g. based on moods and emotions) may interact with rational information-processing.

REPRESENTATIONS OF TECHNOLOGY-USER INTERACTIONS

This theme emphasises the interaction between the design and functionality of smart home technologies on the one hand, and the characteristics and identities of prospective users on the other. A neat distinction between technology and user is artificial; this theme is concerned with issues that clearly involve both. These centre on how smart home technologies are used, and the extent to which this use is in accordance with, or is a reaction to, the form and purpose of the technologies' design. How technologies are used can be broadly examined at two levels: a more immediate, practical level concerned with questions such as how a user inputs settings; and a more conceptual, symbolic level concerned with questions such as how a user relates to or identifies with the technology. These considerations of technology use thus draw attention to the design of smart home technologies and particularly around the design of user interfaces, and to the broad conceptualisation of the relationship between users and smart home technologies, particularly relating to issues of control and automation.

User involvement in technology design

In general terms, and to try and improve technology uptake, technology developers are increasingly concerned with processes of co-design in which the user is an active partner in the resolution of design issues both before technologies are sold and installed, and during the *in situ* use of the technology. At

the two extremes, smart home technologies may be installed as fully pre-designed systems that users have to take (or leave), or they may allow or encourage users to tinker and adapt them to their own needs, both functional and aesthetic.

As Figure 12 makes very clear, industry consensus is very strong on this issue. None of the materials we analysed highlight a role for users in co-design, whether through user adaptation *in situ* or through user testing prior to installation and use. IBM, for example, emphasise that users need not become 'IT-managers'. In short, the marketing materials suggest that users should only become involved with smart home technologies once they are installed in their homes and that user involvement should then occur solely through user interfaces.

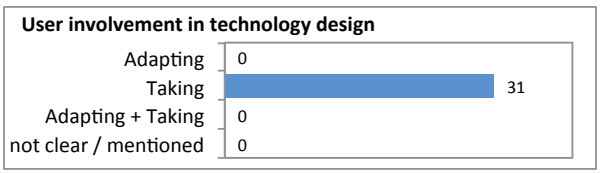

Figure 12. User involvement in technology design.

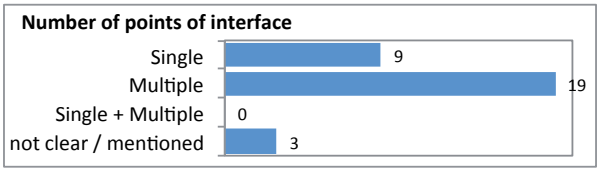

Figure 13. Number of points of interface.

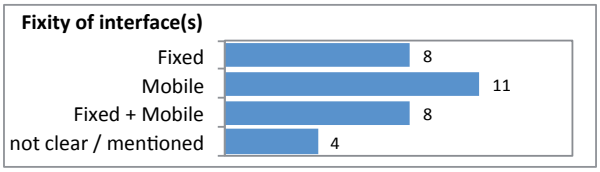

Figure 14. Fixity of interface(s).

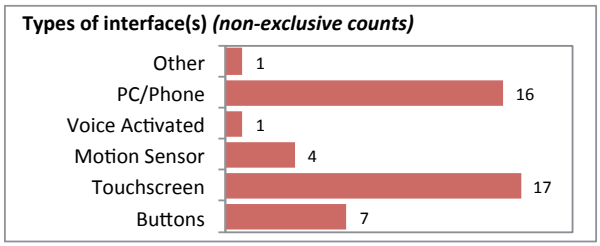

Figure 15. Types of interface(s).

User interfaces

The interfaces through which users interact with the hardware and software of a smart home may be characterised in many different ways. These include: whether there is just one central interface (e.g., a control hub) or whether there are multiple, dispersed interfaces (e.g., smart plugs); the extent to which interfaces can be moved, either within the home, or with the user (as the user moves in and out of the home); the precise form and design of the interfaces such as whether they are familiar or novel to the user and the manner in which users actually interact with them which can either emphasise physical interaction via hardware like buttons, knobs, switches, and motion sensors, or can reduce the importance of physicality through voice-activated commands, smart phone apps, touch screens, and so on.

As Figure 13, shows, the clear emphasis in the marketing materials is on multiple interfaces ('Multiple' n=19). This is often achieved through a more or less static interface (e.g., wall-mounted, or an energy monitor) alongside some form of remote access (e.g., smart phones or PCs). Cases in which single interfaces are mentioned ('Single' n=9) usually state a desire to rationalise systems, for example "a single control panel for all the engineering systems in the home" (ProNet).

With respect to the fixity of user interfaces (see Figure 14), the dominant category within the materials analysed is mobile an issue associated particularly with interfaces integrated into smart phones ('Mobile' n=11). For systems with multiple points of interface, a combination of both mobile and fixed interfaces is also quite common ('Fixed + Mobile' n=8). Solely fixed interfaces are also represented ('Fixed' n=8).

With regards to the design of user interfaces, as Figure 15 shows, a touchscreen design is the most common form of interface mentioned ('Touchscreen' n=17). Many of the phone/PC-integrated interfaces are also based around touchscreens ('PC/phone' n=16). By contrast, other types of interface, such as motion sensors and voice-activated systems are far less prevalent in the marketing materials ('Voice activate' n=1; 'Motion sensor' n=4). Where these less common interfaces are mentioned, this is sometimes to account for specific user needs. For elderly users, for example, Accenture emphasise that "rather than having to navigate with a keyboard or mouse, the elderly person can make contact just by standing in front of the picture, which becomes a dedicated communication channel". Perhaps the key point to emphasise here is that the types of interfaces chosen tend to be discussed in the materials as familiar to users, intuitive and easy to use. For example, as Intel suggests, smart home technologies should "provide ease of use, with interfaces similar to other popular consumer devices".

As Figures 13, 14 and 15 show, there is a degree of consensus within the marketing materials we analysed that smart home user interfaces should be multiple and mobile, and that to provide ease-of-use they should be designed around forms of control that are already familiar to users.

User control of technology

There are many different ways in which users may control smart home technologies. With regards to the general pattern of control (rather than more specific issues such as interface design, see section "User interfaces") this may range from fully user-controlled programming and settings on the one extreme, to fully automated user-bypassed background functioning on the other.

As Figure 16 shows, the marketing materials strongly emphasise user control ('User-Control' n=15), exemplified by "your home is as individual as you and the way you live

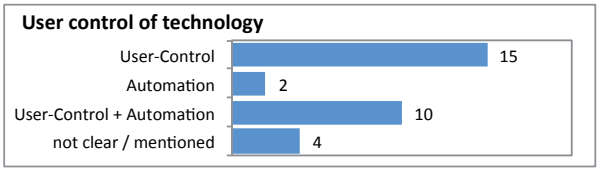

Figure 16. User control of technology.

should be determined by you, not the system" (Philips). Both user-control and automation are possible through systems in which the user sets some initial conditions after which point direct control is rare if not entirely absent ('User-Control + Automation' n=10). A common way in which this is achieved is through a 'set and forget' approach in which users are initially active in setting pre-sets/scenes/preferences, but can then allow the system automatically to look after itself. By contrast, the marketing materials very rarely emphasise fully automated systems ('Automation' n=2). For example, although T-Mobile talk of 'a house that thinks for itself', in general the marketing materials are very strong in their emphasis that the user is always in control.

Summary: user interaction with smart home technologies

In summary, there is strong consensus within the marketing materials we coded that users are not expected to get involved in the design, installation of construction of smart homes (as the social science literature requests). Rather, user interaction begins only once technologies are already installed and occurs exclusively through the user interfaces. As user interfaces thus become the sole conduit through which users engage with smart homes, it is perhaps unsurprising that there is consensus within the materials on the design of these interfaces. In short, they are presented as multiple (each smart home may have many user interfaces), mobile (accessible from anywhere anytime – usually through smart phone) and familiar, being easy-to-use and 'intuitive' through the use of familiar forms of control and information display.

Although user interaction with the technologies occurs through the user interfaces alone, the marketing materials we coded also demonstrate strong consensus, and place great emphasis on, the idea that users are always in control of smart home technologies. Despite the strong focus on automation in the engineering and technical sciences literatures, for example, the marketing materials rarely place emphasis on the automatic aspects of smart homes preferring instead to emphasise that users can 'set and forget' their smart home and that they always have the capability to over-ride their pre-sets should the need arise.

Discussion and conclusions

Throughout, we have been very clear that the analysis presented here is a work in progress and, therefore, that any inferences or conclusions drawn from it should be seen as provisional and preliminary. At the same time, a number of key issues have already emerged that we feel are worthy of further reflection and research. In this short concluding discussion we will highlight the key points of consensus, dissensus and ambiguity raised by the content analysis of industry-produced smart home marketing materials. To conclude, we will then briefly reflect on the (dis)connections between the marketing materials and the academic literature on smart homes.

Throughout the content analysis, several points of relative consensus emerged about smart home technologies, their users and about technology-user interactions. These were as follows:

- An appeal to a general rather than specific audience. Aside from a few niche applications e.g. for disabled or elderly users, the marketing materials tend to target a general purpose audience and do not differentiate to any great degree between potentially different categories of user.
- Although the materials do mention security, leisure and health applications of smart home technologies, the dominant focus was on home energy management.
- A dominant assumption that user decision making is predominantly rational in nature based on information processing to produce optimal outcomes against pre-defined aims and objectives.
- A dominant understanding of users everyday lives as made up of relatively stable routines for which smart home preferences and settings can be set in advance.
- Smart homes will be developed incrementally and in modular fashion. Users will make their homes 'smart' through the gradual accumulation of smart technologies.
- Smart home technologies will predominantly be integrated into existing domestic appliances or will be additional to them. They will very rarely substitute for, or replace existing appliances.
- Smart home interfaces will be multiple, mobile and familiar in their design.

In addition to these points of consensus, our analysis also identified a number of points of absence, dissensus or ambiguity in the marketing materials where visions and understandings of smart homes and their users were far less clear. These were as follows:

- Near total silence within the materials as to how smart homes will deal with issues of co-presence among users and how these may impact on access to and control of smart home technologies.
- Uncertainty with regards the overall visibility and conspicuousness of smart home technologies. Whilst some aspects of smart home technology (e.g. user interfaces) are represented as highly foregrounded and visible, others (e.g. control hubs, sensor networks etc.) are represented as backgrounded and invisible.
- Whilst a 'set and forget' approach is generally favoured which, it is claimed, puts users in control. The materials also strongly emphasise the potential for users to over-ride their settings. This suggests uncertainty around whether user

practices are stable, routine and predictable or involve variability and unpredictability.

- Some ambiguity in the materials regarding users being represented as, on the one hand, always 'in control' of and empowered by smart home technologies whilst, on the other hand, the technologies being capable of operating automatically and thereby allowing users to simply set them and forget them.

In general terms, therefore, the marketing materials converge quite strongly in their understandings of who smart home users are likely to be, how they make decisions, how they will interact with smart homes, and about how the design, installation and overall functionality of smart homes. The materials exhibit less convergence, however, around broader issues of how smart homes will be integrated into users everyday lives, e.g., whether the technologies will be visible, what balance to strike between control and automation, how the technologies will cope with multiple users, and about the relative stability of users everyday routines. It is here, on these broader and perhaps more conceptual issues that the academic literature on smart homes is worth revisiting.

Comparing our analysis of the marketing materials with understandings of users and smart homes in the academic literature reveals, again, several points of both convergence and divergence. Within the engineering and technical sciences literature, for example, a central concern is with automating smart homes based on gathering of contextual information and utilising ambient intelligence. By contrast, contemporary marketing materials downplay automation preferring instead to emphasise users as active and in control rather than passive. Ultimately, there appears to be less certainty within the marketing materials that users' routines are stable and predictable and, therefore, that smart home technologies will be capable of responding to them adequately. At the same time, there is strong convergence between the marketing materials and the engineering and technical sciences literature that users will interact with smart homes solely through user interfaces and will not be involved in the design, manufacture and installation of smart home technologies.

Within the medical and health sciences literature, the focus is on developing smart home technologies for specific user groups with specific needs e.g., for easy to use, intuitive and unobtrusive technologies. Here, because of this precise focus, there is very strong convergence between marketing materials and the academic literature about what users will want and how smart home technologies can help to achieve this.

Finally, the social science literature is perhaps most divergent from the marketing materials we analysed. Within this body of literature, the emphasis is placed on the complexity, messiness and many contingencies involved in users everyday lives. By contrast, these aspects of everyday life are almost entirely absent from the marketing materials where the emphasis is placed, instead, on the possibility of generating pre-sets for regular and stable routines. At the same time, the social science and marketing materials do converge around issues of control. Social science research on smart homes is very clear in its understanding that users will wish to retain control over smart home technologies and will be wary of systems that appear to think and act for themselves. By stressing that users always have ability to over-ride their pre-sets and to control smart homes remotely, the marketing materials appear to recognise this (even if only implicitly). A delicate balance is therefore already being negotiated between developing intelligent and automated technologies on the one hand, and reassuring users that they are always in control on the other. Getting this balance correct is of critical importance in both shaping the future development trajectory of smart home technologies and in determining whether or not users will actually want to purchase, install and ultimately use smart home technologies. It is here that further research on smart homes and their users, from whichever disciplinary perspective, has a vital contribution to make.

References

Cook, D.J. 2012. How Smart Is Your Home? Science, 335, pp 1579–1581.

Das, S.K., Cook, D.J., Battacharya, A., Heierman III, E.O., & Lin, T-Y. 2002. The role of prediction algorithms in the MavHome smart home architecture. IEEE Wireless Communications. December 2002, pp 77–84.

Davidoff, S, Lee, M.K., Yiu, C., Zimmerman, J., & Dey, A.K. 2006. Principles of Smart Home Control. Ubiquitous Computing (Ubicomp 2006) Lecture Notes in Computer Science Vol.4206, pp 19–34.

Demiris, G., Hensel, .K., Skubic, M., & Rantz, M. 2008. Senior residents' perceived need of and preferences for 'smart home' sensor technologies' International Journal of Technology Assessment in Health Care. 24(1), pp 120–124.

Demiris, G., Rantz, M.J., Aud, M.A., Marek, K.D., Tyrer, H.W., Skubic, M., & Hussam, A.A. 2004. Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study. Medical Informatics and the Internet in Medicine, 29(2), pp 87–94.

Edwards, W.K., & Grinter, R.E. 2001. At home with ubiquitous computing: seven challenges. (Ubicomp 2001) Lecture Notes in Computer Science 2201, pp 256–272.

Friedewald, M., Da Costa, O., Punie, Y., Alahuhta, P., & Heinonen, S. 2005. Perspectives of ambient intelligence in the home environment. Telematics and Informatics, 22, pp 221–238.

Haines, V., Mitchell, V., Cooper, C., & Maguire, M. 2007. Probing user values in the home environment within a technology driven Smart Home Project. Personal and Ubiquitous Computing 11, pp 349–359.

Hamill, L. 2006. Controlling Smart Devices in the Home. The Information Society. 22(4), pp 241–249.

Koskela, T., Väänänen-Vainio-Mattila, K. 2004. Evolution towards smart home environments: empirical evaluation of three user interfaces. Personal and Ubiquitous Computing, 8, pp 234–240.

Orpwood, R., Gibbs, C., Adlam, T., Faulkner, R., & Meegahawatte, D. 2005. The design of smart homes for people with dementia – user-interface aspects. Univ Access Inf Soc, 4, pp 156–164.

Park, S.H., Won, S.H., Lee, J.B., & Kim, S.W. 2003. Smart home - digitally engineered domestic life. Personal and ubiquitous computing. Vol.7, pp 189–196.

Ricquebourg, V., Menga, D., Durand, D., Marhic, B., & Laurent Delahoche, C. 2006. The Smart Home Concept: our immediate future. IEEE International conference on 'E-learning in Industrial Electronics' Dec 2006.

Rohracher, H. 2003 The Role of Users in the Social Shaping of Environmental Technologies. Innovation: The European Journal of Social Science Research, 16(2), pp 177–192.

Tabar, A.M., Keshavarz, A., & Aghajan, H. 2006. Smart Home Care Network using Sensor Fusion and Distributed Vision-based reasoning. Proceedings of the 4th ACM International Workshop on Video Surveillance and Sensor Networks (VSSN). Santa Barbara, California. October 2006, pp 145–154.

Taylor, A.S., Harper, R., Swan, L., Izadi, S., Sellen, A, & Perry, M. 2007. 'Homes that make us smart' Personal and Ubiquitous Computing, 11, pp 383–393.

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