

The Process of Designing Appropriate Smart Homes: Including the User in the Design

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Abstract. Information and Communication Technology (ICT) has recently been relocated from an external entity brought into the home, to an internal feature of the domestic environment extending the range of the home beyond the 'bricks and mortar'. Whilst other European countries such as Germany and Sweden have embraced the technology for its environmental and functional properties, the UK has been slow to adopt smart home technology except as a toy for the rich and famous. A number of research projects have considered the use of smart home technology within a range of social spheres, demonstrating the technology for a wide range of people with differing levels of disabilities and older people whilst developing a software suite that enables people to design smart homes that reflect people's needs. Smart homes can be useful; enhancing the quality of life for people whose life is limited by their domestic environment. This paper seeks to consider how smart home technology can be incorporated appropriately within the design process, exploring the difficulties in determining the most appropriate type of technology to meet the needs of people. The paper concludes with a set of guidelines to inform future designs within this area.

Keywords. Smart home technology, home automation, appropriate design, disability, older people.

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Introduction

Information and Communication Technology (ICT) has recently been relocated from an external entity brought into the home, to an internal feature of the domestic environment extending the range of the home beyond the ‘bricks and mortar’ (Dewsbury and Edge 2001). It is no longer solely confined to the conventional products such as lighting, washing machines or fridges but has begun to become situated within the fabric of the home through the introduction of and continual development of smart home technology. Smart homes are not a new phenomenon as the technology has existed for decades within the realm of the office block or shopping arcade, yet the technology has made slow impact within the UK domestic environment.

Whilst other European countries such as Germany and Sweden have embraced the technology for its environmental and functional properties, the UK has been slow to adopt smart home technology except as a toy for the rich and famous. Part of the reason for the lack of adoption is that the technology has not been entirely marketed the domestic sectors, as higher profits exist within the large commercial contracts. Correspondingly, the cost of the technology has tended to reflect its use in large-scale commercial projects, where profit levels can be much higher than in mass housing markets. Clear evidence suggests that smart home technology has a role within the household where its usage can extend beyond the ‘plaything of the rich’ into the area of enabling and empowering people how have disabilities or older people.

A number of research projects have considered the use of smart home technology within a range of social spheres. The ASTRID project clearly demonstrated that smart home systems could enable people with dementia to lead more empowered lives if used in the appropriate manner (Marshall 2000). The INCLUDE COST 219 project demonstrated the efficacy of smart homes for older people and people with disabilities.¹ The CUSTODIAN project demonstrated the technology for a wide range of people with differing levels of disabilities and older people whilst developing a software suite that enables people to design smart homes that reflect

¹ <http://www.stakes.fi/include>

people's needs.² Smart homes can be useful; enhancing the quality of life for people whose life is limited by their domestic environment. However, technology for technology's sake can be debilitating and disempowering. This paper seeks to consider how smart home technology can be incorporated appropriately within the design process. It also considers that the process of design of smart homes for people with disabilities requires the designer to undertake a number of tasks to remedy the mismatch between need and technology. The paper also explores the difficulties in determining the most appropriate type of technology to meet the needs of people. The paper concludes with a set of guidelines to inform future designs within this area.

Smart homes?

The domestic environment in the UK has undergone considerable modification in the last hundred years (Dewsbury and Edge 2001). At the start of the twentieth century, the home was the mainstay of the traditional family unit, acting as the locus of identity, position and external evaluation. Currently, more people live independently than they did in previous decades. Additionally, the UK, like much of the developed countries in the world, has seen an increase in life expectancy and better health care leading to a greater proportion of older people who are active members of the population. Older people are sometimes living in isolation, as most people no longer live in extended families. The UK has also seen the rise of the welfare state in which medical and social interventions by the state are recognised in order to maintain a minimum quality of life for people who are incapacitated physically or mentally (ibid). Consequently, health care providers are required to provide a high standard of care for older people in the community, and people with disabilities. The choice of how this care is provided and meets the needs of the users is of considerable importance to policy makers and the care providers.

Smart homes can be useful; enhancing the quality of life for people whose life is limited by their domestic environment. The design process is something that requires needs to be considered within a framework of barrier free design. However, technology for technology's

² <http://www.rgu.ac.uk/subj/search/research/SustainableHousing/Custodian/Home.html>

sake like inappropriate design can be debilitating and disempowering. This paper seeks to consider how the process of designing smart home technology can be undertaken appropriately. It also considers that the design of smart homes for people with disabilities requires the designer to undertake a number of key decisions to remedy the mismatch between need and technology.

The technologised home

A smart home is a harmonious home, a conglomeration of devices and capabilities working according to the Zen of Home Networking. (Briere and Hurley 1999)

Smart homes are just one example of a range of technologies that come under the heading of assistive or augmentative technologies. Smart home technology can be split into two main categories. *Active devices* such as control panels and switches, with which the home occupant will directly interact with and use. *Passive devices* such as sensors and receivers, over which the home occupant has no direct contact, function to enable and empower the living experience of the occupant. These devices and other technologies provide four main types of augmentative technology that can enhance independence, namely

1. Assistive Technologies, which are devices or systems allowing an individual to perform a task they would otherwise be unable to do or which increases the ease and safety with which the task can be performed;
2. Adaptive Technologies, through which any system or device can be modified according to the needs of an individual so that a task can be performed more easily and safely;
3. Inclusive Designs or 'Design For All' Technologies are developed on the principle that devices and systems can be used by as wide a range of the population as possible.
4. Medical Devices cover all products other than medicines, which are used in the healthcare environment for the diagnosis, prevention, monitoring, treatment or alleviation of illness or injury.³

³ Source: *Inclusion of Disabled and Elderly People in Telematics*: www.stakes.fi/include. Quoted in *The Parliamentary Office* (UK) 2000.

The manner in which devices interact and are interconnected provides the functionality that can enhance the quality of a person's life. The relationship between active and passive components enables a designer to build up a structured need derived system. Of considerable importance is the appropriate level at which to apply existing and new technologies to produce the defined system.

Intelligent health care systems in the home will utilise a myriad of technologies in their implementation. (Warren *et al.* 1999)

Smart technology is not the Holy Grail of the system of care for older people in the new millennium. But used sensitively alongside person centred care it can be a vital and valuable companion in a journey that will bring a happier, more fulfilling life to those of us about to join the silver generation. (Burley 1999)

Visions of what technology can do... are rarely based on any comprehensive understanding of needs and in some cases are blatant technology push. (Tweed and Quigley 2000)

As societal forces and technological push collide, the use of appropriate technology becomes increasingly more viable and cost effective. In determining the appropriateness of the technology it is easy to over compensate and become one sided within the debate.

The use of technology appears to present dramatic compromises in social activities, role definition, and identity. (Gitlin 1995)

Gitlin observes that technology becomes part of the self-concept. Just as technology can enable it can equally be the cause of disablement and low self concepts leading to greater needs being unmet. Sidsel Bjorneby (2000) notes that the reliability of the technology is essential.

Technology that does not function properly is extremely confusing and distressing to everybody, but exceptionally so for people with dementia and their carers. (Bjorneby 2000)

Reliability and robustness can have many facets, not just considering that a device acts in the appropriate manner, but considering the hidden effects related to the properties of the network.

With the increase of radio frequency devices and the advancement of technological protocols such as Bluetooth, and WAP integration, the networking properties become significant.

It is important to note that information surety (i.e., security, integrity, reliability, safety, and availability), plays an extremely important role in this architecture, since it is distributed by nature. (Warren *et al.* 1999)

Any technological system should be protected against potential hackers and people who might wish to compromise the integrity of the overall system, yet as the digital age progresses, technology increases apace whereas security systems to maintain reliability are often a secondary consideration. This could be problematic, should a house be configured to work using a standard protocol that falls into the hands of a person who wishes to burgle the home. If all that is required is that they emit the correct signals or Infrared sensor configurations for all the doors and security systems of the house to be deactivated there are clearly going to be a number of unhappy people and insurance companies will be considering whether to insure houses which have technology of this ilk within them.⁴

The design solution is not straightforward, often there is a balance to be struck where the designer has to weigh up the odds of the differing possibilities and discuss these with the relevant people before settling on a provisional design specification. To illustrate this, the graph (Figure 1) below is intended to demonstrate the cost / efficiency of two different smart home systems, the EIB (European Installation Bus) fieldbus and X10. Field bus systems such as EIB or Lon, it is contended have a high cost even for the most basic system whereas a basic X10 system can be installed very cheaply. However, fieldbus systems enable more devices to be integrated together to work with each other to create a rich functionality. Furthermore it is suggested that they are more reliable since they rely on more sophisticated bi-directional protocols.

Configuration of a field bus system is the method by which an installer couples a command initiator to one or more command receivers. For simple systems such as BatiBUS and X10 configuration is achieved by

⁴ See <http://www.smarththinking.ukideas.com/>

setting hardware thumb wheel switches to identical address numbers. For complex systems such as LonWorks and EIB configuration is achieved using a PC connected to the bus and a graphical interface through which devices are set to communicate with one another. One such interface allows a configurator to enter the electrical points on architectural drawings and using the mouse group and assign luminaries to switches. (Allen and Dillon 1997)

The sophisticated protocols used infield bus systems means the devices are more complex and expensive (Berlo 1999). If in addition, strict compliance standards are enforced by an agency such as EIBA (European Installation Bus Association) this will further add to the initial cost of the devices but means that installation and commissioning of the system is straightforward. To summarise, it is contended that fieldbus systems are more expensive but have greater serviceability and reliability and can be integrated to achieve a wider spectrum of configurations than the unidirectional X10 (see Berlo 199; Dewsbury *et al.* 2001).

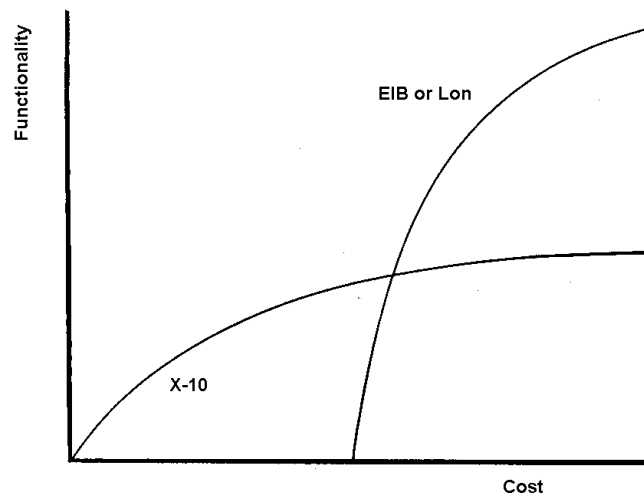


Figure 1. The efficacy of two types of smart home technologies

The above graph also demonstrates that at the bisection of the technologies, the designer is required to consider which is likely to be most appropriate for the greatest time. A number of factors will influence the decision. This does not mean that X10 systems are substandard, as there is clear evidence of their utility and appropriate applicability for a number of users.

Sacrificing high-end reliability for a cheaper but effective system might be the better course of action if the design enables the person to achieve the goals they desire.

Allen and Dillon (1997) compares a number of differing busline technologies and concludes that there are significant differences between EIB and X10 in terms of suitability for use with people with disabilities.

EIB bus is very suited to exploitation in the rehab field for the following reasons:-

- ❑ Availability of commercial products
- ❑ Technology is open to third parties for exploitation
- ❑ Development kits are available
- ❑ Established network of training centres
- ❑ Interface to M3S has been developed by FST in Switzerland

The one major drawback of the EIB bus is that the technology has so far only been applied in great measure to the twisted pair medium. This implies that if an existing home is to receive an EIB bus a certain amount of re-wiring will need to take place. However, the technology can be applied to other media and products do exist for Infrared and Power Line media. The EIBA is also carrying out development for the coaxial cable, optical fibre and radio frequency mediums...

X10 is suitable for simple environmental control applications in the rehabilitation field for the following reasons:-

- ❑ Availability of low cost commercial products
- ❑ Ease of configuration and installation

However it has the following major drawbacks:-

- ❑ Technology is propriety and unavailable to third parties
- ❑ Limited On/Off type protocol with no possibilities for improvement. (Allen and Dillon 1997)

The designer must decide on the appropriate reliability required from the smart home system that matches the needs, abilities and circumstances of the person. This is especially the case when financial constraints might make X10 the only viable system. Similarly, as Dewsbury (2001) and Taylor (2001) acknowledge, technological solutions can often be used in preference to conventional solutions, when the conventional would be more effective. It is all too easy to technologise solutions for the sake of using technology over conventional methods of design.

Today, we really do have the opportunity to tap into wires already in place in our homes for security and telecommunications purposes to enable constant monitoring, tracking, and transmitting of home care patient information to and from our homes. But we also really do have the opportunity to think carefully about what applications these collecting capabilities can have. (Kinsella 2001)

Appropriate design for smart homes

It is known that many products are not accessible to large sections of the population. Designers instinctively design for able-bodied users and are either unaware of the needs of users with different capabilities, or do not know how to accommodate their needs into the design cycle. (Keates *et al.* 2001)

Historically, home automation has targeted those areas which already have a strong element of control in them, such as the automatic control heating and lighting. As with mainstream computer applications, some activities are more amenable to automation than others. Increasingly, however, the lofty goals of home automation are being eclipsed by the more modest ambitions of creating the on-line home, in which information appliances are appearing on the market that still rely heavily on human action to control them - they just provide more information about their status and how they might be used. (Tweed and Quigley 2000)

Designing smart homes for people with disabilities or older people is not different from designing the home for people without any form of impairment on the one hand. On the other hand, there is a perceptual shift that is required in order to ensure needs are met from all stakeholders. There is a need to determine the needs of the occupant(s) and reflect these needs within the overall design. The designer is required to interface with other professionals and trades, such as architects and electrical contractors etc to determine that the needs of the person are reflected in all areas of the design process. The entire design process is one of iteration. The initial design may be modified considerably in the process. However, the earlier that changes are made to the design, the less these changes should cost. The design should be frozen before installation work commences (see Figure 2 overleaf).

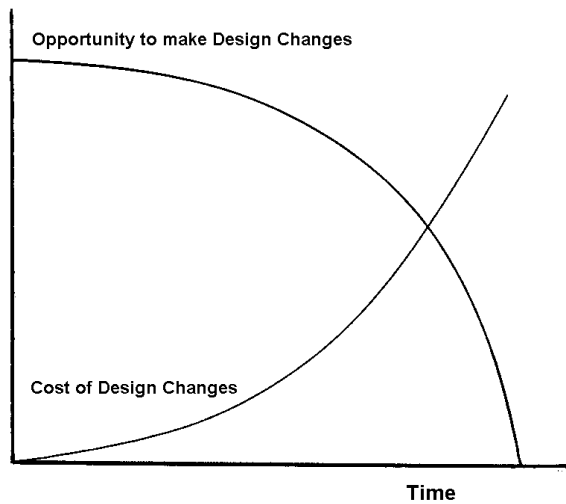


Figure 2: The opportunity to make changes in design vs. cost

It is fundamental that the designer is able to interpret qualitative information as well as qualitative data and reflect the determined needs into appropriate configurations and devices. Therefore, the designer of the smart home should be acquainted with the appropriate technology to match the clients disability/disabilities and possess knowledge of the disability, its aetiology, and its outcomes, as well as skills in inclusive design, basic electrical systems and the roles and nature of employment of the people they are likely to encounter in the design process.

It is useful to draw a number of case scenarios for different problems in order to determine how technology can benefit the person in different situations as well as ascertain where technology will be limited and ineffective. Often simple case scenarios can become more complex once the problem is considered properly. As an illustration, consider the case example of enabling a person with cognitive impairments to make a cup of tea. To design a system that enables the person to actively participate within the process and still enable the system to monitor and control for incorrect actions becomes extremely complex and almost impossible. How can it be determined that the person has put enough water in the kettle? How can it be ascertained that the person has not put the milk or sugar in the kettle or the teapot? The use of Case Scenarios allows the designer to consider every eventuality in order to

determine the most appropriate technological response (Taylor 2001). In the case of the cup of tea most likely technological response will be limited or no technology as the system would prove to be too complex to be rehabilitative or produce independence. Here the needs of stakeholders will inform the design process and determine the level of interaction that is required between the user and the technology.

The process of iteration is demonstrated by Clarkson and Keates (2001) who show the stages through which the designer needs to pass. The following adapted diagram attempts to illuminate this procedure further.

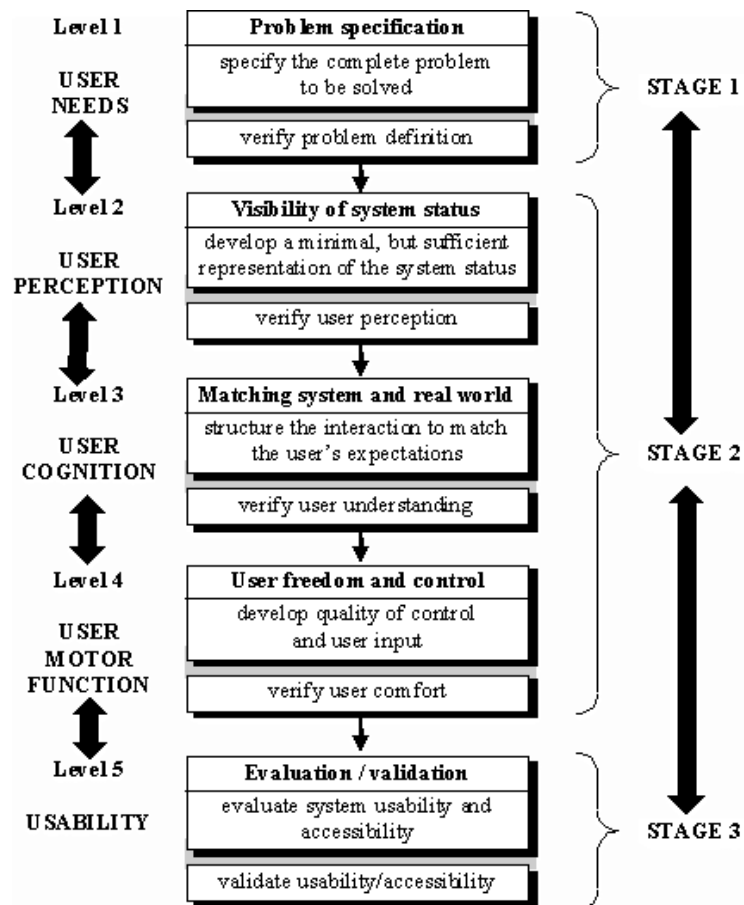


Figure 3. The methodological iteration of the design process (adapted from Clarkson and Keates 2001)

Evidently, designing appropriate smart home systems is complex and requires the designer to consider a number of qualitative and qualitative possibilities. The iterative process of design

and the Use Case Scenarios should enable a designer to work through most problems and eliminate others before they arise. Some problems cannot be followed through in this fashion and it is with this in mind that the following suggestions and considerations on the design process have been developed. These considerations will not always be applicable in every design, but as guidelines, they should prove to be a useful starting point.

Some Smart Home Design Considerations⁵

1. Appropriate Inclusive design criteria are required before technology is considered.
2. A long-term view of a person's condition should be undertaken in the assessment. If a person's condition is to degenerate slowly than the technology will be useful for longer.
3. Undertaking a full user needs assessment is critical to determine if technology is appropriate to meet the needs of the person.
4. Assessments and judgements should consider how the person is to interact with the technology from a psychological, emotional, physical and social perspective.
5. Assessments should not just consider what the technology can do for the person but what it can do for all stakeholders.
6. The implementation of the user needs assessment by professionals requires that appropriate technology be used in the correct manner, with the correct devices undertaking the correct functions when and if they are supposed to do so
7. The long-term efficacy of the technological design should reflect the needs of all stakeholders, the person(s) with disabilities, carers, and others.
8. Seeing technology as enabling and empowering is essential to the design process, whilst it is important to recognise that inappropriate design is disabling, debilitating and disempowering.
9. Specifying devices to meet the needs of stakeholders must also include specifying how the devices will interact with each other.

⁵ Adapted from Dewsbury (2001).

10. Technology requires regular maintenance and it is essential that the system is regularly checked to ensure it still functions correctly and meets the needs it was designed to meet.
11. Technology should not be considered predominantly in terms of being cost saving or a labour saving intervention; social exclusion or dependency should not result from the design.
12. Technology should not be seen as the panacea for all ills in the world.

These guidelines have been developed through designing smart homes to meet the needs of specific people. They demonstrate the conflicting requirements that the designer faces and illuminate the decision making process that produce effective and robust designs. There can never be a standardised smart house that will meet the needs of all, the universal design process can only make certain considerations come to the fore, but the process of designing smart homes for people with disabilities does require the designer to undertake a dialectical approach in which people with disabilities or older people are the norm and able bodied people are marginalised to the periphery.

Conclusions

Everything has become an operation, everything has to have a function and a use. (Fromm 1995)

When technology is incorporated within the home, the people who live with the technology on a day-to-day basis have tended to be overlooked (Tweed & Quigley 2000). Any attempt to produce definitive guidelines for the design of smart homes is likely to be deficient in some aspects. The process of design is complex and involves a number of extraneous factors that cannot be covered within the scope of a paper such as this. Instead, this paper has attempted to outline the main considerations and problems the designer has to take into account in the process of designing smart homes. The nature of the home is evolving and undergoing constant change in definition and as such is required to become responsive to the needs of people throughout their whole lifetime and in most circumstances.

The home as a fixed entity is unresponsive and unable to accommodate the new demands placed upon it. The social care/ housing sectors act as reactive bodies to situations such as this and provide mechanical aids to enable the individual to reside within the home, but here there are obvious limitations and constraints embedded in this process. The home, it is contended, should be considered as more than just a physical entity. Moreover, it is proposed that smart technology should be thought of as an essential part of the design process and not an after-thought. (Dewsbury and Edge 2001)

The home is the locus of esteem and self-concept that enables the isolated person to be less trapped and more independent. Any design process requires the designer to consider the home from a proactive and lifetime perspective. Ideally, smart homes should be a rehabilitative and therapeutic structure that augments the current care services and enables and empowers individuals who live within them.

The reality is that the home, even without intelligence is not so much bricks and mortar, but increasingly a series of personal care services. With the advent of the smart home the range of services that the home provides may be about to undergo a radical change. (Edge *et al.* 2000)

The investment in field bus systems is coming from the world's major electrical companies. If they are successful and succeed in penetrating the market, the result will have a direct positive effect on the lives of people who have disabilities. Rehabilitation companies will exploit the emerging technology and make available low cost environmental control systems. These systems will be truly integrated with a buildings electrical system and will provide much greater functionality than the "add-on" systems which are currently available. (Allen and Dillon 1997)

This paper has asserted some basic guidelines on the process of designing smart homes that meet the varied needs of people with disabilities or older people. Firstly, it has been put forward that it is necessary to consider all stakeholders within the design. Secondly, it is suggested that it is important to map the intended design on paper or computer and seek clarification for the User Case Studies from the stakeholders. Thirdly, it is contended that the designer must choose the best-fit technological solution to meet all stakeholder needs with an appropriate reliability and minimum cost. Fourthly, the paper has shown that the designer is required to be flexible and responsive to the changes that occur during the design process. The

design process is not stage processes but can be undertaken within the iterative process of appropriate design throughout the course of the overall design.⁶

⁶ For further information please visit the SMART Thinking website at: www.smarthinking.ukideas.com

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