Designing Dependable Digital Domestic Environments

Guy Dewsbury, Karen Clarke, John Hughes, Mark Rouncefield, and Ian Sommerville

Departments of Computing and Sociology, Lancaster University,

Lancaster, England, UK

Main Contact: Guy Dewsbury [***g.dewsbury@lancaster.ac.uk***](mailto:g.dewsbury@lancaster.ac.uk)

A paper prepared for HOIT 2003, The Networked Home of the Future Conference, 6-8 April 2003, Irvine, California

---

ABSTRACT: The aim of this paper is to examine the distinctions between home and organizational settings with particular reference to assistive technologies (AT) and outline a model for assessing dependability issues in these environments. For the purposes of this paper we consider assistive technologies to be software-controlled networks of assistive devices. Clearly a home is a personal concept and a social construction, which imbues different meanings to each individual through social actions and the assignment of meaning to those actions. It is therefore important that any method of investigation is sensitive to the changing meanings and nature of people's conceptions of home. This paper outlines the fundamental concepts used by the Lancaster team and proposes a method of conceptualizing dependability within a home context.

This paper suggests that the design of AT involves a number of factors that can be derived from a number of sources but essentially all design should place the user at the centre of the process. We aim to show that the home is different from the standard organization and as such deserves consideration in its own right and technology systems need to meet certain criteria within domestic situations that are not covered within traditional organizations. We extend this notion by considering the use of AT in terms of previous models of design and assessment. We also acknowledge that older people are not a homogenous category, and that designing for a group requires sensitivity to the individual needs of the person rather than the categorization of the person. We then consider the role of systems development and deployment from the perspective of designing AT systems for older people and this brings us to consider the problems that are associated with dependability. We contend that standard dependability analysis falls short of the full picture of analysis when applied to domestic settings.

---

1 Introduction

> *Many people blame the aging process for problems they encounter with daily activities, when instead quite often it is the design of the home itself that creates unnecessary disabilities.* (Bakker, R (1999)

Designing appropriate and acceptable technology for older people requires the acceptance that devices and systems are becoming more discrete, ubiquitous and is likely to be part of the fabric of the home of the future. Technology interventions are becoming central to maintaining older and disabled people within their homes whilst ensuring their quality of life, through the use of assistive technology. As the pace of technology increases, items are becoming more discrete and more functional allowing a greater variety of options to the user. Through the ubiquity of technology in the home, older people must rely on "experts" to determine which technological systems are most appropriate to meet their needs. Assistive technology (AT) originally consisted of one-off systems that performed single tasks, but has now been refined and reconfigured to include multi-tasking systems that comprise elements of the "*Smart*" or "*Intelligent*" houses. The term assistive technology is an umbrella technical term for any device or system that allows an individual to perform a task that they would otherwise be unable to do or increase the ease and safety with which the task can be performed. The purposes of such technology are to allow older people to maintain their maximum independence and autonomy.

Cook and Hussey (1995) suggest that strategies, practices and services don't have to be separated from technology. They define AT as a broad range of devices, technical aids, strategies, services, practices, with the main objective of improving the quality of life of the disabled and the elderly. In other words, AT is concerned with extending the quality of life for people with cognitive, physical, emotional or social disabilities, encompassing all ages. Where as Cowan and Turner Smith (1998) see AT as

> *As an umbrella term for any device or system that allows an individual to perform a task they would otherwise be unable to do or increases the ease and safety with which the task can be performed.*

Our concern in this paper is to determine where dependability issues become important in the design of networked AT systems within the home of older people. Although we accept these definitions, for our purposes we consider AT to represent networked software-derived systems of support that can be configured and linked to each other interfacing with the user. We consider that future homes will have more communicative technology that is will allow the user to control their environment wherever they are through radio frequency, or similar devices that will allow short-range communications within domestic spaces.

> *The person's sense of self and the role of AT in her or his life are the key considerations in the equation used to match an AT device with personal needs* (Gray et al 1988)

Dependability we consider to be central to deign of appropriate systems. Dependability models allow the designer to see how each system will interact with other systems and the potential conflicts and problems. Older and disabled people require that any technology used to support their lifestyle should be robust, reliable, and acceptable otherwise the technology is likely to be rejected and the potential benefits lost. The traditional model of dependability has been applied to software and safety critical systems and has recently been considered within organizations (Reason, 1997)). This paper attempts to further examine the ideas of dependability within a home context which we suggest is different from previous dependability work. As a term, dependability is connected with ensuring that critical systems do not fail though problems relating to software, hardware or human error. Within the home dependability is mediated through standardization and standards that ensure the minimum quality of a produced item. Dependability becomes central to design when the people for whom the design is being undertaken are disabled or older, as technology must be reliable and appropriate.

> ***Dependability** is defined as that property of a computer system such that reliance can justifiably be placed on the service it delivers. The service delivered by a system is its behavior as it is perceptible by its user(s); a user is another system (human or physical) which interacts with the former.* (Laprie 1995, 42)

2 Understanding Requirements for AT

Older people are a heterogeneous group as Risborough (1998) contends therefore their needs are different and dependent on the individual's issues that they face in their everyday life. The 'external networks' such as School, Shopping/Banking are not always undertaken solely by the occupant of the home. Often external activities are occasions that require the assistance of family of care workers for active participation. These 'simple' activities also need to be scheduled in to the week and be worked around as the rhythms of daily life vary.

Traditional designs of AT systems have tended to be undertaken by social care workers who initially define the problem and then pass the needs list to the AT 'expert' who is skilled in the design of the AT system. The latter designer tends to understand the hardware and software of systems from an engineering perspective, which is usually a result of their training, but they are not trained to understand the people for whom they are designing. Hence the designs tend to be static, unresponsive and inappropriate to meet the real needs of the client.

There are two forms of requirements that must be considered namely, requirements on the AT to be installed and requirements on the AT to be designed. Evidently, for designs to meet the needs of the user(s), the user(s) must be considered as the essential point from which the design is derived. Social care workers use a range of tools and tests to assist them in their assessments, yet people who actually know and understand the user have undertaken the best designs. There are a number of difficulties associated with obtaining good requirements for design, and one of the major factors is actually getting to meet the user in their own natural surroundings. Technology assessments for older people, as with disabled people, are usually based on task analysis as well as introspective assessments of needs. When the assessor believes that assistance is required there are two options open to them, either provide a person to assist in the task or provide some form of AT that will enable the person to undertake the task himself or herself. On rare occasions, the assessor will be required to provide a person and technology in order for the task to be undertaken properly. Technology assessments are made in the person's own home, usually, and the prescribed technology is usually selected from familiar equipment and devices.

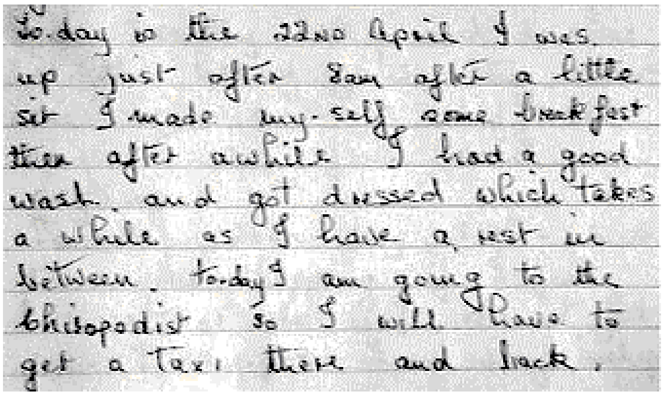
To-day is the 22nd April I was
up just after 8am after a little
sit I made my-self some breakfast
then after awhile I had a good
wash and got dressed which takes
a while as I have a rest in
between. to-day I am going to the
chiropodist so I will have to
get a taxi there and back.

Figure 1: An Illustration of daily rhythms from the field

2.1 Cultural Probes

> *Developing useful and applicable guidelines for systems design is a thorny issue, as it requires a balance to be struck between the need for the emergence of general principles and the importance of detailing everyday situated practice. If we are to provide more general design principles techniques need to be uncovered that allow the results of ethnographic studies to be married with more general statements of design.* (Hughes et al, 2001)

The main body of the research data is a result of cultural probes used in a number of UK locations. The settings for our project include homes of older people and residential hostels for former psychiatric patients. As a general, and important, principle any technology introduced into the settings should contribute to the development independent living skills and/or 'ageing in place' in some way and add to the person's quality of life. A technology that merely completes a task for residents does little in promoting their independence but merely shifts reliance onto the technology. Figure 2 illustrates a typical set of cultural probes used by the team. The probes include, a diary, tape recorder, instant camera, and disposable camera, drawing pad and crayons as well as cards addressed to the researchers. The Probes enable the participant to use a number of different media to illustrate their design requirements and every day activities. The probes also contain a small questionnaire that enables the researchers to gain answers to key questions. Cultural Probes (Gaver et al, 1999) were adapted to be used by older and disabled people which allow the person to undertake a number of tasks to describe and demonstrate important issues to the researchers. Cultural probes are one way in which we can attempt to meet what Edwards and Grinter (2001) regard as a major challenge for designers:

> *… to pay heed to the stable and compelling routines of the home, rather than external factors, including the abilities of the technology itself. These routines are subtle, complex, and ill-articulated, if they are articulated at all ... Only by grounding our designs in such realities of the home will we have a better chance to minimize, or at least predict, the effects of our technologies.*

Figure 2: The Cultural Probes Pack

Cultural Probes have gained some prominence as a means of inspiring interactive systems design in domestic settings (Lebbon et al, 2003). The approach is concerned to address what role technology might play in the home of the future and, specifically, how it can support the domestic values that motivate the adoption and use of technology. Gaver argues that domestic values are very different from those operating in the workplace and that as a consequence design requires different methods to understand the unique needs of residents situated in domestic settings.

2.2 Insights from the Probes

There is a danger that as technology moves from the office into our homes, it will bring along with it workplace values such as efficiency and productivity at the expense of other possibilities (Gaver, 2001). Probes are about understanding people in situ, uniquely not abstractly en masse, and the results of the probes exercises are highly individual, emotive, and idiosyncratic. As Gaver et al (2002) puts it, domestic probes

> *… offer fragmentary glimpses into the rich texture of people's home lives. They allow us to build semi-factual narratives, from which design proposals emerge like props for a film.*

What has emerged from our investigations of residential settings, even those as unconventional as community care settings, is that everyday life is made orderly by members through the accomplishment of routine activities that give reflexively rhythm to their lives. From our perspective design is concerned with interventions into these orderly, rhythmic settings to support the timeliness, reliability, dependability, safety or security of everyday activities. Explicitly orienting to and paying careful attention to the orderliness of everyday life in residential settings provides one way in which a philosophy of care may be integrated into the design of assistive technologies and ubiquitous computing more generally, in much the same way as other philosophies such as the scientific and the modern for example, have already been incorporated into design.

Through the use of cultural probes we have been able to illuminate the rhythms of daily life of the participant as well as the possible problems and difficulties that they are faced with in relation to technology in their homes. To illustrate some of these elements, Figures 3-5 illustrate certain features of difficulty including a staircase that on participant uses daily to carry his wife up and down stairs (she has dementia). This staircase has been fitted with an extra handrail, but this is of little use if both hands are used to support the other person being carried. Similarly, Figure 4 demonstrates a persons attempt to ensure that their demented partner does not turn the gas on whilst they are not in the room, so they have put a shut off valve in the bottom of a low cupboard, but it is extremely difficult to reach and therefore might not be too effective.

Figure 3 and 4: House Adaptations

Finally Figure 5 illustrates the daily rhythms of a respondent who notes in her diary that her life is punctuated by periods of rest. Any activity must be based around these periods of rest and other times when she has the strength to continue with what is required. These illustrations have considerable implications for the designer of appropriate assistive technology as they illustrate the difficulties that people have in their lives as well as the routines and activity patterns which are mediated by housing structures, domestic appliance usage and physical health conditions of the users (Environment, User and System).

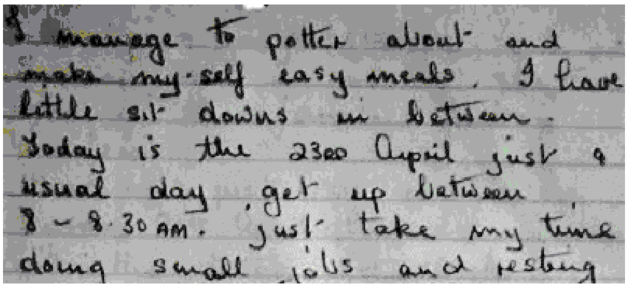
I manage to potter about and make my self easy meals. I have little sit downs in between. Today is the 23rd April just a usual day, get up between 8 - 8.30 AM. just take my time doing small jobs and resting

Figure 5: Time appears to slow down

The Cultural probes have allowed the issues that concern the participants to come to the fore, as well as allowing the researchers to glimpse instances, rhythms and situated actions within their daily routines (Crabtree et al, 2002). These glimpses have informed the model described in this paper and allowed us to question the nature of dependability in relation to home setting. The home presents a range of potential exploratory areas. These can be themed together to produce what Crabtree and Rodden (2002) term '*chains of actions'*, and '*activity centres'*. There are also suggest that there are '*chains as objects to be designed for*', '*chains as application resources to be designed with*', '*Activity centres as objects to be designed for*', and '*Activity centres as application resources to be designed with*', which can be used to articulate the organisation of coordination, how routines and practices are interpreted by individuals within their living spaces. The patterns of activity within a domestic environment are constantly changing as needs of individuals change. It is therefore important to recognise that these patterns and rhythms of daily activity are central to design and the research agenda.

3 System Dependability

> *Print, radio, telephone services, and television were previous technologies that brought the outside world into the household… Even though much research on diffusion of innovations and consumer behavior has examined how households adopt new technology, much less has examined how they domesticate it, incorporating it into the ebb and flow of their daily lives.* (Kiesler, et al, 2000)

Technology usage within organizations and the home rely on systems (Venkatesh & Mazumdar, 1999; Venkatesh et al, 2001a; Venkatesh et al, 2001b). Organizations impose 'acceptable practices' upon the individual and are therefore more standardized and controlling of technology's usage. Products and people are covered by safety plans and work practices that are designed to reduce accidents and improve productivity whereas households are governed by legislation and personal constraints.

Within the home people can choose whether or not to use technology, how to use it and where they wish to use it, whereas in organizations technology is controlled and these choices are more limited. The table below (Table 1) outlines some of the differences between technology use in organizations and the home environments; it is not to be applicable to *all* organizations or *all* homes, but a rough guide.

Usage: how do people use technology in the home or in an organization
Standardization: How standardized technology is in these two areas
Processes: What processes are involved in the use of the technology
Operators: What skills and training are the operators of technology required to possess
Operations: What operations are involved in the use of the technology in these two areas
Actions and activity: How is the technology used in these areas, what activities and actions are performed as a result of the technology
Safety: What safety measures are used to ensure the technology is used appropriately

The core features of dependability models tend to assume that dependability is a technical attribute that the dependable features are within the software itself. Figure 6 demonstrates the five main attributes of traditional dependability adapted from the work of Laprie.

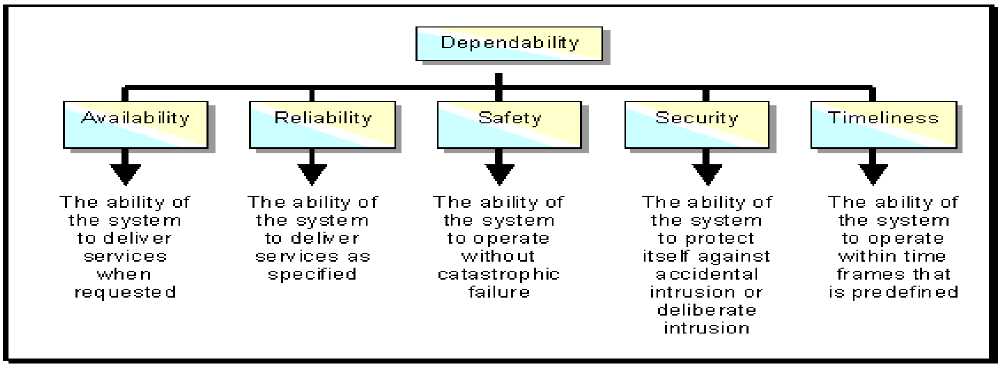

Figure 6: Sommerville's Software Development Dependability Model Adapted from Sommerville (2000)

Although there are differences in dependability definitions, it tends to consider the system as a digital system and humans as an afterthought. Within the context of home systems the user(s) of the system are central to the design and central to the consideration of dependability. The dependability of home systems is played out daily through the routines and situated actions of the people in the home. Therefore, we contend that the requirements of dependability in the home setting are derived from different roots from traditional dependability models of software design, as the emphasis should be derived from a person centred rather than a technology centred perspective.

Dependability in the home differs from organizational systems in many ways. Systems (activities and processes) are consistent in organizational systems but not in the home systems where greater flexibility exists. Activities tend to be set in regular procedures, such that work begins at prescribed times, lunch hours exist between certain hours, and work finishes between certain times. The organizational system has regular processes through which activities must follow. There are also consistent security and safety policies and programs, which bear little resemblance to those activities, and process that are undertaken in the home. Hence the most significant difference between the organizational system and the home system is that processes and timing standardized functions are dissimilar. Home routines are often unplanned and lacking rigid structure, unless a person is older or disabled in which case foreseen events in the day may be planned and situated into a daily/weekly/monthly schedule.

CRITERIA	HOME CONTEXT	ORGANISATIONAL CONTEXT
USAGE	AD HOC AND UNCONTROLLED	SYSTEMATICALLY CONTROLLED
STANDARDISATION	LEGISLATIVE AND PRODUCT SPECIFIC	STANDARDISED WITH ORGANISATIONAL ENVIRONMENT
PROCESSES	UNCONTROLLED AND AD HOC	CONTROLLED AND SYSTEMATISED
OPERATORS	UNTRAINED AND UNSKILLED	TRAINING AVAILABLE
OPERATIONS	UNRESTRICTED AND AD HOC	RESTRICTED AND SYSTEMATISED
ACTIONS AND ACTIVITY	UNDEFINED AND UNCONTROLLED	PREDEFINED AND LIMITED
SAFETY	SUGGESTED BUT DIFFICULT TO ENFORCE	CONTROLLED THROUGH SYSTEMS

Table 1: Home and Organizational Differences

Table 1 illustrates that the home does not provide the safeguards and assurance that many Organizational environments are required to do. Technology in the home and organizations must pass rigorous standards laid down by law (ISO etc) that ensure the integrity of the product for standard use in the home or workplace, but few products dictate how they should be used in the domestic arena. The home user must rely on their own judgment and skill to determine the most appropriate manner in which to use the technology. The home resident controls the use of any product in the home whereas safety standards and company policies suggest selective and appropriate usage in organizations. The organization attempts through health and safety standards and procedures to ensure that products are operated correctly within specific safety margins that legally safeguards them, whereas the home has no such restrictions.

The use of devices in the home also illuminates other distinctions between organizational systems and home systems. When a device fails in an organizational system it can be very costly as the organization could lose a considerable level of productivity as a consequence. In the home, by contrast, if a device fails it is usually worked around. If the washing machine is not working, then clothes are hand washed or sent to the launderette. Therefore, the failure cost model is different. Sometimes in the home support systems, devices are of considerable importance and their failure can be critical to the lives of the occupants, such as health monitoring devices or fall detectors. This critical incident is unlikely in most organizational systems where devices are maintained regularly and company liability is assumed.

The reliability of systems extends beyond the hardware and software into the social and lived experience of the home dweller. As Lupton and Seymour (2000) suggest, technology becomes part of the self-concept for the user and therefore it is essential that reliability means that the system does what it is expected to do all the time, 24/7. People depend on technology within their home and its reliability is central to ensuring a dependable home system.

The notion of acceptability was initially conveyed through advocates of Universal Design of whom Jim Sandhu was critical. Sandhu considers that the basic notion of UD requires the architect and designer to consider a number of properties and attributes. Sandhu (2002) uses an ISO standard definition to extrapolate a diagrammatic representation concerning system acceptability within a Universal Design context:

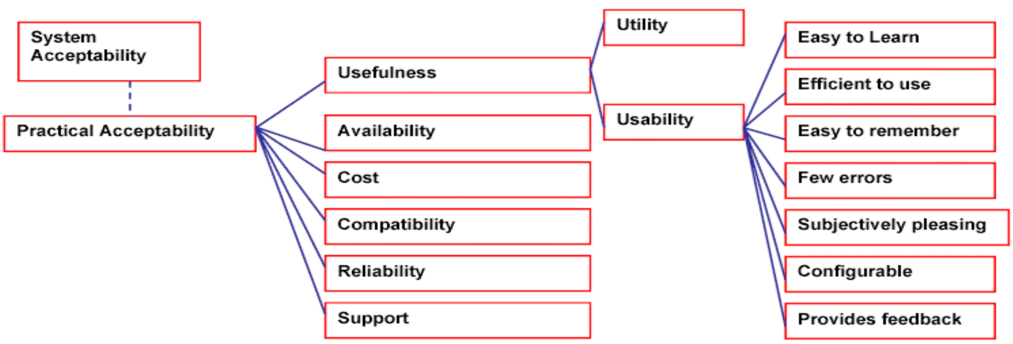

Figure 7: Sandhu's System Acceptability Adapted from: Sandhu (2002)

Sandhu's diagram illustrates that for systems to meet his definition of Universal Design criteria there are a considerable number of attributes and properties that the system and designer must address which are similar to those derived by software engineers considering dependability. The model that Sandhu proposes is useful in that it actually situates the user and the product in the same model whereas dependability theorists had tended to consider the user as an afterthought. We consider that acceptability is a fundamental attribute and critical dependability criteria. Acceptability reflects the users preferences into the design as well as the users preferences for the finished product and they way it is to be used. Acceptability is essential as the support that a system is designed to give will be negated if the system is not accepted by the user. We have endeavored to extend Sandhu's HCI illustration through the use of our 'Building Blocks' to make a more inclusive interactive model which we term the "Interdependent Model".

4 A Dependability Model For Home Systems

> *There is a sense in which routines are the very glue of everyday life, encompassing innumerable things we take for granted such that each ordinary enterprise can be undertaken unhesitatingly. This is especially pertinent in the home where the highly disparate priorities of different family members have to be coordinated without the commonality of an orientation to some shared work objective to bind them together. Routines help provide the grounds whereby the business of home life gets done.* (Tolmie et al, 2002)

Dependability in the home and home systems is derived from a different set of attributes and conditions that form a new critical system dependability model based around acceptability and reliability. Our current theoretical approach to the study of dependability of Assistive Technology in the home of the future is informed by what we are calling the "USE Model" (Figure 8) that conceptualizes the home as a constellation of three overlapping spheres. The User is consists of all occupants and people who will be likely to use the space(s). The System is where all technical systems, such as wiring etc, as well as activities and patterns etc., are located. The Environment is meant to reflect external forces that affect the other systems and cause responses (for example cold weather means more heating, housing structure, location etc). Each category is interdependent on the others within the design process. All activities, actions and processes undertaken in the home fall within one or more of these three categories. The appropriate design of AT systems for the home must consider the USE dimensions within the overall design.

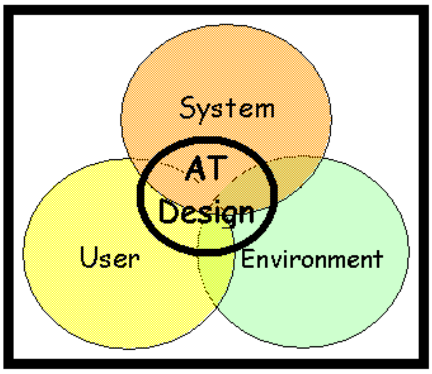

Figure 8: The Home System USE Assistive Technology Design Model

This model provides the designer with a clear and simple view that the home is constructed from three main categories that are influential in designing AT and home systems. The model demonstrates the interactive socio-technical nature of design of these systems. As an isolated model it is not so useful in assisting appropriate design beyond explaining that the home is a series of interconnected systems. We therefore need to look to other areas such as dependability and field studies to illuminate a clearer model. It is useful to use the notion of dependability to ensure home systems are reliable, although the question is whether the home can adopt the concept or whether the concept needs to be redefined in terms of the acceptability of the system to the user(s), from which the following questions are derived:

- Is the system right/appropriate
- Is it the right/appropriate system
- Is the system predictable and usable
- Is the system robust and reliable

?? How is the system to be used
?? How is the system likely to be changed
?? How robust and reliable is the system

These questions form an interactive model that allows us to question the acceptability of a system for a user based on these six facets. Figure 9 shows the interactivity of these questions:

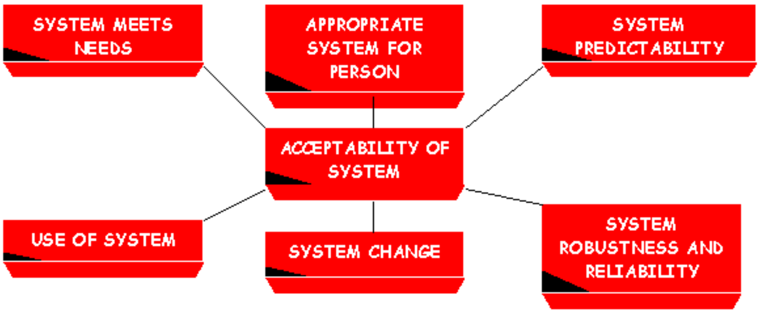

Figure 9: Attributes of System Acceptability

Meeting need through system design means ensuring the system is acceptable. Acceptability is multifaceted and the six dimensions outlined in Figure 9 reflect the beginning of the unpacking of this notion.

The "USE Model" demonstrated a useful way of encapsulating the main dimensions of the design process, but the functional elements that makeup the appropriate design (Dewsbury et al 2002). Through the fieldwork we developed a list of issues that have been addressed by participants in the study. The list dependability comprises of twenty-one features, which are alphabetically as follows: aesthetics; availability; configurability; consistency; cost models; ease of remembrance; efficiency of use; extensibility; few errors; integrity; interoperability; learnability; patterns and routines; privacy; process and timing; provides feedback; repairability; safety; support; understandability; utility; verification- use of system. In order for a system to be supportive and actively used in the home, it is required to be *aesthetically* pleasing, blending in with the décor of the existing home and the users taste. The system must be *easy to learn* and remember, *usable, useful*, do what it is intended to do and what it is expected to do whilst being easily understood. The system should also be within the *budget* of the person allowing for *maintenance and repair costs* in the future. The system should be *supportive* to the person allowing them to access help as and when required, as well as being safe and enabling the person to feel *safer* in their home. The system should be *available* whenever it is required and *support* the *patterns and routines* (daily rhythms) that the person has in their life including supporting the level of *privacy* they wish to retain. This also extends to supporting the *process and timing aspects* of the person's life such that *patterns and routines* are not substantively affected by the system. The system is also required to be *efficient* to use (both in terms of power and operationally), which relies on the components of the system (the indivi dual devices) being *consistent*, and *interoperable* as well as *extensible*, so new devices can be added at a later time when required without fear of conflicts or false actions. The robustness of the system also requires that *errors and faults are minimized*, both in terms of the programming of the devices and the devices failure, hence the *integrity* of the system as a whole, including the user, environment and system aspects is intrinsic to the dependability of the design.

In domestic environments it is important that devices have some form of repairability. This could be limited repairability in the same way computers allow one to restore and repair certain facets of them without the user actually doing anything more than responding to the message do you wish this to be repaired? We see repairability as an essential quality to home system devices. We also extend this such that devices should be repairable from user errors, so the ability to reset a system or go-back is perceived as important within any device or system. Before purchasing a device the consumer is likely to ask himself or herself whether the device can be repaired. This is distinct from maintainability, as it requires a more long-term forecast in relation to the technology. Purchasers rarely consider maintenance costs of devices (exceptions being washing machines and fridges where the power consumption is used as a selling indicator). Ideally all devices will have their own self-diagnostic functions built into them.

Future devices have a number of potential specifications that follow from the above. There is a requirement for a level of openness within the operation of the systems so they are explicit to user of the device. There is also a level of configurability that is required for devices and tools in the home so the user can modify settings and operational functionality. Learnability and Configurability are central to a good system within the home. It is important to consider that devices in home systems are to be used by the occupants. They are not black-box devices and require interaction. There is also a need for devices to be adaptable to the evolving schedules that are present in home systems. Systems should remove barriers for disabled and older people and support the lifestyle that they wish to have whilst being responsive to the changing needs of the individuals within the home.

Within the homes of disabled or older people, these lacks of restriction can make life dangerous and difficult especially if the technology does not operate in the expected manner when it is required. For disabled or older people technology becomes something that is depended on to ensure the maintenance of a quality of life. Yet, technology is required to be more reliable and technological home systems should not fail, as the consequences of failure can be fatal or a seriously bad outcome (Monk and Baxter 2002). The way in which technology is used is also different for each person, as their own limitations will reflect the amount and manner in which the technology is used. We can still consider failures as important; for example, failure to use the technology for whatever reason is actually a system failure in that the system is not considered to be dependable.

Current technology has differing levels of interactivity that allow most people can undertake simple tasks such that they can operate the required device, but more complex tasks are also available for the experienced user. As we get older our functional abilities decline and technology might be required to compensate for our lacks. In these cases technology is required to be suitable for anyone to use with ease.

4.1 Building Blocks

A number of homes have semi-structured schedules dictated by environmental and situational factors such as getting kids to school, waking up and leaving the homes in time to get to work etc and these form patterns. However, these patterns rarely follow through to the weekend or holiday periods. Home systems need to be responsive to these changing, rhythmic structures. Timeliness can be defined as the ability of the system to operate within time frames that is predefined. This recognizes the fact that time has granularity to it in which differential temporal aspects are considered within the system. Within the home the user has their own granularity of temporal regularity. Zerubavel (1985) considers four aspects of timeliness, or 'temporal regularity', in his words. The rhythms of domestic life make use of the three patterns in terms of scheduling and in terms of privacy and public behaviors where the temporal aspects of everyday life are explicated. Clearly these patterns and rhythms are not standardized in all homes. Certain aspects of daily life are standardized such as getting up after going to bed, having meals at certain times etc, but these patterns change throughout the life cycle. Bedtime changes with age as do most activity patterns, yet these rhythms are central to dependable design as technology should fit into these patterns and enhance the person's life. If technology ignores the rhythms of a person's life, then it is likely to be unresponsive to the subtle changes that occur throughout the person's day.

> [Within the home] *Time is definitely not structured in large blocks of free time surrounded by non-free time. Rather, the day consists of a large number of small blocks of time, each of which is constrained to varying degrees.* (Mateas et al, 1996*)*

The home provides the focus for events and actions that are mediated by temporal systems derived from the occupant(s). Technology is required to fit into these temporal regularities or temporal rhythms in order to sustain the patterns and routines of the occupier Tanzi (2000). The rhythms and modulations within the home produce differing messages as people age. The rhythms change over time. The design of technology should reflect these modulating rhythms although appropriate design might change the tempo in a positive manner by enhancing the person(s) life.

Socio-technical systems are not static but evolving and modulating with the rhythms of daily life. For a system to be dependable it is required to have a number of *diagnostic* levels. Ideally the minimum level of diagnostics is three: Expert Diagnostics, Semi Skilled Diagnostics and Simple Diagnostics. These levels allow the technology to be diagnosed and possibly repaired. Clearly certain repairs will have to be undertaken by experts, such as when a device is broken, whereas other less severe issues should be able to be undertaken by the user in the home. Clearly it is important to allow for changes in the set-up and in the functionality of devices and this should not require an expert to be called in to undertake these modifications. Moreover, the system should possess a self-monitoring function that would allow the users to be aware of problems before and when they occur, in order to undertake a possible repair. Similar, but more cooperative, systems should be available to the user of technologies in the home. For the slightly more expert system user, tweaks should be possible, to allow changes to timing and other functions to suit their needs. The system should ideally be easily reconfigurable in situ; by the person using the system, this extends to allowing the system to be reset if problems with *configuration* are reported. The system should provide *feedback* in the manner that is most useful to the user, and the system is required to be able to be verified by the user to determine if there are problems with devices of programming.

The dimensions can be subdivided into three categories that reflect the relationship of the system to the home dweller. We determined that these were: Acceptability Attributes, Reliability Attributes and Other considerations (Table 2).

Critical System Dependability Characteristics		
Acceptability Attributes	***Reliability Attributes***	***Other Considerations***
Aesthetics	Availability, Efficiency of Use	Cost Models Financial Considerations
Understandability, Ease of Remembrance and Learnability	Integrity, Configurability, Consistency, Interoperability	
Patterns and Routines Support	Extensibility	
Process and Timing Support	Few Errors, Repairability Predictability	
Support for user and carer	Provides Feedback and Verification	
	Safety	
	Privacy	

Table 2: Critical System Dependability Characteristics in the Home

The dimensions outlined in Table 2 demonstrate the complexity of systems design from the perspective of dependability, although the table conveys a linear static nature to the dimensions and does not show the fluidity, interactivity and interdependence, which is why we developed the Building Blocks in preference. The criteria allow for the interactivity of the user and the devices to be considered in the overall design. Home systems have a number of properties and attributes that influence the system's dependability (Table 2). We refer to these as building blocks as they are as much a fabric as the house as the bricks and mortar, and these blocks are derived from our field studies. There is little doubt in the minds of the authors that these blocks are symbolic of often-wider building blocks and can also be divided into smaller blocks. Additionally, the authors do not suggest that these are the only blocks that are likely to make up a dependable system or that the list is in any respect definitive. The home can be built ion many different ways to suit many differing needs and still be a dependable system, but the blocks outlined are tentative suggestion to begin the journey into developing a model for home system dependability. The building blocks are used as a method of conceptualizing some of the intricacies and interdependencies of home systems. Through the relative relevance of each block in the design process the designer can begin to probe the users social activities and actions as well as their routines and standard actions. Consequently, the blocks serve as little more than a hint for the explorer, which can illuminate activities, patterns and rhythms of home life. The development of the building blocks (Figure 10) is a result of the ethnographic fieldwork that has been undertaken. In the field certain categories were illuminated as having substantial influence on the design of appropriate assistive technology for older or disable people. We do not consider that these blocks are the only significant features of the design process. The intention of the blocks is to provide a foundation from which to build appropriate design and allow the designer to consider some of the fundamental aspects of design from a person-centered perspective. Each block can be subdivided into smaller blocks or become part of a larger block as directed through the users specifications. In many ways, this adds to Sharrock and Anderson's (1994) notion of the "scenic feature of design". The concerns and reactions of 'the user(s)' are central to the design process giving pragmatic orientation and legitimation to the potential designs. The building blocks are receptors to allow the voice of 'the user' to be heard within the design forum.

> *While pervasive systems will most likely not be mission and safety critical, their criticality will increase as they will become an even more integral part of the infrastructure upon which our society depends. Although the decreasing size and price of devices make it feasible to build and sell pervasive systems, the complexity of such systems might prevent us to install, operate, and maintain them… Pervasive dependability differs from traditional dependability in the sense that it targets pervasive systems instead of mission or safety critical systems. Designing a pervasive dependable system imposes a new set of requirements that – as we believe – cannot be solved using traditional dependability approaches.* (Fetzer and Högstedt. 2002)

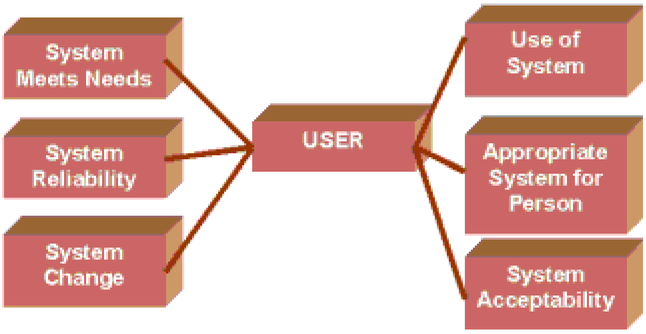

Figure 10: The Building Blocks

The can be a number of arguments about the prioritization of each block, but this would detract from the interactivity of the blocks. Each block can be seen as the part of the foundation of appropriate design on which other blocks can be laid. As we have already stated the foundational structure for these blocks is the interaction "USE Model" User, Environment and System (Figure 8) that provide the designer with the choice and order of the blocks to be laid. The blocks act as a focus for the designer to prompt consideration. It is important to recognize that technology is not panacea (Dewsbury, 2001) and through the building blocks designers can accept or reject different options. This building blocks stress the interactivity and fluidity of the design process. They also draws attention to real concerns of people in relation to whether they can trust technology; whether it is reliable; does it do what it is supposed to do. Moreover, t also addresses common concerns such as the appearance of technology and whether the user can manipulate it such they have control over their environment. The USE and Building Block models also address dependability issues from the technology perspective, ensuring that the system is compatible, configurable, maintainable, repairable, extensible and easily used in the manner it is supposed to be used. Technology should provide these as a baseline, but often this is illusory, as the technology cannot do what is expected all the time.

The model can be used to design acceptable devices and systems from scratch or as a means of determining the most appropriate existing system to meet the needs of the user. By ascertaining the baseline building blocks (based on user needs) the designer is able to construct their own pattern of design criteria (using prescribed or additional criteria). The Model described above is an attempt at a working perspective that allows the real world rhythms, activities and actions of older people (and/or disabled people) to be explored in relation to dependability and acceptable assistive technology. As with all models it serves little purpose if it becomes static and rigid and therefore the simplicity of the model allows for additions and subtractions according to the persons' perspectives, criteria and needs. The main point of the model is demonstrates the interdependency of the core design features. The model enables appropriate design of AT through situating the key notions of people and technology that are built around the environment, the system and the user within a contextual framework that is defined through the stakeholders and mediated through their domestic contexts, actions, routines and rhythms of daily life. The ability to distil everyday experience into a design framework that is appropriate and takes account of the subtleties and rhythms of everyday life are part of the essence of the design process. Systems are designed for people and should be adjusted to reflect the patterns and routines of the person for whom the design is made, as opposed to the person adjusting to the new system. This is why we feel it is important to understand the needs of the user and advocate ethnographic investigations to illuminate these needs. Consequently, the application of prescriptive generic models only serves to negate and subsume the user experience within the design format. We therefore suggest that through the judicious use of the interdependent Model outlined above, the designer can begin to explore the user and the technology without being mediated by concerns external to the task in hand.

5 Conclusion

As technology disappears, becomes ubiquitous, more pervasive and more integrated into the fabric of the home, the designer of AT of the home of the future is faced with a number of dilemmas concerning dependability and assistive technology. These dilemmas are often ignored through a lack of a simple model to enable the design process from a user perspective. This paper sets out to provide a tentative model based on the idea of using building blocks to construct an appropriate system to meet the needs of the user. The paper suggests that through the use of ethnographic investigations, cultural probes and the use of the model, the designer of the future should be better equipped to ensure the stability and dependability of the design whilst also ensuring the users acceptability of the technology. Designing dependable digital environments for older and disabled people should rely on rigorous and informed knowledge that ensures the adaptations and systems meet the needs of the user through appropriate technology. The USE model and the interdependent model's Building Blocks, we contend, act as useful aids to appropriate design of assistive technology networked systems and a useful method of analyzing dependability criteria.

6 Acknowledgements

The work described in this paper is distilled from the ongoing research undertaken on the EPSRC funded DIRC (www.dirc.org.uk) and EQUATOR (www.equator.ac.uk) projects which are concerned with dependability and ubiquitous computing. We would also like to thank Age Concern, Barrow, and the other sites for their assistance.

7 References

1) **Bakker, R** (1999) Elderdesign: Home modifications for enhanced safety and self-care, Care Management Journals (Winter 1999) 1(1) 47-54.
2) **Cook A & Hussey S**, (1995) Assistive Technologies: Principles and Practice, Mosby-Year Book Inc, USA
3) **Cowan J, & Turner-Smith A**, (1998), The Role of Assistive Technology in Alternative Models of Care for Older People, With Respect To Old Age – Research Vol2, Appendix 4, HMSO
4) **Crabtree A, Hemmings T, Rodden T, Cheverst K, Clarke K, Dewsbury G, & Rouncefield M,** (2003) "Probing for information", paper under review for the CHI 2003 Conference on Human Factors in Computing Systems, 5th-10th April, Florida: ACM Press
5) **Crabtree A & Rodden T** (2002) Routine Activities and Design for the Domestic, Report Equator-02-037, Nottingham, September 2002
6) **Dewsbury G,** (2001) The Social And Psychological Aspects Of Smart Home Technology Within The Care Sector, New Technology In The Human Services, Vol 14, No 1-2, 2001, pp 9-18.
7) **Dewsbury G, Clarke C, Rouncefield M, & Sommerville I,** (2002) Home Technology Systems, Housing Care and Support Journal, 5, 4, 23-26
8) **Edwards, K & Grinter** R. (2001) At Home with Ubiquitous Computing: Seven Challenges in G. D. Abowd, B. Brumitt, S. A. N. Shafer (Eds.): Proceedings of Ubicomp 2001, LNCS 2201, pp. 256-272, 2001. Springer-Verlag Berlin Heidelberg 2001
9) **Fetzer C, & Högstedt K** (2002) Pervasive Dependability: Making Pervasive Systems Feasible,
10) **Gaver, W., Dunne, A. & Pacenti, E** (1999) "Cultural probes", Interactions, vol. 6 (1), pp. 21-29
11) **Gaver W** (2001). Designing for Ludic Aspects of Everyday Life, ERCIM News No.47, October 2001
12) **Gaver W, Beaver J, & Benford S** (2002) Ambiguity as a resource for design. Technical Report Equator-02-024, Equator, September 2002.
13) **Gray D, Quatrano L., & Lieberman M** (1998) Designing and Using Assistive Technology: The Human Perspective, Paul H. Brookes Publishing Co.

14) **Hughes J, Jon O'Brien, Rodden T, Rouncefield M & Viller S** (2001) Patterns of Home Life: Informing Design For Domestic Environments.
15) **Kiesler S, Zdaniuk B, Lundmark V, & Kraut R** (2000) Troubles With the Internet: The Dynamics of Help at Home, Human-Computer Interaction, 2000, Volume 15, pp. 323–351
16) **Laprie, J-C**. (1995) Dependable Computing: Concepts, Limits, Challenges FTCS-25, the 25th IEEE International Symposium on Fault-Tolerant Computing, Pasadena, California, USA, June 27-30, 1995, Special Issue, pp. 42-54
17) **Lebbon C, Cheverst K, Clarke K, Dewsbury G, Hemmings T, Hughes J, Martin D, Rouncefield M & Viller S**, (2003) 'OBSERVATION FOR INNOVATION' In John Clarkson, Simeon Keates; Roger Coleman, Cherie Lebbon (eds) INCLUSIVE DESIGN, Helen Hamlyn Research Centre, Royal College of Art
18) **Lupton D & Seymour W** (2000) Technology, selfhood and physical disability, Social Science & Medicine 50 (2000) 1851-1862
19) **Mateas M, Salvador T, Scholtz J, & Sorensen D** (1996) Engineering Ethnography in the Home, Proceedings of CHI96
20) **Monk A & Baxter G** (2002) Would you trust a computer to run your home? Dependability issues in smart homes for older adults, Paper presented to HCI 2002, London, September 2-5
21) **Reason J,** (1997) Managing the risks of Organizational Accidents, Ashgate, England and USA
22) **Risborough M** (1998) Setting the Quality Standard for Independent Living: A Discussion Paper, Hope, Housing Corporation.
23) **Sandhu J**, (2002) Multi-Dimensional Evaluation as a tool in Teaching Universal Design, In Christopherson, J, (Ed) (2002) Universal Design, Hausbanken, Norway,
24) **Sharrock W**, **& Anderson B**, (1994), The user as a scenic feature of the design space, Design Studies, Vol 15, Number 1, January 1984
25) **Sommerville I**, (2000) Software Engineering, Addison-Wesley
26) **Tanzi D**, (2000) Time, Proximity And Meaning On The Net, C-Theory, 3/8/2000, Article 081
27) **Tolmie P, Pycock J, Diggins T, Maclean A & Karsenty A** (2002) Unremarkable Computing, CHI 2002, April 20-25, 2002)
28) **Venkatesh A, & Mazumdar S** (1999), "New Information Technologies in the Home: A Study of Uses, Impacts, and Design Strategies", in Mann T (ed) The Power of Imagination, Environmental Design Research Association (EDRA), p216-220.
29) **Venkatesh A, Kruse E, & Chuan-Fong Shih E,** (2001a) The Networked Home: An Analysis of Current Developments and Future Trends, CRITO Working Paper, 1-34.
30) **Venkatesh A, Stolzoff N, Chuan-Fong Shih E, & Mazumdar S** (2001b) "The Home of the Future: An Ethnographic Study of New Information Technologies in the Home," in Gilly M and Myers-Levy J. (eds.), Utah, Association for Consumer Research, Advances in Consumer Research, June
31) **Zerubavel, E** (1985) 'Hidden Rhythms: schedules and calendars in social life. University of California Press.