

# Dependable Domestic Systems Design: A Socio-Technical Approach

## Abstract

This paper describes a model that defines the attributes of domestic systems that lead to system dependability and a user-oriented specification method for support systems based on this model. We start by discussing technical dependability models and discuss how these have to be extended for use in a domestic context. We present an extended dependability model based on a socio-technical perspective. This extends the technical notion of dependability to take into account fitness for purpose, acceptability and adaptability. We then go on to discuss MDDS – a questionnaire-based method that reflects the socio-technical dependability model. It is intended for use by social care professionals who are specifying and designing support systems for older or disabled people. MDDS provides a basis for examining a design from a dependability perspective. We illustrate the use of the method and conclude with a discussion of its qualitative evaluation.

## 1 Introduction

Over the past 20 or so years, research in safety-critical control and protection systems has resulted in major advances in our understanding of the factors that lead to and that mitigate against system dependability. However, dependability issues are no longer solely the concern of control system developers – system dependability is now a key issue for almost all computer-based systems. In our work, we aim to extend methods and techniques for designing dependable organisational systems to simpler support systems that are used in the home.

Our research has been concerned with domestic alarm systems and with systems that provide assistance to people who suffer from some disability such as hearing, mobility, motor control, eyesight problems or cognitive impairment. Such systems are sometimes termed ‘assistive technologies’, although this term is not used in a consistent way across different professional disciplines. To avoid ambiguity, therefore, we use the term Home Support (HS) systems to refer to domestic systems that either sense their environment and inform some agent if problems arise or that provide support for users to carry out the normal activities of everyday life.

HS systems are critical systems because failure of these systems, at best, adversely affects the activities of everyday life of their users and, at worst, can cause real harm to the people that they are supposed to help. As improved medical technology prolongs life and an increasing proportion of the population are elderly, developing effective HS systems is essential to allow elderly people to live in their own home and maintain their quality of life.

In general, HS systems are constructed using off-the-shelf, electronic and mechanical components with, perhaps, some software to integrate different components. For example, if an older person has mobility problems, a system may be constructed that allows them to remotely open their door to allow visitors into their home. Such a system may include a video camera, speaker and microphone positioned by their door, a switching facility to allow them to see on their television who their visitor is and a motorised door-opener that can be remotely controlled from anywhere in their home. All of these devices may be integrated through a controlling software system.

The overall goal of our research was to investigate approaches to HS system design that lead to more ‘dependable’ systems. That is, systems that met some real needs of users and that they could trust to support these needs. Our view of dependability is socio-technical rather than technical. Dependability isn’t just about the hardware and software operating to specification but is also a reflection of how well the

technical system fits into the environment where it is used. The importance of the socio-technical issues in systems design has been investigated by researchers for many years. The earliest work was probably that of Mumford in the 1970s (Mumford and Weir 1979) but Suchman's seminal book (Suchman 1987) brought socio-technical issues to the attention of HCI and computer science researchers. Since then, many researchers, particularly from the HCI and CSCW communities have carried out studies to help understand socio-technical environments (Heath and Luff 1991; Bentley, Rodden et al. 1992; Heath, Jirotko et al. 1994) and have looked at how to use this knowledge to support software design (Heath, Jirotko et al. 1994; Hughes, Rodden et al. 1994; Hughes, O'Brien et al. 1997; Viller and Sommerville 1999; Crabtree 2003; Jirotko and Luff 2006).

The practical experience of one of the authors in working with older and disabled people using HS systems was that these were often unused because they were unsuitable for their operating environment (Dewsbury, Clarke et al. 2004b). We wished to examine why unsuitable systems were installed and to derive new approaches that would address some of the problems that we perceived in HS system design.

With this overall goal in mind, we carried out field studies where we looked at HS technology installed in people's homes and discussed with them how and when it was used (Dewsbury, Clarke et al. 2004b). We concluded from our practical experience and from these studies that dependable HS system design required the existing notion of what was meant by 'system dependability' to be extended. The problems discovered were not simply problems of usability and hardly ever problems of HCI design. Rather, we discovered that many if not most HS systems were designed around the disability of the user and did not take into account how the users lived their normal home lives and their wishes and needs for support (Dewsbury, Clarke et al. 2004a).

We concluded that an extended notion of dependability for domestic systems that includes the user and the system's environment rather than positioning them outside the system boundary was required. When an HS system is installed in a domestic environment, we should not just be concerned with whether or not that system is failure-free insofar as the hardware and software behave as specified. Rather, the overall system dependability also depends on if, when and how that system is used. An HS system that is unusable in a particular context by a particular user or which does not improve the overall quality of life for a user *cannot and should not* be considered to be dependable, even if that system operates without technical failure.

The initial version of the dependability model was published in 2003 (Dewsbury, Sommerville et al. 2003). However, such a model, on its own, is divorced from practical design issues. Therefore, we further developed the model with the goal of discovering how to use it in practice to help with the design of HS systems. Our research objective was to develop a method that was derived from the model that could help social care professionals to design dependable HS systems.

This paper draws together our work on a socio-technical dependability model for HS systems and the associated method for supporting the design of HS systems. In the remainder of this paper, we briefly describe the 'traditional' techno-centric systems dependability model and discuss the weaknesses of that model as far as domestic systems dependability is concerned. We then go on to describe our extended dependability model for domestic systems dependability and discuss how this model has informed the design of MDDS. This is a user-centred method for supporting the specification of dependable HS systems that are intended to provide support for everyday activities. We explain how we have evaluated the MDDS approach and reflect on the strengths and weaknesses of both our model and the MDDS method.

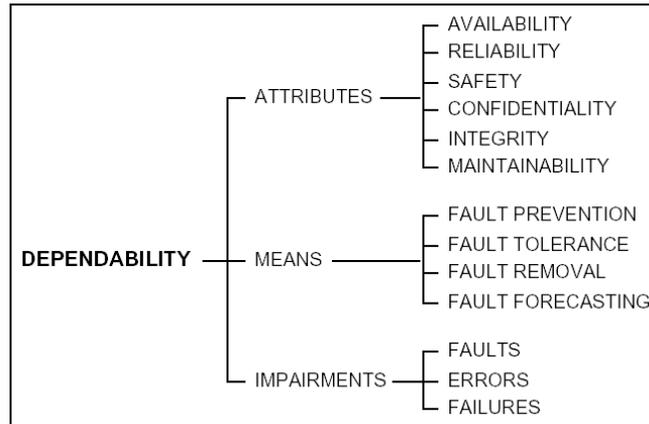


Figure 1: Laprie's dependability tree

## 2 Computer system dependability

The dependability of a computer system (software+hardware) reflects the extent that a system can be trusted to operate without failure in a particular environment. Laprie (Laprie 1995) succinctly sums this up as:

“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.”

This view of dependability has been presented and refined in a number of papers by Laprie and his collaborators, with its most recent instantiation in a paper that defines concepts and a taxonomy for dependable and secure computing (Avizienis, Laprie et al. 2004). Central to this notion of dependability is a dependability model or ‘dependability tree’ (Figure 1) which summarises dependability attributes, the means to achieve system dependability and the impairments to dependability.

Laprie suggests (Laprie 1995) that dependability can be considered to be an amalgam of a number of different attributes:

- the readiness for usage leads to *availability*,
- the continuity of service leads to *reliability*,
- the non-occurrence of catastrophic consequences on the environment leads to *safety*,
- the non-occurrence of unauthorized disclosure of information leads to *confidentiality*,
- the non-occurrence of improper alterations of information leads to *integrity*,
- the ability to undergo repairs and evolutions leads to *maintainability*.

The means by which dependability can be achieved can be framed within the notions of ‘fault prevention’, ‘fault tolerance’, ‘fault removal’, and ‘fault forecasting’, which enable the software designer to avoid, trace and prevent undesirable problems. Fault prevention is concerned with techniques to avoid introducing faults into a system, fault tolerance with techniques to continue correct operation in the presence of faults and fault removal with the elimination of faults before system deployment. Fault forecasting is concerned with estimating the number of faults in a system and their possible consequences.

The impairments to dependability are related insofar as a failure is an externally visible transition from correct to incorrect operation, a fault is the hypothesized cause of an error and an error is an undesirable system state that has the potential to lead to a failure. For example, an observed failure might be the failure of an automatic door to close; the related error might be an incorrect value in a system variable e.g. the

‘door\_open’ variable is false rather than true; the error (the reason why this value is incorrect) might be the omission of an assignment statement in the door opening code that alters the ‘door\_open’ variable.

This model, which views dependability as primarily a technical issue, has been generally accepted by the system dependability research community for many years. In papers discussing general dependability issues, human factors and human error (Rasmussen 1987; Reason 1990), are recognised as important but somehow separate from technical issues of dependability.

In both Randell (Randell 2000) and Laprie’s writings on dependability (Laprie 1995; Laprie, Arlat et al. 1995; Avizienis, Laprie et al. 2004), there is an implicit assumption that the fault-error-failure model discussed above applies equally to humans as it does to technical system components. For example, Randell suggests that failures of largely human development systems may lead to faults in operational software systems:

*“the result of a programmer’s error is a (dormant) fault in the written software (faulty instruction(s) or data);”*

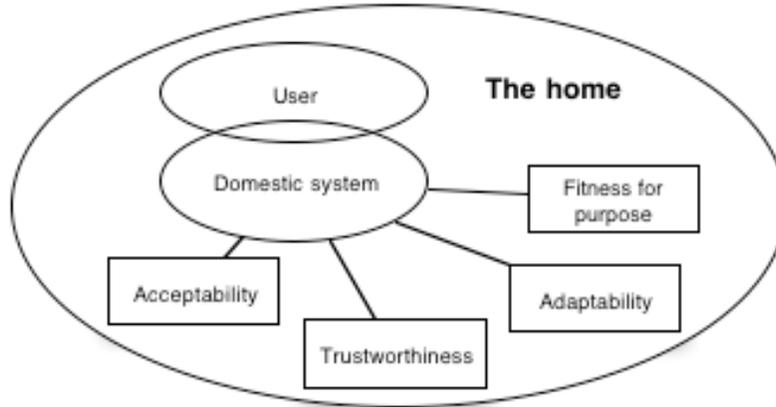
Philosophically, we are uncomfortable with the notion that techno-centric models designed for automated systems should be applied, without change, to the humans that design and operate such systems. The fact that people are non-deterministic, self-aware, thoughtful individuals means that their behaviour should not be compared to the behaviour of software-controlled computers. Nevertheless, let us assume that, in some circumstances, the technical dependability model can be used as a basis for understanding and assessing human dependability.

In order for it to be successful, we have to be able to identify faults, errors and failures in human activities. A failure might be considered as a deviation from some defined process that operators of a system should follow, in the same way that a software failure is a deviation from some defined system specification. Errors and faults are rather more difficult to pin-down when applied to humans but we might assume that an error (an undesirable system state) can be identified by a person articulating their understanding of a situation that led to a failure (i.e. externalising their internal state). The associated fault is the reason why this understanding was incorrect – e.g. lack of appropriate training, forgetfulness, etc.

However, explicit process descriptions are not part of the home life of most people but are organizational constructs that are designed to codify the ways in which some job might be done. Thus, identifying ‘human error’ as a deviation from a process is not really meaningful in a domestic context. Therefore, we argue that, if the techno-centric model of dependability is to be applied to system users or operators, then it is only applicable in an organizational context where defined processes and procedures governing the use of systems are in place. For home support systems, we need to adopt a human-centred rather than a techno-centred approach to system dependability.

### **3 A dependability model for domestic systems**

The notion of a ‘smart home’ where embedded computer systems support the inhabitants has been the subject of research for some time. Some of these have been ‘lifestyle demonstrators’ such as the Orange house (Harper 2003). However, there is a larger body of work concerned with how domestic systems can enhance the quality of life of older and disabled people (Allen and Dillon 1997; Gann, Venables et al. 1999; Bjørneby 2000; Marshall 2000; Dewsbury 2001). Software-based methods to detect incidents where a person in need might require assistance were developed and trialled throughout the world (Edge, Taylor et al. 2000; Kinder 2000; Fisk 2001; Miskelly 2001). The ability to predict potential issues and send alerts is the foundation of lifestyle monitoring which is the basis of telecare systems that are currently being advocated and, indeed, installed in a number of special housing projects (Woolham and Frisby 2002; Brownsell and Bradley 2003; Fisk 2003; Blythe, Monk et al. 2005).



**Figure 2: An holistic view of domestic system dependability**

The key problem with such installations and any smart home technology is how to ensure that the devices and installations meet the real needs of the occupants. This was the primary motivation for the development of our dependability model and method.

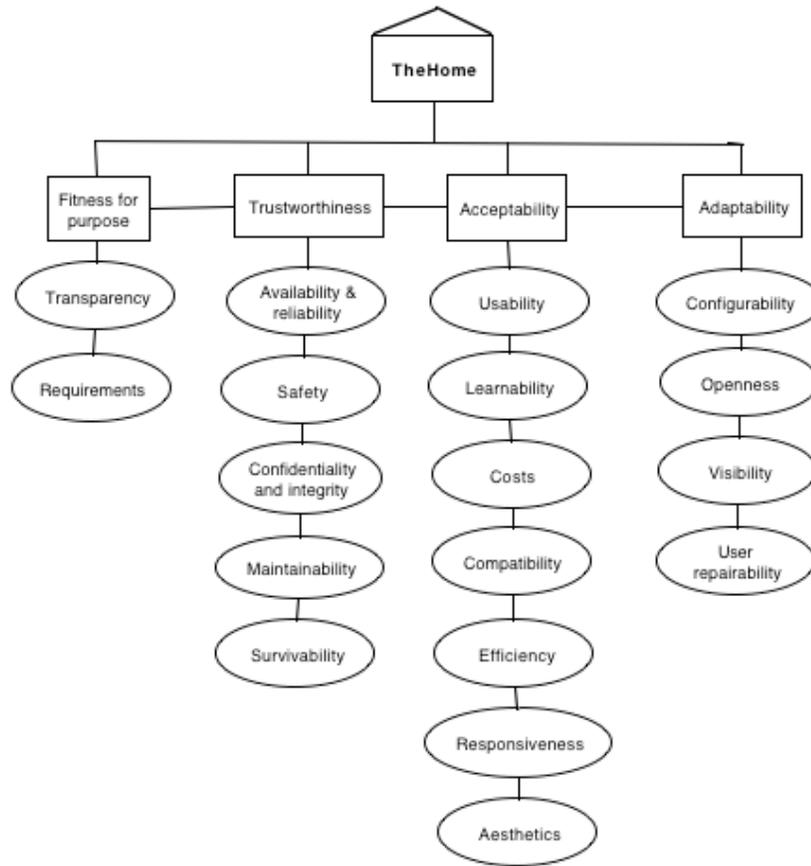
The differences between domestic and organizational environments are one reason why dependability models that focus on the technical attributes of the system have to be extended for domestic systems. In the home, there are no defined operational processes, enormous variation in the competence and experience of system users and no ‘quality control’. In contrast to organisations where technologies and processes may be restricted, there are no rules about using computers and other technology and often no support for comparing different systems that may be used. General wisdom is that people do not read instruction manuals (Spolsky 2003), they are not trained in the use of domestic technologies and there is no formalised way for users to get help and support.

The consequence of this is that many users, particularly older and disabled users with little experience of HS systems, find it difficult to be proactive in the choice of systems that are installed. Technology choice may be ‘accidental’, reflecting the experience of relatives, friends or carers helping users choose an HS system or reflecting generic choices made centrally to simplify procurement. We found that, in many cases, system designers adopted a formulaic approach (Dewsbury, Clarke et al. 2004a) based on a short list of equipment to support specific disabilities. Insufficient attention was paid to analysing what the users really needed or wanted or to the environment where the system was to be used.

However, once installed, users can choose whether or not to use HS systems and, all too often, they do not use them (Gottlieb and Caro 2000; Gitlin 2002). If a domestic user, *because of the attributes of a system*, chooses not to use a home support system, we argue that this constitutes a failure of the overall socio-technical system design and so is as much a design failure as programming error that leads to technical failure of the hardware or software.

For example, if an older person is offered a communication aid that they cannot fit into a pocket of their normal clothing, practical circumstances mean that they cannot use that system. Therefore, the *availability* of the communication aid system in reality is drastically limited. The communication aid itself may be technically dependable but its (lack of) portability means that the goal of helping with communication has not been achieved. In essence, the socio-technical total communication system (device + user) is undependable, because of non-functional characteristics of the device.

To achieve dependability, we must take an approach that integrates the user and environment with the technology rather than simply focusing on technical issues and the operational processes involved in using a system. The dependability of domestic systems extends beyond the hardware and software into the



**Figure 3: Dependability attributes of domestic systems**

social and lived experience of the home dweller. As Lupton and Seymour (Lupton and Seymour 2000) suggest, it is essential that dependability does not just mean that a system behaves according to the expectations of its designers. Systems have to be designed so that they are *acceptable to* and *accepted by* users.

We consider domestic HS systems to be socio-technical systems where the system includes the user, the home environment and the installed system (Figure 2). The model of domestic dependability that we propose organises the characteristics of domestic HS systems under 4 headings, shown in Figure 2, each of which represents a set of system attributes. These 4 general headings reflect the functionality of the system, its technical quality of service, the suitability of the system for a particular user in their own home and the ability to the system to change in response to changing user needs.

We discuss the background to the domestic dependability model in more detail elsewhere (Dewsbury, Sommerville et al. 2003) but, in summary, the attributes in our model reflect the attributes identified in a study by Batavia and Hammer (Batavia and Hammer 1990). They used focus groups to identify seventeen factors such as consumer and supplier repairability, personal acceptability and dependability which effect the selection and evaluation of assistive technology. Our model takes these further by considering fitness for purpose as a critical dependability element and by decomposing dependability into the more specific attributes as discussed by Laprie (Laprie 1995). The model also incorporates Sandhu’s acceptability attributes (Sandhu 2002).

The top-level headings that encompass related system attributes are:

1. *Fitness for purpose* For a domestic system, the fitness for purpose of that system reflects the extent to which that system meets the real needs of its users. In short, is it the right system for the user's functional needs. If not, then the system is undependable as it will not deliver the required support to the user.
2. *Trustworthiness* In order for a system to be dependable, the user must be confident that the domestic system will provide the expected services when required and without undesirable side-effects. The trustworthiness of a system reflects the technical dependability attributes of availability, reliability, safety, etc.
3. *Acceptability* The heading embraces those system attributes which govern whether or not the user of a domestic system is willing to accept it for use. These relate to the ease of use of the system, its efficiency and compatibility both with other systems and with the home itself, rather than the functionality of the system or its technical dependability characteristics. If a system is not accepted by its user for whatever reason, then it clearly does not deliver the services that are required.
4. *Adaptability* Within the home both the environment and the users of the systems change. This is particularly true for older people whose capabilities tend to decline as they age. Therefore, if system dependability is to be maintained, then a home support system must be able to evolve over time, ideally without interventions from the system's designers.

Figure 3 shows the system attributes that are covered by these broad categories. Of course, there are overlaps between these attributes but the broad categorisation provides a useful basis for describing the dependability model. Not all attributes are relevant for all users and all systems and, as we discuss later in our discussion of a design method, a designer has to choose which are the most important attributes. The fitness for purpose attributes are always necessary but the significance of the other attributes is a matter of judgement for the system designer.

There are also possible conflicts between attributes – making a system more usable may mean that it is less secure; making it configurable may make it both less usable and less transparent. Increasing reliability may reduce responsiveness because of the time required for additional checks carried out by software. There are no easy answers to resolving these conflicts – we rely on the judgement of the system designer to decide which attributes are most important.

Although our domestic dependability model was created specifically to support the design of dependable HS systems, we believe that it may have a wider applicability. The characteristic of home support systems is that their use is discretionary. That is, the people who live in the home can decide whether or not they use the system. This means that system designers cannot fall back on re-engineered organizational processes to compensate for deficiencies in the system.

The model should therefore be applicable to any other systems where the user has a choice of whether to accept or reject them. This includes other domestic systems, such as home entertainment systems. In a business context, senior professionals such as doctors or lawyers have the authority to choose which systems that they use – they require technology that supports their normal way of working. Failure to provide computer-based systems that meet their real needs, simply means that these systems will not be used. Thus, where people have discretion over whether or not to use a computer system, issues such as fitness of purpose, acceptability and adaptability are likely to be important factors that influence the system design.

### **3.1.1 Fitness for purpose**

The fitness for purpose of a domestic system reflects the extent to which that system meets the real needs of its users in all conceivable situations of use. A system's fitness for purpose depends on both the functional requirements for the system and what we term its 'transparency'. That is, the extent to which the functionality of the system is visible to and can be accessed by a user. Functionality which cannot be readily accessed is, in our view, is likely to be unused.

Fitness for purpose attributes are important because an HS system should be carefully tailored to the specific needs and limitations of its user. For example, a generic voice-activated system may be installed to help older users set off an alarm in the event of accident or illness, where the system recognises a call for help. This system may work reliably so long as the user's voice is strong enough. However, when injured, it is fairly common for an older person's voice to be weakened so, if this is not taken into account, the system will fail to operate – it will not be fit for its intended purpose.

Of course, this is not just an issue for domestic system but a more general dependability concern. Dependability is not just about getting the system right, but also getting the right system (Boehm, Brown et al. 1978). For organisational systems, dealing with this concern is seen as a specification issue i.e. failure to meet real needs is equated to a specification failure. Various techniques, such as simulations, prototyping and requirements reviews are used (not always successfully) to check that the system specification defines a system that is fit for the purpose for which it is intended.

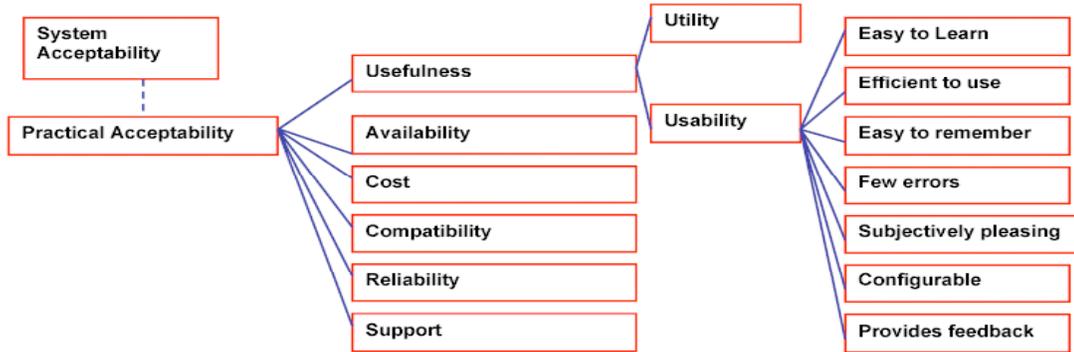
However, designers of HS systems do not have the time or resources to derive and analyse detailed system specifications. Using their knowledge of an older or disabled person's problems plus their knowledge of available technology, they have to propose an HS systems design. One of the principal aims of our work was to provide support for such designers in moving from problem understanding to HS system specification and design. Our approach is intended to help the designer choose the right system for a specific user rather than simply design a system that compensates for the user's disability.

#### **4.1.2 Trustworthiness**

The trustworthiness of a domestic system corresponds to the technical notion of dependability as discussed earlier in this paper. That is, the trustworthiness reflects the availability, reliability, safety, confidentiality, integrity, maintainability and survivability of the system (Avizienis, Laprie et al. 2004). In the home, as in organizations, trade-offs between these attributes and between these attributes and other system attributes such as performance and cost inevitably have to be made. Note that we use the term 'trustworthiness' here in a fairly narrow way – it does not encompass broader social and psychological notions of trust.

1. The availability of a system reflects its ability to deliver services when required;
2. The reliability of a system reflects its ability to deliver services as expected by the user. Notice this is different from the organisational notion of reliability which is to deliver services as specified. We have not yet met a user of a domestic system who has read its specification!
3. The safety of a system reflects its ability to operate without risk of injury or harm to users and the system's environment;
4. Confidentiality and integrity are related security attributes – confidentiality reflects the system's ability to limit access to the system and its data to authorised agents and integrity reflects its ability to ensure that the system and its data are not corrupted.
5. Maintainability is the ability of a system to undergo evolution with the corollary that the system should be designed so that evolution is not likely to introduce new faults into the system. We define maintainability here as the process of making engineering changes to the system, perhaps involving the system designers and installers. This is in contrast to adaptability, which is the process of changing a system to configure it for its environment of use.
6. Survivability is the ability of the system to continue to deliver essential services in hostile environments. For example, in a domestic context, it reflects the ability to deliver services in circumstances where mains power becomes unavailable.

Security (covered by the confidentiality and integrity attributes) can be a particularly problematic area for HS systems. While the need for integrity goes without saying, the issue of confidentiality is more difficult



**Figure 4. Sandhu's system acceptability model**

in situations where older or disabled people depend on monitoring technology that alerts relatives and carers when a problem arises. These users often value their privacy and wish to maintain the confidentiality of their personal information. On the other hand, this may compromise the safety of the overall system as it may limit the speed and type of response in the event of a problem. Ideally, the level of confidentiality of the data maintained by an HS system should be programmable and responsive to an analysis of the events being processed by the system. However, this is not yet realisable with current HS technologies.

### 3.1.2 Acceptability

The notion of acceptability (Figure 4) was initially conveyed through an advocate of Universal Design (Sandhu 2002). Universal Design is an inclusive approach to design where the designer tries to avoid design choices that exclude particular groups of users, such as users with disabilities. The model that Sandhu proposes considers the user and the technology together and so reflects our views on the central significance of the user when considering system dependability.

A user will only accept a system for use if they believe that the benefits that they receive justify the costs and effort of buying, installing, learning to use and using the system. If an unacceptable system is designed and deployed then it will either not be used or will not be used to its full potential. Hence, we argue, the required services are not being delivered to users and so the system is undependable.

In our model, the acceptability characteristics for domestic systems are:

1. *Usability* It must be possible to use the system on a regular basis without error and without having to re-learn how to benefit from the system.
2. *Learnability* It should be possible to learn to use the system without a steep learning curve before any benefits emerge.
3. *Cost* The cost of the system should be such that it is within the budget of the person or the organization buying the system. Over-engineering and 'gold plating' are undesirable.
4. *Compatibility* The system must be compatible both physically and electronically with other systems that are installed in the home.
5. *Efficiency* The effort and time saved by using the system must significantly exceed the effort involved in making use of it.
6. *Responsiveness* The system must respond in a timely fashion to user requests and provide feedback on its operation to the user.

7. *Aesthetics* If a system is to be actively used in the home, it should be aesthetically pleasing, blending in with the décor of the existing home and the users taste. If a system is aesthetically offensive (e.g. an industrial casing in a living room), our experience has shown that some users will simply refuse to have it installed in their home.

Of course, these characteristics may conflict - for example, lower-cost systems may use industrial casings and be aesthetically unappealing. Resolving such conflicts is a matter for the designer but the acceptability attributes of the domestic dependability model are a means of highlighting potential conflicts and ensuring that these issues are not ignored in the system design.

### 3.1.3 Adaptability

Homes and the people living in these homes change with time (Brand 1995). Spaces are reconfigured to cope with changing demands and tastes, new people come to live in the home, children grow up and the capabilities of older people typically decline as they grow older. Consequently, the requirements of users in the home for home support systems are constantly changing. If these systems cannot be adapted *in situ* to meet new requirements they are likely to become less and less used and, hence, less dependable.

Of course, it is well known that dependability problems in computer systems regularly arise because of errors made during system maintenance. These occur in spite of extensive quality control and testing mechanisms that are in place. There are no such mechanisms in the home so clearly the potential for undependability after modification is significant. This fact, along with the need to support system change leads to the following adaptability attributes that are relevant to dependability:

1. *Configurability* This attribute reflects the ability of users or equipment installers to adapt the system to cope with a range of human capabilities such as variable hearing, eyesight, balance, etc.
2. *Openness* This attribute is concerned with the system's ability to be extended with new equipment, perhaps from different manufacturers.
3. *Visibility* This attribute reflects the extent to which the operation of the system can be made visible to users and installers of that system (e.g. does the system produce meaningful error messages). This is particularly important when problems arise as it increases the chances that these problems can be diagnosed without expert assistance.
4. *User repairability* This attribute reflects the extent to which faults in the system can be repaired by users (or perhaps their helpers) without specialist tools or knowledge. This is important for assistive technologies as it means that the system can be brought back into operation quickly and the overall availability of the system is increased.

## 4 MDDS: A dependability-driven method for HS systems design

The dependability model for HS systems may be used as a basis for discussing and analysing these systems as it provides a vocabulary and structure for discussing system dependability. However, we believe that models should also be of practical use and so we have used the dependability model as a basis for a systematic approach for assessing the dependability of proposed or installed home support systems. The method is intended to highlight issues of HS system dependability that designers should consider when proposing a system for an older or disabled person. Our aim was to design a systematic approach for social care professionals where they could use their knowledge of the necessary functional disability support along with our dependability model to create a more dependable system design.

The need for dependability was evident from a number of studies in which we were involved where it was discovered that a very high percentage of installed HS systems were either non-operational for most of the time or were never used (Dewsbury, Clarke et al. 2004b). This has been confirmed in a number of other studies (Gottlieb and Caro 2000; Gitlin 2002). Phillips and Zhao (Phillips and Zhao 1993) suggest that the non-use of HS systems is due to one of four reasons:



**Figure 5: Interacting with a door opening system**

- lack of consideration of user opinion and selection,
- simplistic device procurement,
- poor device performance,
- changes in users needs or priorities.

All of these are covered by our extended dependability model.

As an illustration of the problems that can arise, the following quote arose during discussions with a user during our evaluation of the MDDS method:

*“Our original (warden call) system was run on batteries. Every time the batteries ran out on a device the alarms started ringing and would not stop ringing until the battery was changed and we only had the handyman here three times a week. So that was a nightmare.”*

In this case, the problems were caused by the designer’s failure to consider issues of *user repairability*. The designer did not think about what would happen when the batteries ran down and chose a system that could not be repaired by the system users. Predictable problems arose periodically and users were faced with an inoperable system until the batteries could be replaced. A key objective of our method was to highlight such issues at an early stage of the process so that expensive, post-deployment changes to installations could be avoided.

In the UK, the process of designing an HS system for older or disabled people involves a specialist in disability support (an occupational therapist) and a system provider. The occupational therapist assesses the capabilities of the person requiring support and, with advice from technology experts, proposes some support system. The system provider then develops this design in detail and installs the specified equipment in the user’s home. Our studies showed that this process suffered from problems that often led to the installation of inappropriate systems:

- The training of the occupational therapists is such that they tend to ‘design for disability’ and propose a generic solution for a particular disability rather than consider the broader issues of how the user interacts with the technology (Dewsbury, Clarke et al. 2004a). Figure 5 illustrates one of the problems we discovered where a door opening system was installed where a user could not reach the switch and so had to use her walking stick to open the door. In this case, the generic door opening system was installed without consideration of how it impacted on other uses of the room. Furthermore, disability specialists cannot be familiar with the dependability characteristics of all available equipment. They can’t assess the likelihood of failure or analyse the consequences of anything but the most obvious failures.

- The customer of the system provider is usually the social care department of a local authority rather than the end-user themselves. Therefore, providers may not take the end-users preferences into account. For example, we observed completely inappropriate, industrial style casings for alarms in domestic living rooms. These were hated by the older people in whose homes these were installed.

We designed the MDDS method to address such problems. The introduction in the method handbook (Dewsbury 2005) sums up our overall goal:

*“The MDDS method is a support tool for assessing whether a person can benefit from an HS installation. It is a way of highlighting some of the key issues that might be forgotten in designing an HS system. Most importantly it is a way of producing a better, more dependable system for the user that meets explicit and implicit needs.”*

MDDS does not exist in isolation and complements other methods that can be used in the area of home support systems. Baxter and others have developed a post-installation technique (Baxter, Dewsbury et al. 2005; Baxter and Monk 2006) which can be used to assess the risks associated with a newly installed system. Other approaches have been developed to support the installation of assistive technology and by HCI researchers.

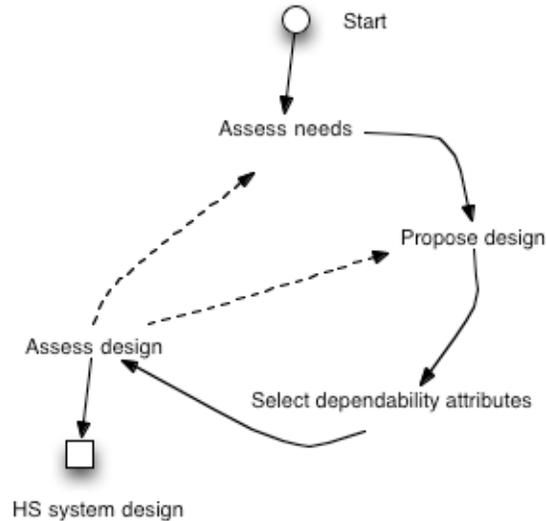
Researchers in assistive technologies have developed an assessment framework which is used to determine if a technological device is suitable for a person. QUEST (Quebec User Evaluation of Satisfaction with Assistive Technology) is a standardised and structured measure to evaluate user satisfaction with a wide range of technology devices. The concept of satisfaction that it measures is made up of factors related to the assistive technology device and the service process surrounding it. The individual rates each item with regard to the degree of satisfaction and the also the importance they ascribe to it (Demers, Weiss-Lambrou et al. 2000; Fuhrer 2001). QUEST’s predecessor PIADS (Psychosocial Impact of Assistive DeviceS) is a self-rating scale designed to measure the impact of rehabilitation orientated technology products on the quality of life of the users of these products. PIADS rates products on items that reflect important aspects of quality of life: adaptability, competence, and self-esteem. (Day, Jutai et al. 1999). Both of these are derived from the study by Batavia and Hammer (Batavia and Hammer 1990) discussed earlier in this paper.

Human factors informed methods consider technology acquirement from a range of diverse positions. Blythe et al (Blythe, Monk et al. 2005) consider domestic technology from the position risk and hazards, and a social context for technology use. Maciuszek et al (Maciuszek, Aberg et al. 2005) considered our notion of domestic dependability and reframed it considering nine dependability requirements namely: Adaptability, Availability, Relevance, Acceptability, Reliability, Competence, Safety, Adaptivity, Security.

#### **4.1 The structure of the MDDS method**

The MDDS method involves a number of stages as shown in Figure 6. It is an iterative process where, based on an assessment of the user’s needs, a design is proposed and assessed with the assessment based on the attributes in the dependability model. After the dependability assessment the design may be refined or, in some cases, the user’s needs revisited.

As our method was intended for use by social care professionals working with older and disabled users and their relatives, it was not appropriate to design a method that required detailed technical knowledge or the use of specialised notations. We therefore decided to support each of the stages of the method with questionnaires that helped designers collect information about users and their setting and prompted them to ask specific questions or to look at the design from a dependability perspective. These questions encapsulate knowledge of dependability issues and good practice and can be understood and used without extensive training.



**Figure 6: The stages in the MDDS method**

**4.1.1 Assess needs**

The process of needs assessment involves examining the capabilities of the potential system user and proposing a system that will improve their quality of life. Of course, occupational therapists (OTs) already have a range of techniques for such capability assessment and our approach is intended to be used with these techniques. It provides occupational therapists and others involved in the design of HS systems with reminders based on good design practice. We also wanted to empower users and their relatives and carers so that they could carry out their own assessment and so interact in an informed way with OTs and others involved in the design process.

The initial assessment focuses attention on whether an HS solution is really required and, if so, the nature of that solution. In short, its aim is to help choose the ‘right system’. In our view, the ‘right’ system is one that improves the quality of life of the disabled user without imposing severe restrictions on how they live their life.

We have devised an initial assessment questionnaire that includes the following questions:

- Why is a new system being considered?
- Will the system do what is expected of it?
- How will the system make the user feel better, safer, or more in control of their environment?
- In what ways will the system enable the user to undertake tasks they previously found to be too complex or too difficult?
- Could the user be confused by the system (this is particularly important for older people suffering from dementia)? Are there possible interaction problems?
- Will the system constrain the user to act in certain ways or require them to modify their behaviour so that the system will work appropriately?
- How will it be determined that the current or new system is best suited to the user?
- Could the user benefit from further system enhancements
- Is the system affordable?

An MDDS user may chose to fill in answers to the above questions on a standard form as a means of recording the rationale for design decisions. However, MDDS method is not document driven and, in some cases, there is no tangible outcome from this stage of the process. Rather, it may simply result in designers having a better ‘feel’ for what would be best for the older or disabled system users.

#### 4.1.2 Propose design

Based on their knowledge of user needs, available technology and other installations, occupational therapists and system engineers propose a design solution for a user. Like all design, this is a knowledge-based activity depending on the creativity of the designer. Our intention in providing design support was to highlight good practice that would remind the designer of important issues that should be considered when proposing a design. We were reluctant to suggest any specific design process as different care professionals had evolved their own ways of working and proposing changes to these would certainly have been opposed. Therefore, we developed about 20 good practice guidelines for HS system design that were intended to prompt designers to think about the implications of their design proposals.

Some examples of the design guidelines are:

- *Think about system failure.* The more complex the design, the greater the chance of things going wrong. In larger systems, you might want to build in a level of redundancy (more than one device monitoring the same task) so that if one system fails the other should take over.
- *Check that the user really wants the technology.* Often people are given technology because others think that they can benefit from it. Users are not consulted and consequently may never use the HS system.
- *People care about how things look.* Modern technology might not look good to the person having it in their home, so attempt to blend technology into the fabric of the building wherever possible.
- *Avoid actuators wherever possible.* Actuators (motors that open or close things such as doors and windows etc) can be costly and unreliable and may require changes to the structure of the building. Fixing actuators is often problematic and costly as it may require rewiring and ugly casings.

These are pragmatic guidelines derived from the experience of one of the authors in designing and installing HS systems and from a series of ethnographic studies which examined how user's actually used (or, often, did not use) HS systems that had been installed in their homes.

After completing this initial analysis, the system designer should have a clear idea of what the user really needs and should have established the type of HS system that is most suitable to the user needs. They then move on to a more detailed analysis of the environment and the proposed system, driven by the attributes of the dependability model. However, as we illustrate later, things are not always as simple as this – political and economic factors influence the choice of support and a less than ideal support system may be selected at this stage. The later stages of MDDS may therefore either provide information to reject the proposed system or demonstrate that, although imperfect, the system proposed is good enough.

#### 4.1.3 Select dependability attributes

Our dependability model identifies 18 attributes that may influence the dependability of a socio-technical HS system. Obviously, not all attributes are relevant in any one situation. The important attributes depend on the user, the environment and the type of system that is to be installed. This stage of the method is intended to focus the designer's attention on the critical attributes that should be considered in their design.

To identify the critical attributes, we ask the designer to complete a location-space form that encapsulates our checklist for this stage of the method. It points to the dependability attributes are likely to be of most significance in a particular setting and the specific issues that have to be considered in that setting. It identifies the devices to be installed and the activities in the location where the device will be used.

An example of location-space form that was completed during an evaluation of MDDS for an electronic window-opening system is shown in Figure 7. In this example, you can see that several attributes have been identified as “not applicable” and issues such as the need to blend in with existing décor have been highlighted. You can see that, as well as identifying relevant dependability attributes, the specifier has used the location-space form to write reminders to themselves about the required system.

To simplify the process of attribute identification, we have suggested, for different classes of HS system, the dependability attributes that are likely to be of most significance. These classes are based on the criticality of the system:

1. *Simple, non-critical devices*. These are typically single units carrying out a non-critical function – for example, a remotely controlled window opener. Key issues that the specifier should consider are the user requirements, the device availability and reliability, maintainability, usability, cost, compatibility with other installed devices and aesthetics.
2. *Alert systems*. These are systems that can issue an alert for help in the event of a problem. For example, users may wear a call button around their neck that sends a signal to a special phone that then calls a pre-programmed help number when an alert is raised. These are more critical systems and, in addition to the attributes considered for non-critical devices, important attributes are safety, confidentiality and integrity, learnability and responsiveness.
3. *Personal support systems*. These are intended to alert the user to a potentially serious problem where failure can have an immediate effect on the user's well-being. An example of such a system might be a blood pressure monitor where a rapidly rising level of blood pressure may be the precursor to a heart attack or stroke. For such systems, the technical dependability attributes under the trustworthiness heading are of particular significance as are fitness for purpose and usability.

Of course, this is a guide rather than a rigid prescription and system specifiers should consider each case on its own merits and decide if the set of suggested attributes should be expanded or contracted.

#### **4.1.4 Assess design**

The final, most detailed stage the method is design assessment where the dependability of a design is analysed using a set of assessment questions. There is one questionnaire per dependability attribute and each of these checklists starts with a key question and follows this up with more detailed system related and user-related questions. System-related questions are concerned with the technology to be installed whereas user-related questions communicate user issues that must be considered under each system attribute. In essence, we see the questions associated with each attribute to be prompts for the system specifier to help reduce the chances of them forgetting important dependability issues.

On completion of this stage of the method, the designer must decide if their design proposals need to be amended so that the system delivers a higher-level of socio-technical dependability. Sometimes, it may even be necessary to scale down the needs of the user if the assessment demonstrates that the proposed system cannot satisfy the needs in a dependable way. More often, however, the assessment results in some design modifications, a set of specific equipment requirements that must be met by the technology provider and installation requirements for the HS system.

As there are 18 possibly relevant dependability attributes, we cannot show all of these here but, rather, illustrate these questions, using the questions associated with the availability and reliability (Figure 8), usability (Figure 9) and user repairability (Figure 10) attributes.

MR SMITH: WINDOW OPENER: LIVING ROOM WINDOW

**Checklist Addendum**

The location-space forms

Section	Element	Location	Proposed Device	Main Activity within location	Secondary activity within location	Issues concerning potential devices
Fitness for Purpose	1 Transparency					
	2 Requirements	WINDOW OPENER	off the shelf	watching T.V. READING, CDS TVDS	SLEEPING SOCIALISING	ONE-OFF SYSTEM
Trustworthiness	3 Availability and Reliability	N/A	MUST WORK WHEN REQUIRED	NOT INTERFERE WITH REMOTE CONTROLS OR PHONE		CONFLICT WITH EXISTING DEVICES
	4 Safety	✓	✓	✓	✓	✓
	5 Confidentiality and integrity	N/A	N/A	N/A	N/A	N/A
	6 Maintainability	N/A	SERVICING COSTS ETC	N/A	N/A	N/A
	7 Survivability	N/A	→			
	Acceptability	1 Usability	N/A	REMOTE CONTROLLER	→	
2 Learnability		N/A	"	N/A	→	
3 Cost		REPAIRING DAMAGE TO WALLS ETC	MAINTENANCE ETC	TIME LEARNING	N/A	→
4 Compatibility		✓	✓	✓	✓	✓
5 Efficiency		N/A	N/A	N/A	N/A	N/A
6 Responsiveness		✓	✓	✓	✓	✓
7 Aesthetics		✓	✓	✓	✓	MUST BLEND WITH DECOR
Adaptability	3 Configurability	✓	✓	✓	✓	✓
	4 Openness	N/A	N/A	→		
	5 Visibility	N/A	→			
	6 User Repairability	N/A	→			
Other Issues						

Figure 7: An example of a completed location-space form

<b>Key question</b>	<b>Questions about the use of the system</b>	<b>Questions about the system</b>
Does the user need a continuous and reliable service from the system?	Could the user (accidentally) physically break any components of the system?	What are the consequences if the system fails to work when required?
	Is the system only used at specific times of the day or must it be available all the time? If specific times, when?	Could system failure be caused by components/features of the system which are not really needed by this user?
	What user interactions could cause the system to become unavailable or unstable or produce false readings?	What could happen if the system responded unexpectedly?
	Could different people in the same household use the system in different ways?	How would the system respond in the event of power or telecommunications failure?
		Is it crucial for the sensors to accurately measure what they are supposed to measure? What are the consequences if they don't?
		What are the consequences if the system produces (a) false positives (b) false negatives?
		Does the system need to have a backup so that service can be continued after some failure?

**Figure 8: Questions associated with the reliability and availability attributes**

<b>Key question</b>	<b>Questions about the use of the system</b>	<b>Questions about the system</b>
Are the ways of interacting with the system appropriate for that user?	Does the user understand how the system should respond to different inputs?	Are the interaction devices used (e.g. keyboard) appropriate for that user?
	Could the user cause a critical failure by inputting the wrong information? How can this be avoided?	Are all the devices (e.g. switches) positioned so that they can be easily accessed?
	How does the system alert the user to faults, errors and failures? Could these alerts be confusing?	Are the devices installed discretely and securely? How likely is accidental activation?
	Does the user have to input information within a specific time for the system to operate correctly?	Is text in system messages of the correct size, font, colour and contrast?
	Does the system provide visual/audible/textural cues to assist the user in operating the system?	Are audible alerts audible and clearly understandable by the user?
	Does the user have physical problems that restricts how they might use the system?	Could visual alerts exacerbate other conditions, such as epilepsy?

**Figure 9: Questions associated with the usability attribute**

<b>Key question</b>	<b>Questions about the use of the system</b>	<b>Questions about the system</b>
Can the user or a helper fix the system if it goes wrong or has to be reset?	Does a user need special access codes, to change the system? How do users get these codes?	What user repairs are possible? What repairs can be done on site by a technician? What repairs require the system to be returned to the supplier?
	How does the user reset the system to its default settings?	Are tools required to open the casing?
	Is there built-in system support for repairing detecting and repairing problems?	Will the system tell the user if a fault has been detected?

**Figure 10: Questions associated with the user repairability attribute**



**Figure 11: A standard door opener**

## **4.2 MDDS in use**

To illustrate the use of MDDS, we use a simple scenario that has been derived from our experience in initial tests of the method. We have combined elements from different situations to demonstrate how the method might be applied. In this case, the method is used to reject a ‘standard’ solution and justify the choice of an alternative system.

*Mrs Jones is a retired art teacher and lives alone in what has been her family house for 40 years. She has mobility problems and walks, with difficulty, using a frame. She cannot manage the stairs so her house has been adapted so that she lives in the downstairs rooms. However, she does not have serious problems with her hands so is still an active painter. She uses her living room as a studio. She has regular visits from her art club friends but because walking is such an effort, it takes her up to 10 minutes to get to the front door and let them into the house. She feels bad about making people wait such a long time at the front door and is worried that she may sometimes miss important visitors.*

*She discusses the problem with her occupational therapist. The OT has been introduced to MDDS and is keen to experiment with the method. Her functional assessment of Mrs Jones is that ‘she has considerable mobility problems which means that she is socially isolated as she cannot manage to open the front door in time to respond to visitors’. Investment in a home support system is therefore justifiable.*

*The local authority has recently entered into an agreement with a supplier to provide ‘smart’ automated door opening systems with a remote control and a link to the TV system. These allow users to see who is at the door on a standard TV and then to open the door using the remote control device. They have instructed OTs that these should normally be fitted in situations where the user has difficulty opening the door. Mrs Jones’s OT therefore suggests that this system should be installed.*

### **4.2.1 Assess needs**

The OT has skipped the first stage of the method (Assess needs) and has chosen an off-the-shelf solution. The reason for this is that she already knows Mrs Jones and her situation and that Mrs Jones is articulate enough to explain her difficulties in opening the door to visitors. We anticipate that missing out this stage will be fairly common for professionals but, as previously explained, we have included it so that MDDS may be used by carers and relatives of people who may require home support systems.

### **4.2.2 Propose design**

The initial design proposal is actually determined by external factors – the local authority’s decision to standardise on one type of door opening system. As suggested earlier, this is a common situation – for reasons of cost or because of specific procurement agreements, OT’s may have a limited choice of systems that they may propose.

The OT uses the MDDS checklist associated with this stage (the initial design checklist) to perform an evaluation of the design proposal. The key guidelines here are:

#### ***Avoid actuators wherever possible***

This system involves an actuator to open the door (Figure 8) This is enclosed in a grey metal box and

requires external wiring for power. Installing the system will involve disturbing the decoration in Mrs Jones's hall. The OT has had previous experience of problems with door openers and has some concerns about the decision to standardise on them.

***People care about how things look***

The OT shows Mrs Jones a brochure with a photograph of the door opener. Mrs Jones is not happy with the 'clunky' look of the actuator that opens the door (Figure 11) – she has a strong sense of aesthetics and has thought carefully about how her hall is decorated.

***Check that the user really wants the technology***

Mrs Jones makes the point that she doesn't actually watch television much but prefers to spend her time painting. Therefore, when the doorbell rings, the system proposed would mean that she would have to turn on the television before she could see who was there. She would find this a nuisance.

By this stage, the OT is concerned that the 'standard' solution is not appropriate in this case and that it would cause as many problems for Mrs Jones as it solves. However, to justify a decision not to use this standard system, more specific information is required, so the OT moves on to the next stage of the method.

**4.2.3 Select dependability attributes**

The next stage in the method is to assess the revised solution for dependability in the broad socio-technical sense that we have discussed here. The OT uses a location-space form as shown in Figure 6 to decide on which of the dependability attributes are most important. For space reasons, we have not included this here but, after discussions with Mrs Jones, she decides that the most important dependability attributes are availability and reliability, safety, usability, aesthetics and user repairability.

**4.2.4 Assess design**

Using the checklists associated with each dependability attribute, the OT assesses the proposed solution.

***Availability and reliability***

The availability of the system is influenced by the fact that Mrs Jones does not watch much television. As the system is dependent on a TV, then the system would not be available on demand.

There are general problems with door opener reliability although there are no reports that this model is worse than average.

***Safety***

Mrs Jones is concerned about safety with an automated door opener. These normally leave the door open for a predetermined time period so that people who move slowly can get in or out. She is concerned that this could allow an intruder who followed a legitimate visitor access to her home.

***Usability***

To use the system, Mrs Jones may have to switch on her TV when the doorbell rings. This is in the same room as her easel but is positioned so that she can't see it from her painting chair. Her painting chair is set up so that her easel catches the light – the TV is situated in a corner of the room, away from the light. Thus, to use the system, Mrs Jones would have to get out of her seat and move across the room - negating the goal of the system to help her open the door without having to walk.

***Aesthetics***

This is an issue which Mrs Jones feels particularly strongly about. She has worked carefully to maintain period features in her house. She says that she would rather not have a door opener than have an industrial casing with intrusive cables.

***User repairability***

Mrs Jones is concerned about what would happen if anything went wrong with the system. Can it simply be reset or would this require a technician to call. How long might it be out of action? In fact, the proposed

system is not user repairable and, if it fails, it may not be possible to open the door at all until a technician calls to repair it.

Once the assessment has been completed, the OT is completely convinced that this is the wrong system for Mrs Jones and has sufficient evidence to justify an alternative approach. As the requirement is primarily to let visitors in rather than to let Mrs Jones out, there is actually no need for a system that both unlocks and opens the door. Rather, what is needed is a door unlocking system. Visitors can then let themselves in so long as they know when the door is unlocked. Mrs Jones keeps a telephone on a table beside her painting chair so that she can answer calls easily – ideally she could use this along with an intercom to talk with visitors and tell them when the door is unlocked. The OT therefore proposes an alternative design using an intercom and an automated door lock with the lock switch on a ribbon that Mrs Jones can wear around her neck.<sup>1</sup>

The dependability assessment is repeated and demonstrates that this solution is more appropriate for Mrs Jones and that she will be happier with it.

## 5 Method evaluation

The evaluation of any design method for HCI design, software or socio-technical systems is problematic. It is practically unrealistic to carry out parallel studies where two systems are designed, one with and one without the method, and their designs compared. Specialist knowledge (in this case, the needs of older and disabled people) is often required to complete a design, so experiments with student volunteers are meaningless. Dependability assessment adds to these problems as a well-designed system will fail infrequently, so assessing the delivered dependability in terms of observed failures can take months or years.

For these reasons, we made no attempt to answer the question which we would like to address namely ‘Does MDDS deliver more dependable HS systems?’. Rather, we adopted a qualitative approach which looked at the usability, readability, and learnability of MDDS and which collected opinions from method users on its applicability and usefulness. The question addressed in the evaluation therefore was ‘Do designers believe that MDDS helps them design more dependable systems?’. Our aim was to discover how to improve the method and its presentation.

The primary evaluators were 2 occupational therapists, and 5 specialists in assistive technology specification. We also involved 5 managers of care homes who had extensive experience with the installation of assistive technology systems and 3 social workers who worked with older people. The evaluation involved distributing the MDDS handbook along with an explanation of what we were trying to achieve and following this up with semi-structured interviews which helped us understand the evaluator’s opinions of our approach.

The questions that were used as starting points in the interviews were:

1. What is your overall impression of MDDS?
2. Would you consider using it?
3. What could be improved?
4. Was the language clear and understandable?
5. Was the information accurate?
6. What was omitted that should have been included?
7. How long did you spend working with MDDS?

---

<sup>1</sup> For an example of such a system which is commercially available, see <http://www.independentliving.co.uk/door-entry.html>. This also shows the connection of such a system to a TV.

8. We are considering supporting MDDS using a computer program that could be used on a PDA. If it were available in this form would you find it acceptable?.

These questions were intended to start a discussion and responses were very varied. Some were one-word answers, others prompted several minutes of discussion. As a consequence, a summary of the responses is not really useful.

MDDS has been advertised on the Foundation for Assistive Technology website and we have made it available for download for the past 18 months. As a result of this, there have been 40 downloads of the method handbook. There has also been an evaluation response sheet for people to download, complete and return available from the same download site. This evaluation form contains the above questions with half a page to write in a response.

At the time of writing, responses to the evaluation forms have been limited, with only 3 evaluation forms returned. A typical response received was 1) good... but long 2) possibly 3) Yes make it shorter 4) Yes most of the time 5) Seemed to be 6) Specialist wheelchair provision 7) Just read it 8) yes probably. These types of response are of little real value, but the shortness of them is not unexpected. This, along with the small number of responses, reflects the limitations of remote evaluation without face to face discussion.

In the evaluation discussions, we guided evaluators to the dependability model and asked them to comment on its clarity and usefulness. Most respondents saw this as a useful starting point and a diagram that seemed clear and helpful, although one evaluator noted that the priorities were not as she would have them.

*“Should it be prioritised? For me ‘Requirements’ should be first, does the building require it or do I require it. (flicking from checklist to checklist and examples) Then for availability and reliability, for a single device/non-critical they are almost the same, so I would probably go in that sort of order, and that would help me. If it was my checklist personally.”* (Care manager)

*“Yes it’s a methodical process, I like it”* (Occupational therapist)

Other comments referred to more general aspects of MDDS and its applicability and necessity.

*“I suppose with something like this it might make you think... it might provoke questions...I personally would never have thought of... I want something that looks nice is easy to use and is reliable, that would be my first thing and then obviously I would have to consider the cost of using the method... So there is a cost implication for that.”* (Care Manager)

*“This could be a really important model as it seems to hit the spots other models fail to reach”*  
(Rehabilitation engineer)

*“I like the categories, the way you have approached things from a person point of view is really good”*  
(Occupational Therapist)

*“It is after the system is installed we start to ask the questions...”* (Care Manager)

The latter comment is commonly expressed. Designers are not totally sure how the system will perform until after it is installed. The questionnaires attempt to break this cycle by ensuring that most dependability issues are covered. However, some people felt the method was too complex for their existing needs, and would have preferred a simpler version with fewer questions. They thought that some of the language used in the handbook was too technical:

*“I was just going to say, you would have to wait until the person was familiar with what they were doing to start and bring this in at a later date otherwise it would confuse them totally as they will not have come to grips with assessing the situation making a referral getting to know the technologies, you know? ... Some social workers would not understand what you mean by this, you know reconfiguring the system it might go over their head... I mean it is a valid question! I would leave it in as it is needed. It is just a funny time as you are a bit ahead of the game... You see these questions, they require familiarity with the*

*systems, 'cos they (current social workers) wouldn't have a clue at the moment. (Scanning through the checklists) mmm 'Compatibility' ... that's a grey area isn't it!" (Care Manager)*

*"It was not considered suitable for our use on its own as it was not immediately clear how it works - again, the size, language and layout was perceived to be hard work to get to the crux of what to do." (Care Manager)*

Respondents considered a positive aspect of MDDS is that it extends beyond the functional qualities of design to consider aspects such as aesthetics and the building structure. Within the building where one respondent works they are currently undergoing substantial work on the call system. This has meant that the architectural features in some rooms are likely to be damaged in the process.

*"Going on to the fire system that is going to have to be involved in altering, because they are going to have to lift carpets and bore things through. We have a beautiful room, directly above the sitting room... it has the most beautiful cornices ("are you going to have to destroy these") well we have been well warned. You know... the lads are doing really, really hard to do what they are doing, the problem is that they are going to have to take all the wires from all the rooms etc because it has to all be hard wired... two rooms! ... to the master board which is just out there...Aesthetics: it's their home, we don't want it to look institutional, so you have to make it as aesthetic as possible... we put a lot of work in." (Care Manager)*

The design guidelines section, which contains twenty suggestions on principles and guidelines to assist designers, proved to be well received and many respondents considered these to be very helpful. The following excerpts are from respondents' views of this section:

*"I suppose Question 3 (Keep designs simple) is very important you just tend to focus in on a part... or problem actually... And does the person want the technology... that's a good one as well... Its good yeah" (Care Manager)*

*"Even just now, you know, looking at it just now, I can see a few bits that would certainly prompt thoughts....And I can even think of situations we currently have where it might be an idea for us to start using it to see if we can find a solution to things." (Care Manager)*

*"These are great; can I use them in teaching? It might make some of my students think outside the box" (Rehabilitation Engineer)*

In general, designers were universally supportive of the need for a method to support HS design and the majority of our evaluators found that MDDS was a useful tool to support their everyday work. The particular value seemed to be in supporting the assessment and adaptation of a generic design solution to the needs of a particular user. This reflected our own experience in initial trials of the method where we used MDDS in the design of technologically-assisted dwellings for autistic residents. Starting from standard design solutions that had already been proposed, we found that MDDS proved invaluable as a short cut to highlight the real needs and aspirations of the potential users of the technology and to identify failure modes that had not been considered.

However, some HS designers felt that the method was over-complex and involved too many checklists with too many questions. They suggested that this would inhibit take-up as busy occupational therapists simply would not have enough time to learn how to use the method effectively. We recognise this as a problem that should be addressed in future revisions of MDDS.

## **6 Conclusions and lessons learned**

In this paper, we have described a model for discussing the dependability of home support systems that help people with the activities of everyday life. We have argued that domestic systems are markedly different from organizational systems and that these differences lead to an holistic model of dependability incorporating the technology, the user and their environment. Our dependability model therefore extends existing technically-focused system dependability models and so provides a basis for understanding what

system dependability ‘means’ in a domestic environment. The dependability model was used as a framework for a method for use by social care professionals, system users and others involved in HS system design. The aim of this method is to ensure that issues of dependability are considered at an early stage in the system definition process rather than after the system has been installed.

The model helps structure discussions of dependability and, as such, was exposed to a number of social care professionals as part of the method evaluation. In general, users of the method found the graphical representation of the model to be useful in highlighting the attributes that they should consider in their systems design. They did not identify any system attributes that were not covered by the model. However, there were concerns about the overall complexity of the model and how this might limit its usefulness. Some users also found the technical nature of some of the terms confusing – in particular, people who are not technical experts do not understand subtle distinctions between availability and reliability. The evaluations did not consider situations where security was an issue but we suspect that the same might apply to confidentiality and integrity. We see this as a presentation problem which can be addressed through better explanation rather than a fundamental limitation of the model.

Comments on the MDDS method were also generally positive. Users liked the different types of checklist and how these brought issues to mind that they would probably not have considered. They particularly liked the people-centred approach that we adopted where the overall needs of the individual central rather than simply focusing on their disability. Again, however, there were concerns expressed about the complexity of the approach.

Our general conclusion, therefore, is that the dependability model is a useful construct that provides a vocabulary and structure for discussing domestic systems dependability and that the MDDS method is a promising approach that uses this model in a constructive way. However, more attention needs to be paid to presentation. We also need to think about how to simplify the method to make it more usable by non-technical users.

This need to deliver a method that is easier to use will be the focus of our future work. We intend to redesign the presentation of MDDS (it is currently delivered as a paper handbook) so that, after completion of an electronic-version of the location-space form, simpler versions of later checklists automatically generated, based on the chosen dependability attributes. We believe that we may be able to reduce the number of questions associated with each dependability attribute may by taking into account the characteristics of the proposed device type.

## **7 Acknowledgments**

Blanked out.

## **8 References**

- Allen, B. and Dillon, B. Environmental Control and Field Bus systems: A study of field bus systems and their potential environmental control application for people with disabilities. Dublin, Ireland: Central Remedial Clinic. 1997.
- Avizienis, A., Laprie, J.-C., Randell, B., et al., Basic Concepts and Taxonomy of Dependable and Secure Computing. *IEEE Transactions on Dependable and Secure Computing* **1**(1) (2004) 11-33.
- Batavia, A. I. and Hammer, G. S., Toward the development of consumer-based criteria for the evaluation of assistive devices *Journal of rehabilitation research and development. J. of Rehabilitation Research and Development* **27**(4) (1990) 425-36.
- Baxter, G., Dewsbury, G., Monk, A., et al., Managing the Risks of Electronic Assistive Technology: Two complementary methods. Proc. 5th Annual DIRC Conference, Edinburgh, 2005
- Baxter, G. D. and Monk, A. F. (2006). A technique for the client-centred evaluation of electronic assistive technology. *Contemporary Ergonomics 2006*. Bust, P. London, UK, Taylor and Francis: 236-40.

- Bentley, R., Rodden, T., Sawyer, P., et al., Ethnographically-informed Systems Design for Air Traffic Control. Proc. CSCW'92, Toronto, Canada, ACM Press, 1992 123—29.
- Bjørneby, S., Smart Houses': Can they really benefit Older People? Signpost **5**(2) (2000).
- Blythe, M., Monk, A. F. and Doughty, K., Socially dependable design: The challenge of ageing populations for HCI. *Interacting with Computers* **17**(6) (2005) 672-89.
- Boehm, B. W., Brown, J. R., Kaspar, H., et al., Characteristics of Software Quality. North-Holland, Amsterdam, 1978.
- Brand, S., How Buildings Learn: What happens After they are built. Penguin Books, New York, 1995.
- Brownsell, S. and Bradley, D., Assistive Technology and Telecare: forging solutions for independent living. (2003).
- Crabtree, A., Designing Collaborative Systems: A Practical Guide to Ethnography. Springer-Verlag, London, 2003.
- Day, H., Jutai, J., Woolrich, W., et al., The Stability of Impact of Assistive Devices. Proc. Resna'99, Arlington, Va., 1999 201-3.
- Demers, L., Weiss-Lambrou, R. and Ska, B., Item Analysis of the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST). *Assistive Technology* **12**(2) (2000) 96-105.
- Dewsbury, G., The Social And Psychological Aspects Of Smart Home Technology Within The Care Sector. *New Technology In The Human Services* **14**(1-2) (2001) 9-18.
- Dewsbury, G. (2005). <http://www.smarthinking.ukideas.com/MDDS.pdf>.
- Dewsbury, G., Clarke, K., Hemmings, T., et al., The Antisocial Model of Disability. *Disability and Society* **19**(2) (2004a) 145-58.
- Dewsbury, G., Clarke, K., Rouncefield, M., et al., Depending on Digital Design: Extending Inclusivity. *Housing Studies* **19**(5) (2004b) 811-25.
- Dewsbury, G., Sommerville, I., Clarke, K., et al., A Dependability Model for Domestic Systems. Proc. Proc. SAFECOMP 2003, Edinburgh, Springer, 2003 103-15.
- Edge, M., Taylor, B., Dewsbury, G., et al., The Potential For 'Smart Home' Systems In Meeting The Care Needs Of Older People With Disabilities. *Seniors' Housing Update* **10**(1) (2000) 6-7.
- Fisk, M. (2001). The implications of smart home technologies. *Inclusive Housing In An Ageing Society: Innovative Approaches*. Peace, S. and Holland, C. Bristol, Policy Press.
- Fisk, M., Social Alarms to Telecare: Older People's Services in Transition. Policy Press, Bristol, 2003.
- Fuhrer, M., Assistive Technology Outcomes Research. *American Journal of Physical Medicine and Rehabilitation* **80**(7) (2001) 528-35.
- Gann, D., Venables, T. and Barlow, J. Digital Futures: Making Homes Smarter. Coventry: Chartered Institute of Housing/Joseph Rountree. 1999.
- Gitlin, L. (2002). Assistive Technology in the Home and Community for Older People: Psychological and Social Considerations. *Assistive technology: Matching Devices and Consumers for Successful Rehabilitation*. Scherer, M. J. Washington, American Psychological Association.
- Gottlieb, A. and Caro, F. Providing low-cost assistive technology equipment through the home care services. Boston: Gerontology Institute. 2000.
- Harper, R., Inside the Smart Home. Springer Verlag, London, 2003.

- Heath, C., Jirotko, M., Luff, P., et al., Unpacking collaboration: the interactional organisation of trading in a city dealing room. *Computer Supported Cooperative Work* **3**(2) (1994) 147-65.
- Heath, C. and Luff, P., Collaborative Activity and Technological Design: Task coordination in the London Underground control room. *Proc. ECSCW'91*, Amsterdam, Kluwer, 1991 65-80.
- Hughes, J., Rodden, T., King, V., et al., Moving out from the control room: ethnography in system design. *Proc. CSCW'94*, Greensborough, North Carolina, 1994 ACM Press .
- Hughes, J. A., O'Brien, J., Rodden, T., et al., Designing with Ethnography: A Presentation Framework for Design. *Proc. Proc. DIS'97*, Amsterdam, ACM Press, 1997 147-59.
- Jirotko, M. and Luff, P., Supporting requirements with video-based analysis. *IEEE Software* **23** (3) (2006) 42-44.
- Kinder, T., A Sociotechnical Approach to the Innovation of Network Technology in the Public Sector - The introduction of smart homes in West Lothian. *European Journal of Innovation Management* **3**(2) (2000) 72-90.
- Laprie, J.-C., Dependable Computing: Concepts, Limits, Challenges. *Proc. FTCS- 25: 25th IEEE Symposium on Fault-Tolerant Computing*, Pasadena, Ca., IEEE Press, 1995
- Laprie, J.-C., Arlat, J., Béounes, C., et al. (1995). Architectural Issues in Software Fault Tolerance. *Software Fault Tolerance*. Lyu, M. R. Chichester, John Wiley & Sons: 47—80.
- Lupton, D. and Seymour, W., Technology, selfhood and physical disability. *Social Science & Medicine* **50**(1851-62) (2000).
- Maciuszek, D., Aberg, J. and Shahmehri, N., Evaluation and refinement of a design framework for generating dependable virtual companions for later life. *Proc. 3rd Int. Conf. on Smart Homes and Health Telematics (ICOST'2005)*, Magog, Canada, 2005 50-64.
- Marshall, M., *Astrid: A Social & Technological Response to Meeting the Needs of Individuals with Dementia & their Carers*. Hawker Publications, London, 2000.
- Miskelly, F., Assistive Technology in Elderly Care. *Age and Ageing* **30** (2001) 455-58.
- Mumford, E. and Weir, M., *Computer Systems in Work Design – The ETHICS method*. Associated Business Press, London, 1979.
- Phillips, B. and Zhao, H., Predictors of Assistive Technology Abandonment. *Assistive Technology* **5**(1) (1993) 36-45.
- Randell, B., Facing Up To Faults. *Computer J.* **45**(2) (2000) 95-106.
- Rasmussen, J. (1987). The definition of human error and a taxonomy for technical system design. *New Technology and Human Error*. Rasmussen, J., Duncan, K. and Leplat, J. Chichester, John Wiley and Sons.
- Reason, J., *Human Error*. Cambridge University Press, Cambridge, UK, 1990.
- Sandhu, J. (2002). Multi-Dimensional Evaluation as a tool in Teaching Universal Design. *Universal Design; 17 Ways of Teaching and Thinking*. Christopherson, J. Husbanken, Norway.
- Spolsky, J., *User Interface Design for Programmers*. Apress, Berkley, CA., 2003.
- Suchman, L., *Plans and situated actions: the problem of human-machine communication*. Cambridge University Press, New York, 1987.
- Viller, S. and Sommerville, I., Coherence: an approach to representing ethnographic analyses in systems design. *Human-Computer Interaction* **14** (1999) 9-41.

Woolham, J. and Frisby, B., Building a Local Infrastructure that Supports the use of Assistive technology in Dementia Care. *Research Policy and Planning* **20**(1) (2002).