A Dependability Model for Domestic Systems

Guy Dewsbury, Ian Sommerville, Karen Clarke and Mark Rouncefield

Computing Department, Lancaster University, Lancaster LA1 4YR, UK

g.dewsbury@lancaster.ac.uk, is@comp.lancs.ac.uk, k.m.clarke@lancaster.ac.uk, m.rouncefield@lancaster.ac.uk,

Main Contact: g.dewsbury@lancaster.ac.uk

Abstract. Technically-based models of dependability such as Laprie's model suggest that there are attributes that should be reflected in the design of a system. These attributes tend to be attributes of the software or hardware and the models assume that system operators can be treated in the same way as software or hardware components. While this approach may be valid for some control systems with tightly specified operational processes, we argue that it must be extended if it is to be applied to systems where there is significant discretion on the part of the user as to how they will use the system. In particular, for systems in the home, we argue that the notion of dependability should be broadened This paper suggests that through the design of assistive technology (AT) systems for older people we can demonstrate the user should be placed at the centre of the process when considering system dependability.

1. Introduction

Ever since computers and computer software were used as essential components in critical systems the dependability of computer-based systems has been a concern. The 1980's, in particular, saw a surge in research in safety-critical systems and major advances in our understanding of the dependability of computer-based systems have been made since that period. This work on dependability has been mostly concerned with the use of computer-based systems as control systems and protection systems so, inevitably, dependability research and practice has been driven by the requirements of this type of system.

Now, however, it is not only protection and control systems that are critical systems. National infrastructures and businesses depend on large scale information systems that must have a high-level of availability and reliability. Embedded systems are no longer just situated within organisations but are also fundamental to the successful operation of our cars and, increasingly, our homes. 'Failure' of these systems can have serious organisational or personal consequences so paying attention to system dependability is essential.

Home systems that incorporate computers are typically composed of assemblies of relatively low-cost, off-the-shelf devices. With a few, very expensive, exceptions these devices are stand-alone devices with hard-wired communications between them. However, in the very near future, it is clear that connecting these devices to a home network with some centralized control system will become a reality. To some extent, standards such as ISO 9000, BS EN 29999 and BS EN 1441 [1] already allow this for assistive technology systems intended to provide support for elderly and disabled people in their home and notions of a 'home media network' have been proposed [2].

In this paper, we argue that the model of system dependability that is appropriate for control and protection systems must be extended if it is to be applicable to domestic computer-based systems. We propose an extended model that embraces the traditional model but which includes the user and the system's environment rather than positioning them outside the system boundary. That is, when a computer-based system is installed in a domestic environment, we should not just be concerned with whether or not that system is failure-free. Rather, the overall system dependability depends on whether or not it fulfils its intended purpose as far as the system users are concerned. If it does not do so, then it will not be used. This situation is equivalent to an unplanned system failure rate of 100% - hardly a dependable system.

In deriving the model proposed here, we have drawn on research that we are undertaking in dependable assistive technology design for installation in the homes of older people. The users of the assistive technologies may suffer from a range of disabilities with assistive technology used to help them overcome these disabilities and cope with everyday life in their own home. These elderly people depend on this technology to maintain a reasonable quality of life but, all too often, the technology lets them down. Sometimes, it simply fails to operate but, more often, it is not or cannot be used as intended because its design does not take into account the specific needs of the elderly users, the context where the system will be installed and the natural human desire to control rather than be controlled by technology.

In the remainder of the paper, we introduce Laprie's dependability model and examine some of the assumptions that underlie that model. We challenge the applicability of some of these assumptions for domestic systems in sections that discuss the role of the user in domestic systems and the distinctions between home and organisational environments. We then go on to introduce our view of dependability as it is applied to domestic systems, suggesting that as well as 'traditional' dependability attributes, dependable home systems must also be acceptable to their users, fit in with their daily routines and lifestyle and support user adaptation as user needs change.

2. Computer System Dependability

> ***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 behaviour as it is perceptible by its user(s); a*

> *user is another system (human or physical) which interacts with the former.* [3]

Traditionally, it is considered that computing systems are characterised by five fundamental properties: functionality, usability, performance, cost and dependability [4]. The core features of dependability models tend to assume that dependability is a technical attribute and that the dependable features are within the computer system itself. Critical systems require that the functionality of the software and hardware are free of faults, resilient to external attacks, and provide a high level of confidence. As Laprie [5] suggests (1995) dependability can be considered according to different properties that allow attributes of dependability to be defined as

> *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.* [6].

These attributes and properties allow the dependability theorist to consider the distinctions between faults, errors and failures. These can be framed within the notions of 'fault prevention', 'fault tolerance', 'fault removal', and 'fault forecasting', which enable the software designer to trace and prevent undesirable problems. Laprie develops these ideas in the forms of a dependability tree which locates dependability within three categories: Attributes, Means and Impairments from which a number of attributes extend (Figure 1). The dependability tree allows the software engineer and the designer to picture how faults and problems are derived, and thus are avoided. Hence dependability can be considered to be the extent to which its operation is free of failure [7].

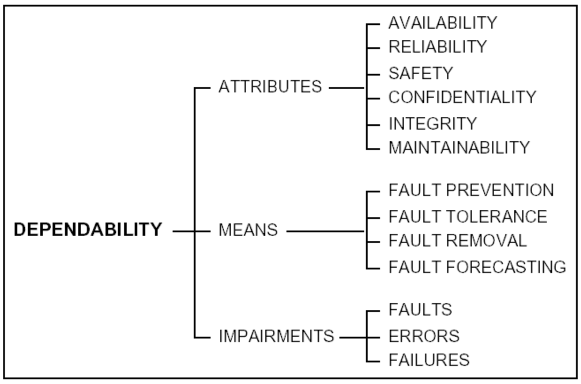

Fig. 1. Laprie's Dependability Tree [8]

The basis of Laprie's dependability model was extensive work on the safety and reliability of computer based control and protection systems. The model therefore reflects the nature of these systems and how they are used and is clearly based on a number of assumptions:

- That errors arise inevitably from faults (the hypothesised cause of an error). Faults can be failures of other systems so a failure of a development system to detect an incorrect variable initialisation is reflected as a fault in the operational system. When this initialisation is carried out, an error has arisen.
- That the system is constructed in such a way that an error (defined by Laprie as 'that part of the system state which is liable to lead to a subsequent failure') can, at least in principle, be detected by an external observer.
- That we can recognise when a system failure (defined by Laprie as a deviation from fulfilling the system function) occurs.

These assumptions are fundamental to the model of dependability that has been accepted by researchers and practitioners for a number of years. However, as we will argue later in this paper, their technical orientation means that they do not properly consider the interactions between the user and the system. Consequently, they are not wholly adequate for domestic systems. Furthermore, because of the differences between the home and organisational environment, we will also argue that, as well as the technical dependability attributes in Laprie's model, additional system attributes are central to the dependability of domestic systems.

3. The Role of the User

Most dependability theory attempts to consider humans as elements in the system that are comparable with other software or hardware elements. In his paper, Laprie recognises the importance of human operators but discusses them in terms of 'interaction faults' resulting from 'human errors'. Although the point is not made explicitly, there seems to be an assumption that the fault-error-failure model applies equally to humans as it does to technical system components.

However, if we examine the assumptions underlying the dependability model from a human perspective, it is immediately obvious that they do not hold.

- People are not automatons and they use their intelligence to discover many different ways of doing the same thing. An action that might be interpreted as a failure for one person (e.g. an air traffic controller placing aircraft on a collision course) might be part of a dependable operational process for another where the controller may have a reliable method of ensuring that they will move one of the aircraft before any danger ensues [9].
- We cannot monitor our brains to identify the erroneous state that has arisen.
- The development process for people from conception (fusing of genetic histories) through nurture to education and training is so extended and complex that identifying the 'fault' that resulted in a consequent failure is impossible.

We accept that, for some classes of highly automated system where operational processes are tightly defined and operators are highly trained then the benefits of adopting a consistent approach to all elements in the system may outweigh the disadvantages of treating the human operators in a simplistic way. However, for other classes of system where use of the system is uncontrolled any dependability model that does not consider the distinct nature of people is incomplete.

For domestic systems, the users of the system are central to the design and central to the consideration of dependability. In the home, there are no defined operational processes, enormous variation in system users and no 'quality control'. 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. To achieve dependability, we must take an approach that integrates the user and environment with the technology rather than considering dependability as a property of the technology alone.

4. Domestic and Organizational environments

Laprie's model for computer system dependability incorporates a further assumption that we have not yet discussed. This assumption is that the critical computer systems are developed and used by organisations rather than individuals. Organisations impose 'acceptable practices' upon the individual and therefore standardise and control the use of technology. As a trivial example of this, many organisations forbid their employees to install software on their own computers and insist that only allowed software be installed by system technical staff.

Products and people are covered by health and safety regulations and work practices that are designed to reduce accidents and improve productivity. Operational processes are defined and staff are trained to follow these processes. There are (at least in principle) sanctions for staff who do not 'follow the rules'. Computer-based systems may be designed and deployed to support and enforce particular processes.
Because there is an 'expected' way of working, it is possible to recognise deviations from these and associated system 'failures'.

Activities and processes are consistent in organisations but not in the home where greater flexibility exists. In contrast to organisations where technologies and processes are limited, within the home people can choose whether or not to use technology, how to use it and where they wish to use it. People do not read instruction manuals, are not trained in the use of domestic technologies and the use of these technologies often depends on their previous technology experience. For example, on early video recorders the process of setting up a timed recording was difficult and error-prone. Although this has been much improved on modern machines, a large number of people simply do not use pre-recording because they consider it to be beyond their capabilities.

Another important difference between the home and organisations is in the timing of activities. In organisations, activities tend to be set in regular procedures, such that work begins at prescribed times. The organisational system has regular processes through which activities must follow. Dependable operation may rely on this timing. For example, in a hospital, a surgeon in a hospital can usually assume that appropriate pre-operative procedures have been carried out. A significant difference between the organisational system and the home system is that processes and timing standardised functions are dissimilar. Home routines are often unplanned and lacking rigid structure, although foreseen events may sometimes be planned and situated into a daily/weekly/monthly schedule.

Table 1: Home and Organisational Differences

CRITERIA	HOME CONTEXT	ORGANISATIONAL CONTEXT
USAGE	Ad Hoc Uncontrolled	Systematically Controlled
STANDARDISATION	Legislative and Product Specific	Standardised with Organisational Environment
PROCESSES	Uncontrolled and Ad Hoc	Controlled and Systematic
OPERATORS	Untrained and Unskilled	Training Available
OPERATIONS	Unrestricted and Ad Hoc	Restricted and Systematised
ACTIONS AND ACTIVITIES	Undefined and Uncontrolled	Predefined and Limited
SAFETY	Suggested but Difficult to Enforce	Controlled through Systems

Table 1 outlines some of the differences between technology use in organisations and the home environments; it is not to be applicable to *all* organisations or *all* homes, but a rough guide.

Table 1 also illustrates that the home does not provide the safeguards and assurance that many organisational environments are legally required to do. Technology in the home and organisations 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 or should not be used in the domestic arena. The organisation 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 overall dependability of an organisational socio-technical system that includes a computer-based system is derived from the dependability of the computer system and how it is used. The controlled nature of the organisational environment means that usage of a computer-based system can be controlled and mandated. In the home, however, the dependability of the socio-technical system, that is, the user plus the technology, depends primarily on how (if at all) the user *chooses* to use that technology. For example, if an elderly person is offered a communication aid that they cannot fit into a pocket of their normal clothing, they may choose not to carry that aid. Therefore, the availability of the communication aid system is restricted to times when it can actually be carried by the user. The communication aid itself may be dependable but the overall *system* of helping with communication is not.

The dependability of systems extends beyond the hardware and software into the social and lived experience of the home dweller. As Lupton and Seymour [10] suggest, technology becomes part of the self-concept for the user and therefore it is essential that dependability does not just mean that a system behaves according to the expectations of its designers. Systems therefore have to be designed so that they are *acceptable* to users. We should not underestimate the difficulty of this design problem, particularly for assistive technologies.

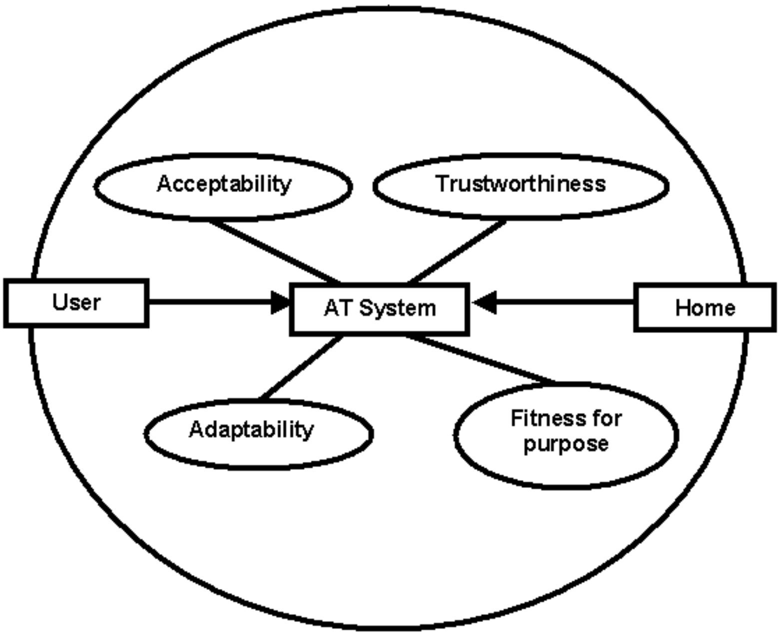

Fig. 2: Dependability Attributes of a Situated AT System

5. Dependability Attributes for Home Systems

We have argued that techno-centric models of dependability are not appropriate for domestic computer-based systems, especially those assistive technology systems that are intended to assist elderly or disabled people. Fundamentally, techno-centric dependability models exclude the user and the user's environment from primary considerations of what dependability means. In principle at least, they can consider a system that is useless and never used to be dependable. We reject this view and believe that we should not just be concerned with dependability in use but also dependability of use. By this, we mean that it is not enough for a system to be dependable whilst it is in operation; it is also essential that we can depend on the system actually being used for its intended purpose.

In this section, we present our initial work on the development of a dependability model for home systems. So far, we have focused on identifying and understanding the attributes of a domestic assistive technology system that contribute to its dependability. These 'dependability' attributes therefore reflect, in our view, that it is critical for practical dependability that the system is used and that its use meets real needs of the user.

For domestic systems, we need to consider the dependability of the socio-technical system as a whole where the system includes the user, the home environment and the installed assistive technology (Figure 2). To achieve system dependability, we propose that the required characteristics of the assistive technology should be considered under four headings. These are:

Trustworthiness In order for a system to be dependable, the user must trust that the system will behave as they expect. We define this attribute to be the equivalent of 'dependability' in Laprie's model. That is, it includes the traditional dependability attributes of availability, reliability, etc. However, we will argue below that these need to be re-interpreted to some extent to take into account the characteristics of domestic systems.

Acceptability We have argued above that a system that is not acceptable to users will simply not be used. Therefore, it is essential that system characteristics that affect its acceptability such as the system learnability and aesthetics are considered in the design process.

Fitness for purpose Fitness for purpose is taken for granted in most of the dependability literature but, socio-technical system failures regularly arise [11] [12] because a computer-based system is not fit for the purpose for which it was designed and users of the system have had to adapt their operational processes to accommodate the system's inadequacies. When the purpose of a system is to cope with disability, users may simply not have this option and the system may simply be unused.

Adaptability Within the home both the environment and the user's of the systems change. This is particularly true for elderly disabled people whose capabilities tend to decline as they age. Therefore, if system dependability is not to degrade, then it must be able to evolve over time, generally without interventions from the system's designers.

Of Course, there are overlapping characteristics but, for the purposes of discussion, we consider them separately here. Now let us examine each of these characteristics in more detail to assess what they might mean for domestic assistive technology systems.

5.1 Trustworthiness

In the context of domestic systems, we consider the trustworthiness of a system to correspond to the technical notion of dependability as defined by Laprie. That is, the trustworthiness reflects the systems availability, reliability, safety, confidentiality, integrity and maintainability. However, the nature of home systems as assemblies of relatively cheap, off-the-shelf devices, the fact that people at home are not systematically trained in the use of a computer-based system and the nature of the home itself means that these characteristics are different in a domestic rather than organisational context.

Availability and Reliability

For assistive technologies, availability and reliability are critical attributes. An elderly or disabled person's quality of life may be dependent on their assistive technologies and failure of these systems has severe implications for them. However, assistive technology system designers are faced with a challenging problem when trying to build systems with high-levels of availability and reliability. Systems are mostly composed of off-the-shelf devices where the overall AT system designer have no control over the engineering of these devices. Typically, hardly any information may be available about device reliability so designers must trust manufacturer specifications and quality control standards which, in our experience, are often optimistic. Furthermore, occupational therapists, for example, who work with users to specify requirements are not trained to understand system dependability issues and frequently mis-specify the system reliability that is required.

Safety

Clearly safety is a very important factor in domestic systems as it is essential that these systems do not injure their users. However, given that most systems are relatively low power systems and must conform to electrical safety standards, we consider that the risks of injury associated with assistive technologies are relatively low. In fact, the home is such an inherently dangerous place, especially for elderly people, that other risks far outweigh the risks associated with assistive technologies. This does not mean, of course, that we should install unsafe systems – however, it does suggest that it is not worth incurring very high costs in activities such as detailed safety analysis.

Some systems may purport to provide people with a safer environment, but through producing false alerts, the person will cease using the device. In this case, the person might be at greater risk than before the technology was installed, as other people might still expect that they are using the technology and are therefore covered against the potential danger.

Confidentiality and Integrity

While the need for integrity goes without saying, the issue of confidentiality is much more difficult in situations where elderly people depend on monitoring technology that alerts relatives and carers when a problem arises. These elderly 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. The level of confidentiality in a system therefore cannot be fixed but has to be programmable and responsive to an analysis of the events being processed by the system.

Maintainability

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 distinguish here between maintainability as the process of making unanticipated *engineering* changes to the system and adaptability which is the process of changing a system to configure it for its environment of use. In general, we consider that the relatively low-cost of AT equipment will mean that replacement rather than maintenance is the often norm so software and hardware changes and upgrades are unlikely. Therefore, we consider maintainability under the adaptability attributes that we discuss later.

5.2 Acceptability

The notion of acceptability was initially conveyed through an advocate of Universal Design (UD). Jim Sandhu [13] considers that the basic notion of UD requires the architect and designer to consider a number of properties and attributes. Sandhu uses an ISO standard definition to extrapolate a diagrammatic representation concerning system acceptability within a Universal Design context:

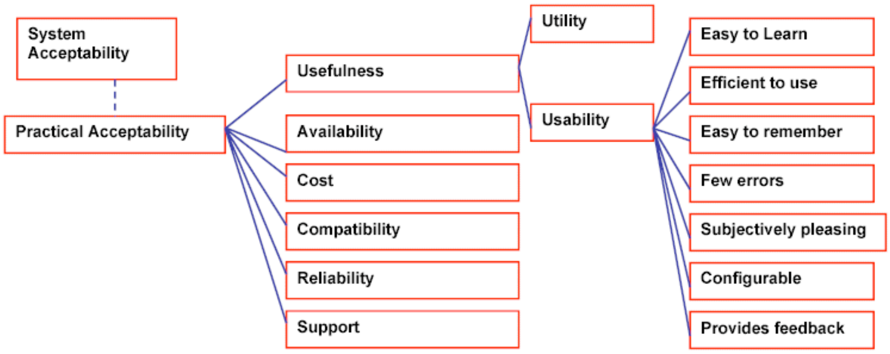

Fig. 3. Sandhu's System Acceptability Model [14]

Sandhu's diagram illustrates that for systems to meet his 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 situates the user and the product with in the same contextual model so reflects our views on the central significance of the user when considering system dependability. 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.

Our view of acceptability takes a simplified view of Sandhu's model as we consider some of his acceptability characteristics such as reliability, availability and configurability under other headings. Essentially, we consider that a system will only be acceptable if the user feels that the benefits that accrue from the system justify the costs and effort of buying, installing, learning to use and using the system. We therefore consider the principal acceptability characteristics to be:

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 relatively easily with no steep learning curve before any benefits can be gained from it.
3. **Cost** The system should also be within the budget of the person allowing for maintenance and repair costs in the future.
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.

5.3 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. This is particularly important for assistive technology systems that are not mass-produced systems but which may be systems that are designed and tailored specifically for an individual set of disabilities. Fitness for purpose is related to but distinct from acceptability. An assistive technology system may be acceptable to a user but if it is not carefully tailored to their specific needs then the compromises that have to be made in using the system may lead to system failures.

For example, a voice-activated system may be installed to help elderly users set off an alarm in the event of accident or illness. This system may work reliably so long as the user's voice is strong enough but if it does not take into account the fact that the elderly person's voice may be weakened in the event of an accident then it is not fit for its intended purpose.

Of course, this is not just an issue for domestic system but a more general dependability concern. 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. Given that the level of specification that is used for critical systems is totally impractical for domestic systems, the issue of fitness for purpose cannot be addressed in this way. Rather, the design of the system has to evolve as it is used to take into account the rhythms routines and activity patterns of the user's life and the particular characteristics of that user and their home.

5.4 Adaptability

Homes and the people living in these homes change with time [15]. 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 elderly adults typically decline as they grow older. Consequently, the requirements of users in the home for assistive technologies are constantly changing. If systems cannot be adapted *in situ* to meet new requirements they will become less and less used and, hence, less dependable.

We can identify three types of modification that may be made to domestic systems:

Addition of new equipment. This can be in addition to existing equipment or can replace obsolete devices. Given the relatively low costs of domestic equipment, this will often be the most cost-effective way to modify a system.

System configuration or re-configuration by its users. In this case, the user (or, in the case of a disabled person, possibly a relative or carer) adapts the system using built-in capabilities for adaptation. For example, if a person's eyesight degenerates, then the default font size on a screen that they regularly read may be increased.

Configuration or re-configuration of a system by its supplier. In this case, the supplier or installer of the system may visit the home to make the system modifications. Alternatively, if the system can be connected to a network, then remote upgrades of the software may be possible. This is already commonplace for mobile phones and digital TV set-top boxes.

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:

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.

Openness This attribute is concerned with the system's ability to be extended with new equipment, perhaps from different manufacturers.

Visibility This attribute reflects the extent to which the operation of the system can be made visible to users and installers of that system. This is particularly important when problems arise as it increases the chances that these problems can be diagnosed without expert assistance.

User repairability This attribute reflects the extent to which faults in the system can be repaired by users without specialist tools or knowledge. This is important for assistive technologies as it means that problems can be fixed by either the user or a helper. Thus the system can be brought back into operation quickly and the overall availability of the system is increased.

6 Conclusion

This paper has begun to outline some distinctions between traditional dependability attributes, as exemplified by Laprie and attributes that have arisen out of designing assistive technology systems for older people. We have suggested that dependability can be reframed to account for human qualities as well as the nature of error and faults and that there is a critical distinction that should be illuminated between dependability in use and dependability of use. It is not enough to simply focus on the dependability of the technical system itself. It is essential to design the system to ensure that users will choose to use it for its intended function whilst limiting misuse. Our focus so far has been on understanding the attributes of domestic systems that contribute to its dependability and, so far, we have not considered Laprie's notions of means and impairments. We plan to address these issues in the next phase of our work.

Although the focus of our work has been domestic systems, we believe that the model we propose here potentially has a wider applicability to organisational systems where use of the system is at the discretion of the user. In particular, professionals such as doctors and senior have sufficient authority that they can choose whether or not to use organisational information systems. These systems must also therefore take into account the need to be accepted by their users.

7 Acknowledgements

The research described here has been funded by the EPSRC in the DIRC (http://www.dirc.org.uk/) and EQUATOR (http://www.equator.ac.uk/) projects. We would like to thank our partners in these projects and Age Concern, Barrow, MHA Care Group Penrith, and Dundee and Aberdeen Social Work departments.

8 References

1. Turner-Smith A, Broadhurst M, Fielden S, and Griffiths P.: IPEM policy on Rehabilitation Engineering Services, The Institute of Physics and Engineering in Medicine, (1999)
2. Bell, G. & Gemmell, J.: A Call for the Home Media Network. Comm. ACM, 45 (7), (2002) 71-75,
3. Laprie, J-C.: Dependable Computing: Concepts, Limits, Challenges FTCS-25, the 25th IEEE International Symposium on Fault-Tolerant Computing, Pasadena, California, USA, June 27-30, (1995), 42
4. Avizienis, A. Laprie J-C, Randell B.: Fundamental Concepts of Dependability, (2001)
5. Laprie, J-C.: Dependable Computing: Concepts, Limits, Challenges FTCS-25, the 25th IEEE International Symposium on Fault-Tolerant Computing, Pasadena, California, USA, June 27-30, (1995)
6. Laprie, J-C.: *op cit,* 42
7. Randell B.: Dependability - a Unifying Concept, Working Paper, University of Newcastle on Tyne
8. Laprie, J-C.: Dependable Computing: Concepts, Limits, Challenges FTCS-25, the 25th IEEE International Symposium on Fault-Tolerant Computing, Pasadena, California, USA, June 27-30, (1995), 43
9. Bentley, R., Hughes, J., Randall, D., Rodden, T., Sawyer, P., Shapiro, D. and Sommerville, I., Ethnographically-informed systems development for air traffic control, in *Proceedings of CSCW'92*, Toronto, ACM Press, 1-4 November (1992), 123-129.
10. Lupton D & Seymour W.: Technology, selfhood and physical disability, Social Science & Medicine 50 (2000) 1851-1862
11. Miller C, Haigh K, & Dewing W.: First, Cause No Harm: Issues in Building Safe, Reliable and Trustworthy Elder Care Systems, American Association for Artificial Intelligence (www.aaai.org) (2002)
12. Edwards, K & Grinter R.: At Home with Ubiquitous Computing: Seven Challenges In G. D. Abowd, B. Brumitt, S. A. N. Shafer (Eds.): Proceedings of Ubicomp 2001, LNCS 2201. Springer-Verlag Berlin Heidelberg (2001) 256-272
13. Sandhu J.: Multi-Dimensional Evaluation as a tool in Teaching Universal Design, In Christopherson, J, (Ed)) Universal Design, Hausbanken, Norway, (2002)
14. Sandhu J.: *op cit,* 111

15. Dewsbury, G. Clarke K. Hughes J. Rouncefield M, and Sommerville I.: Designing Dependable Digital Domestic Environments, Proceedings of HOIT 2003, April 6-8 2003, in Irvine, California (2003)