Towards a practical framework for managing the risks of selecting technology to support independent living

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Abstract

Information and communication technology applications can help increase the independence and quality of life of older people, or people with disabilities who live in their own homes. A risk management framework is proposed to assist in selecting applications that match the needs and wishes of particular individuals.

Risk comprises two components: the likelihood of the occurrence of harm and the consequences of that harm. In the home, the social and psychological harms are as important as the physical ones. The importance of the harm (e.g., injury) is conditioned by its consequences (e.g., distress, costly medical treatment). We identify six generic types of harm (including dependency, loneliness, fear and debt) and four generic consequences (including distress and loss of confidence in ability to live independently). The resultant client-centred framework offers a systematic basis for selecting and evaluating technology for independent living.

Keywords: Risk management, Risk analysis, Domestic technology, Disabilities, Elderly, Independent living, Dependability.

1. Selecting technology for independent living, the need for a principled approach

Telecare technology and services are widely used to enable disabled and elderly people to live independently in their own homes when they might not otherwise be able to do so. Information and communication technology (ICT) can: raise alarms when a person falls; compensate for sensory and mobility deficits; and provide easier, more continuous communication with friends, family and carers. Such developments have clear advantages for disabled and elderly people who prefer to live at home, for their relatives, and for the communities facing an increasing burden in funding state provided care. Further, the UK Parliamentary Audit Commission (2004) recently concluded that such assistive technologies have "huge potential" to improve the quality of care and reduce costs. However, the provision of telecare is often technology-led rather than needs-led (Sixsmith and Sixsmith, 2000). We consider here the problem of providing telecare systems and services that effectively meet clients' needs and wishes, which we have reframed as a risk management problem: technologies and services are selected to reduce the risks faced by the individual.

Elderly people living independently face many serious risks. For example, in the UK in 1999 an estimated 231,000 people over the age of 75 presented at accident and emergency departments with injuries due to falls (Department of Trade and Industry, 2001). For the very frail, even the simplest activity can be hazardous, and the risks of psychological and social harm such as loneliness and fear may be as important as those of physical harm (Blythe and Monk, submitted).

Williams et al. (2000) suggest a two stage process through which risk analysis can be used to select and configure technology for an individual. The first stage is to identify and prioritise the risks currently faced by an individual if they continue to live independently in their own home. This analysis is used

to select an initial set of technologies within the context of a total care package. The risk analysis can then be re-applied to ensure that the overall level of risk is now acceptable and that unacceptable new risks have not been introduced. Williams et al. (2000) list several environmental, human and technological factors that can lead to risk, based on their experiences with existing technology. They do not, however, provide a clear conceptual structure that guarantees a principled approach to risk analysis in this context. This paper provides the basis for a systematic client-centred risk analysis, based on the safety engineering methods that are widely used in high risk contexts (Bahr, 1997), particularly Human Reliability Analysis (HRA; Swain and Guttman 1983, Kirwan, 1994).

2. Risk as harm, consequences and the likelihood of harm

The starting point for this risk management framework for technology in the home was the International Standard on Medical Devices (Application of Risk Management to Medical Devices; ISO 14971, 2000). This standard makes clear that many risk management decisions are necessarily contingent upon stakeholder judgements. Most crucial is perhaps the judgement of what constitutes a tolerable risk, since this determines the overall objectives and defines the circumstances under which remedial action is required.

Risk management has the objective of avoiding harm. As an example, consider the problem of a professional assessing the risk faced by a client using a stair lift. One potential harm is personal injury to the client. Injuries vary in their seriousness, so ISO 14971 proposes the concept of a consequence of harm. An injury where the death of the client is the consequence of harm is clearly serious, the risk is obviously intolerable and something must be done about it.

The seriousness of the consequences of the harm is the first judgement to be made, the second is the likelihood of the harm. The most severe risks are of harm with both a high likelihood and serious consequences, which is

intolerable. The least severe risks are of harm with both low likelihood and less serious consequences, which may be tolerable. In between these two extremes risk may be tolerable or intolerable depending on the combined likelihood of the occurrence of harm and its consequences.

The reader will note that we have not used the word "hazard" in the above definitions of risk. Formal approaches to risk management (e.g., MIL-STD-882D, 2000; UK DEF STAN 000-56, 1996) define hazards in terms of hazardous system states with triggering events. This is not particularly useful in the home context because our system of interest is defined broadly to include the older person, their house and all the equipment in it. That system is always in a hazardous state and the simplest activity by the older person can be a triggering event leading to serious harm (Blythe and Monk, submitted). One cannot prevent this hazardous state occurring, only reduce the likelihood and consequences of harm. To avoid confusion we use the term *potential mishap* when referring to the everyday meaning of the word *hazard*. *Mishap* is the preferred term for a particular instance of harm with serious consequences (Department of Defense, 2000).

A framework for risk management in the home then needs to enumerate the harms to be avoided and their possible consequences. Also, it needs to set out the process of making a judgement about the severity of risk based on the consequences and likelihood of given harms. We will start with an analysis to define the types of harm and consequences that need to be considered.

3. A preliminary taxonomy of domestic mishaps

Systematic approaches to risk identification are broadly classified as bottom-up—such as HAZOP (Bahr, 1997)—or top-down—such as Fault Tree Analysis (e.g., Lee, Grosh, Tillman, & Lie, 1985). Here we adopt a bottom-up approach, using Swain and Guttman's (1983) error modes to generate a preliminary taxonomy for the different activities of daily living (ADLs).

The first stage in any bottom-up approach is to identify the relevant tasks or activities. Technology in the home context is intended to support all elements of daily living, so the scope of the analysis is potentially huge. We started with the ADLs and Instrumental ADLs used by occupational therapists when assessing the needs of older clients, and then extended it to include socialising in and out of the home and entertainment, and, finally, external events that can be considered mishaps in their own right, e.g., fire or flood (see Table 1). We used Swain and Guttman's (1983) guide phrases: *too much*; *too little*; *inadequate*, and *none (unable)* with the entries in Table 1. So, for example, eating, if omitted entirely, would lead to starvation; if done inadequately or too little, it might lead to malnutrition; done too much it could lead to obesity. Not all the guide phrases elicit mishaps. For example, we could not find convincing scenarios for mishaps where *too much* transferring from bed to chair caused harm. Nevertheless, this process resulted in an extensive list of mishaps structured according to the ADL or external event used with the guide words.

Table 1 about here, ADLs and external events

Harms such as starvation and obesity are very specific to the activity concerned. To be useful in a general purpose risk management framework more generic terms are required. Through a process of iteration based around the taxonomy of mishaps, seven Generic Types of Harm (GTH) and four generic consequences were identified. These are listed in Table 2.

Table 2 about here, GTH and G Consequences

Two types of harm are distinguished: physical harm and social and psychological harm. Some physical harm is caused by events that happen quickly, such as a fall. Others have longer time scales: the physical harm caused by poor diet or inadequate heating might take much longer to manifest itself. A fall, where damage occurs in minutes, is described here as an *injury*. Where damage might take days or weeks, this is described here as *physical deterioration*. Intermediate to these two time scales is the physical harm caused by delays in receiving appropriate medical treatment. One major reason for installing technology in older people's homes is to provide access to prompt medical treatment for falls, strokes and heart attacks. Falls cause injury, but additional damage occurs if not treated promptly. The longer the older person remains untreated, the longer they take to recover; lying helpless on the floor for hours can be very distressing.

Physical harm is the traditional concern of risk analyses. Our client-centred approach requires that the GTH also encompass psychological and social harm. A recent survey for Age Concern—a UK charity championing the interests of older people—identified loneliness, fear and poverty among the key problems perceived by their clients (Age Concern, 2002). The importance of non-physical harm was also highlighted in focus groups with older adults during development of an interactive domestic alarm system (Lines and Hone, 2004): boredom and depression were judged potentially as serious as personal attack, illness and falls.

The generic consequences listed in Table 2 follow from the GTH. In general, all the physical GTH could cause any of the consequences identified in Table 2, while all the psychological and social GTH could cause distress and loss of confidence in the ability to live independently.

To test the general applicability of the GTH they were applied to the original taxonomy of mishaps generaated from Table 1. The results of doing this under the heading movement are presented in Tables 3 and 4. Table 3 gives

the GTHs that apply for each ADL and guide word combination. Table 4 gives the scenarios that underlie this analysis.

Tables 3 and 4 about here, (ADL x Guide word with GTH; scenarios)

Occupational therapists are trained to ask clients whether they could carry out some ADL safely, competently and repeatedly; on their own, with help or not at all. A further development of this scheme will explore the need to refine the guide phrases "inadequate" and "none (unable)" to encapsulate these distinctions. The framework as presented above provides a starting point and illustrates what is required. Making these tables more complete and justifying the scenarios is the next step in this work. Also, not all risk analysis schemes distinguish between harm and consequences of harm; in reality there are complex chains of causality. There will be many antecedents of the harm and these antecedents may lead to several kinds of harm. Harms often go together: injury may lead to fear; fear (of going out) may lead to loneliness. Similarly, the consequences listed in Table 1 often go together. Distress may cause depression and, hence, costly medical treatment. Costly medical treatment, particularly hospitalisation, may cause loss of confidence in the ability to live independently. The model of how mishaps occur, the GTH and consequences in Table 2 is a considerable simplification. We believe, however, that if offers a comprehensive list of basic harms that older people living independently may suffer, and provides criteria for judging the seriousness of these harms.

4. A process for managing risk: a case study

The framework is designed to be used for assessing and managing risk for a specific individual in a specific context, that is, where they are living and the

way that they live. The process will thus be illustrated with reference to the following fictional case study.

> Miss G has been identified as a potential recipient of monitoring technology. Miss G lives alone in her flat on the second floor of a five storey block. Several other residents are also in their eighties. There is a lift, but no janitor or warden. Miss G has arthritis and has had both hips replaced. She has type 2 diabetes, poor vision and hearing problems. She recently had a minor stroke and has some loss of function in her right side. She has a daily home visitor but she has no family in the immediate area. She has been assessed as being at risk of further strokes. After the stroke, the hospital consultant recommended she should not be living alone. She does not want to leave her home.

The process follows the steps of Bahr's (1997) approach for identifying and managing risk (see also ISO 14971). Having defined the system and the objectives of the process, there are three further iterative steps. First, the existing system is evaluated to identify the most important risks and to suggest interventions to reduce them. Second, the planned system is evaluated to ensure there are no unforeseen side effects of the interventions. Third, after installation, the new care package is evaluated in light of changes in the client's behaviour and abilities once they are used to the new set up.

Step 1. Define objectives of risk analysis and the scope of the system evaluated

The objective of each iterative step is to identify and rank the seriousness of different risks of living independently and to plan interventions to make the total risk tolerable for a particular individual in those particular circumstances. In terms of the case study, it is simply to manage, i.e., make tolerable, the risks faced by Miss G.

Our client-centred approach requires that the system evaluated is defined to encompass: (i) the flat (equipment and furniture, the technologies needed to

get in and out of the flat, and so on); (ii) Miss G, and any visitors; (iii) the environment encompassing other stakeholders with their own requirements (health trust, relevant regulatory bodies, and so on). A narrower system definition, e.g., focussing solely on an alarm system, would not encompass the concerns discussed here. The above wide definition of the human and mechanical components of the system and the other stakeholders in design could be captured and reasoned about using rich pictures (Monk & Howard, 1998) .

Step 2. Risk Analysis of current situation

The next step is to rank risks within the current situation. The taxonomy of domestic mishaps outlined in Section 3 provides a basis for generating lists of potential harms and their consequences. The ADLs in Table 1 would be discussed with Miss G. The taxonomy identifies the GTH associated with each ADL. The generic consequences of harm from Table 2 facilitate a systematic examination of the seriousness of the harm for a potential mishap.

In order to assess the severity of each risk the likelihood of each of these harms has also to be assessed. Some risk management standards suggest categories of likelihood with objectively defined probabilities for this purpose. For example, MIL-STD-882D (2000, A4.4.3.2.4) uses the terms: frequent, probable, occasional, remote and improbable. The middle three may be useful for our purposes but it is difficult to define them numerically. Even if this were possible there is not the detailed statistical evidence needed to make an objectively defined assessment. There are statistics for accidents in the home (Department of Trade and Industry, 2001), but, in the area of assistive technology the population of technology users has very varied abilities so large population statistics are unlikely to be useful. Experience and common sense will generally be required both to assess the likelihood of harm and to combine this judgement with a judgement of the seriousness of the consequences into a rating of risk severity. Again, MIL-STD-882D (2000,

A4.4.3.2.4) presents an objective scheme for making this latter judgement from which we can only really take the terms used: high, serious, medium or low.

Having identified the high, serious and medium risks (low risks can probably be ignored) interventions are sought to reduce them. Cost and other practical considerations come into the picture here. In a given context, the taxonomy of mishaps could easily be extended to provide advice about the interventions that could reduce the likelihood or seriousness of harm and the cost of those interventions. In Miss G's case, the risks identified are given in Table 5. The most serious risks arise from her mobility problems and the possibility of another stroke. It is decided to install a fall detector to reduce the risk of the harm *untreated medical condition.* While the risk of *injury* is equivalent, the likelihood of the consequences is less, and the personal and monetary costs of the intervention too high. A new door entry system for the whole block of flats is considered. Miss G suffers *distress* from *loneliness* and fear for her personal security. A door entry system is considered to reduce the likelihood of these harms as it would benefit all the other residents and can be funded separately.

Table 5, About here. Miss G's risks

Step 3. Risk analysis of planned system

Having identified a set of practical interventions given the available resources, the analysis is repeated to evaluate the design and ensure there are no unforeseen side effects. New risks caused by the interventions are then assessed and the design adjusted by suitably modifying those interventions. In Miss G's case, the alarm system's cost could be offset by reducing her care package. Re-iterating through the analysis would identify that the resultant

loss of human contact could cause loneliness; a befriending scheme could be used to mitigate this potential harm. The package of interventions would then be agreed and the decision taken that Miss G could continue to live at home.

Step 4. Risk analysis post-installation

The analysis has to be repeated a few weeks after installation to identify any unforeseen problems. By this time Miss G will have adapted to the new system and care package. Also, it is difficult to predict how things may change over time: the reliability of the technology itself may be an issue, as could changes in the client's circumstances and abilities. What is suitable now for Miss G may be inappropriate in six months. A schedule of regular visits would be agreed to review the effectiveness of the equipment relative to Miss G's status.

5. Discussion

The framework described above is based on concepts from medical, industrial and military studies of risk. It has been adapted to the domestic environment by considering social and psychological harms and consequences in addition to the usual concerns of physical harm. In this way, the analysis becomes much more client-centred and overcomes the simplistic view that technology is a panacea for all ills.

Some would argue that psychological and social harms represent political issues that cannot be addressed by technology. This is simply untrue. One of the main motives for wanting to stay in one's own home, and a major motivation for installing technology, is to avoid the psychological consequence distress arising from the psychological harm dependency such a move would entail. Loneliness can also cause debilitating psychological distress (Adams & Blieszner, 1989). Communication technologies provide considerable opportunities for aleviating loneliness. For example, Hackney Borough council have successfully incorporated recreational group telephone conferences into their Friendship Scheme for isolated older people (Reed and

Monk, 2004). Fear of burglary or bogus callers may lead to a loss of confidence in the ability to live independently (Age Concern, 2003), but fear of bogus callers by older people living in a communal dwelling, can be prevented by a good door entry system. Debt, particularly the inability to pay utility bills, also commonly leads to distress (Age Concern, 2002), but technological interventions can increase the efficiency with which energy is used, reducing bills at the same time as well as making sure that the householder is kept warm.

One of the effects of explicitly including social and psychological harms in a risk management process is that it draws attention to the differing perspectives of the stakeholders concerned. Consider the harm suffered by Miss G if she were to fall. The consequence *distress*–pain, fear and worry—is most important to Miss G and her carers; in the UK, the National Health Service would probably consider the consequence *costly medical treatment* to be most important. Should Miss G lose confidence in her ability to live independently this would be important to all stakeholders, particularly if the only possible intervention was to move her into institutional care. Social services would suffer the cost of this intervention. Miss G and her relatives would suffer the distress entailed. It is important to be able to reason about these different perspectives because the domestic context entails a subtle change in the ownership of risk.

In work settings, risk analyses are owned by the equipment manufacturer, or the operative's employer, because of issues of liability and regulation. Safety claims are made to delimit liability and protect the industrial and corporate producers of risk as well as those who might suffer from them. Consider the example of making a safety case for the flight deck of an aeroplane. The manufacturer knows the precise roles of the operators (pilots) and the other personnel they interact with (e.g., air traffic control). Most importantly they can control and prescribe the procedures the operators follow to perform different tasks during flight. These detailed procedures are set out so that if an

accident occurs and the procedures were not followed the manufacturer can claim not to be liable. Responsibility is thus transferred to the company operating the aircraft or the pilot. When an accident occurs liability is established by determining whether equipment and procedures are, in and of themselves, unsafe or whether "human error" has caused the equipment or procedures to be used improperly.

There are liability issues in legislation relating to domestic technology. For example, following a series of campaigns in the 1980s, UK landlords can be held legally responsible if their tenants suffer carbon monoxide poisoning as a result of inadequate maintenance of gas appliances. There can be little doubt that smart home technology manufacturers will face a similar set of complex legal responsibilities regarding the operation of their systems (see Baxter et al. 2004 for a discussion of some of these issues). However, one major difference between domestic and work contexts is the lack of control a manufacturer has over the methods and procedures followed by people as they carry out domestic activities (Dewsbury et al., 2003). This lack of control means that liability will only be an issue in very limited circumstances. The types of risk considered above are unlikely to be the subject of court cases. These risk analyses can thus be owned by the users rather than the manufacturers. This is serendipitous because the users are often best placed to make judgements about the seriousness of the consequences of harm.

6. Conclusions

We have provided a client-centred framework for identifying and evaluating of risk in the home that can be applied to both the needs of the elderly and to those people who present problems arising from physical and psychological disabilities. GTHs were identified together with generic consequences by which the seriousness of the harms may be judged by identified stakeholders. We have described how seriousness of harm can be combined with likelihood to assess the severity of risk. Using this framework, we have provided the beginnings of a taxonomy of domestic mishaps. We have illustrated how the

framework could be used in making decisions about the installation of technology for individual elderly people wishing to live independently. The framework is also relevant to the design of smart home technology more generally.

The big challenge in extending the approach outlined here is to develop a systematic approach to the management of risk accessible to non-technical people. A truly client-centred approach must be accessible to the people who advise older people such as occupational therapists and to the older people themselves.

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Tables

Table 1. Activities of Daily Living (ADLs) and events to be used in risk analysis

Movement
- Mobility (movement involving walking more than a few steps)
- Transferring (e.g., from bed to chair)
- Dressing
- Using steps and stairs
- Entering and leaving the home
- Letting visitors in and out of the home

Nutrition
- Shopping
- Meal preparation
- Eating and drinking

Hygiene
- Toileting
- Grooming
- Bathing
- Housework

Socialising
- Using the telephone and other communication technology
- Socialising at home
- Socialising outside of the home

Other
- Entertainment (e.g., TV)
- Self medication
- Handling money

External Events
- Fire
- Flood
- Infestation
- Crime

Table 2. Generic types of harm (GTH) and the consequences that condition their seriousness.

Harm
Physical
injury (physical damage to the person occurring on a short time scale)
untreated medical condition (physical damage to the person occurring on a medium time scale due to a delay in receiving medical treatment)
physical deterioration (physical damage to the person occurring on a long time scale)
Psychological and social
dependency (reduction in perceived personal worth due to dependency on technology or carers)
loneliness (unwanted isolation from the community)
fear (of attack, robbery etc.)
debt (poverty)
Consequences
distress (pain, fear and worry)
loss of confidence in ability to live independently on the part of the older person or the people who care for them
costly medical treatment
death

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Table 3. ADLs under the category *movement* that may lead to mishaps and the potential harms (GTH) identified by applying the guide phrases. The numbers in the left hand column refer to the scenarios in Table 4 that illustrate the type of mishap referred to.

	ADL	**Guide phrase**	**Potential Harm**
1	Mobility (movement involving walking more than a few steps)	Too much	Injury Untreated medical condition
2		Too little	Physical deterioration
		Inadequate	Injury Untreated medical condition
		None (unable)	Physical deterioration Dependency
	Transferring (e,g, from bed to chair)	Inadequate	Injury Untreated medical condition
3		None (unable)	Physical deterioration Dependency
	Dressing	None (unable)	Dependency
	Using steps and stairs	Inadequate	Injury
		None (unable)	Dependency
	Entering and leaving the home	Inadequate	Injury Loneliness
		None (unable)	Dependency Loneliness
4	Letting visitors in and out of the home	Inadequate	Injury Loneliness Fear
		None (unable)	Dependency Loneliness Fear

Table 4. Sample scenarios describing potential mishaps identified in Table 3. "Loss of confidence" is shorthand for "loss of confidence in ability to live independently on the part of the older person or the people who care for them."

No.	Sample scenarios
1	*Too much* - Mr X overexerts himself while pushing the wheelbarrow around the garden, and has a heart attack. He is unable to get help and so this *injury* is also an *untreated medical condition* leading to *death*. Possible roles for technology: physiological monitoring.
2	*Too little* - Miss Y who regularly sits down in front of the television for most of the day, is eventually unable to get up out of the chair (*physical deterioration* leading to *distress* and *loss of confidence*). Possible roles for technology: activity monitoring.
3	*None (unable)* - Mr W is distressed because he cannot get out of the bed and into the chair without the help of a care worker (*dependency* leading to *distress* and l*oss of confidence*). Possible roles for technology: client operated hoist.
4	*Inadequate* - Miss D's eyesight is failing more than she cares to admit, and she is fearful because of the accounts she has heard of bogus callers. She cannot always recognise who a caller is or read what it says on their badge. This has resulted in *fear* and *loneliness* and hence *distress* and *loss of confidence*. Possible roles for technology: button near front door to connect to call centre for advice.

Table 5. Risks faced by Miss G in her current situation

Severity	Potential mishap	Harm(s)	Consequence(s)	Intervention(s)
Serious	Fall (due to stroke and mobility problems)	Untreated medical condition	All four generic consequences	Fall detector
Serious	Fall (as above)	Injury	All four generic consequences	Move her to a care home
Medium	Lack of social contact (due to inaccessibility of flat)	Loneliness	Distress	Door entry system with video camera for block
Medium	Lack of confidence in her personal security	Fear	Distress, loss of confidence	Door entry system with video camera for block