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Gathering the requirements for a fall monitor using drama and video with older people

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Abstract. A system providing fall detection and movement monitoring to support older people living at home using computer vision technology is being developed. Sensitive design with user involvement is important if such a system is to be experienced as supportive rather than invasive. Four scenarios, based on material from focus groups and anecdotal evidence, have been developed and performed by a theatre group. These feature older people falling at home with different outcomes and carers discussing an older person's needs. They were filmed and shown to three different groups of older people and a group of sheltered housing wardens to provoke discussion. This method of user requirements gathering provided a shared user context which enabled groups to focus very effectively on the details of a system at the pre-prototyping stages. The results of the discussions are described and the use of this methodology is discussed.

1. Introduction

Computer vision technology is being developed which uses ceiling-mounted cameras to monitor the activity of an older person living alone and to autonomously detect falls. The system aims to extend independent living and quality life in a safe, monitored environment with reduced healthcare costs and a more preventive approach than is currently possible. Reduced stress among occupants and carers would also be expected and a more detailed understanding of the lifestyle and behaviour patterns of older people living alone could also be developed. This paper explores the use of a drama-based methodology for assessing user requirements and design constraints for this new technology. In particular, it describes the use of drama on video with groups of potential users of a system for fall detection and movement monitoring in supportive home environments.

Within this project drama is being used

(i) to help investigate the applicability and feasibility of using intelligent visual sensors for automatically monitored supportive environments for older people living independently, and
(ii) to identify the requirements of users, including occupants, family members, professional carers and sheltered housing wardens, during the process of designing, building and evaluating prototype systems.

Drama, derived from the Greek word "dran" meaning "a thing done", implies action; it is about creativity, imagination, feeling, symbol and metaphor. Boal developed a range of methods for the use of theatre to explore political and social issues, which he called Forum Theatre [4]. His work is now well known and is being taught in the UK and other parts of the world. A related Forum Theatre approach has been used to explore issues in community care, medical ethics and other contexts by a Scottish theatre group (Foxtrot Theatre [13]). Theatrical methods are also beginning to be used in the context of product design. Howard et al. [14] have used participatory design sessions, in which contextual scenarios are acted out. This work has followed that of Carroll [8] on scenario-based design. The use of scenarios as a tool in design is discussed in detail by Benyon and Macaulay [3]. The use of actors in design development is a recent development [21,22] and seems to be a very useful and interesting way of establishing a common, shared context for audience participants.

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Both live performances and filmed scenarios offer a very rich stimulant for discussion and can activate imagination in a more powerful way than words. They also keep participants focused on issues that are relevant to system design. In contrast, keeping focus groups 'on task' and retaining their attention while collecting in-depth information has been found to be difficult with groups of more than three older adults [15,17]. The experiments reported here used video recordings of drama, as this can be more economical than the use of live performance in every session.

This paper deals only with the user requirements and comments on the ways in which these are feeding into the technical development of the computer vision-based tracking systems. Details of the tracking systems under development can be found elsewhere [18].

2. Monitored supportive environments for older people

2.1. Demographics and costs of care

Society is ageing: the percentage of people between 16 and 65 to those aged 65 and over is expected to reduce from 4:1 in 1961 to 2:1 by 2040. The European Commission has predicted that between 1995 and 2025 the UK will see a 44% rise in people over 60. This will result in a diminishing ratio of carers to clients and a diminishing ratio of people paying into the social security system to those in need of services [11]. The situation is similar in most other developed countries. More than 34 million people in the United States are 65 or older and on the horizon is the baby boomer generation: 76 million people born between 1946 and 1964, the largest group ever in the United States to head toward retirement.

In the UK, approximately 40% of total hospital and community health care expenditure is on people aged over 65 years, and those over 75 years occupy more than 50% of all available hospital beds [26]. The Royal Commission on Long Term Care reported that it costs £454 per week on average for full time residential care and £250 per week for private home care [25]. Therefore, there is a strong economic justification for transferring resources from residential to home-based care. Mapstone of the Audit Commission reports "we shall spend 10% of GDP by 2050 on care on current trends. If we increase independence by 1% per annum cumulatively, we can contain it to 6% of GDP." (Nick Mapstone – Personal Communication).

2.2. Consequences of falling

The number of reported falls per year is around 60,000 with an associated cost of at least £400 million. Falls represent 38% of all home accidents and cause 70% of deaths due to accidents in the 75+ age group. In 1998, there were around 4,300 deaths and over 172,000 serious injuries in UK homes (Nick Mapstone – Topic Sheet for the ICES Website).

Research [29] found that half of those with a 'long lie' [... i.e. remaining on the ground/floor for more than one hour after a fall ...] died within six months of the fall, and this was even if there was no direct physical injury (death was usually from a complication such as bronchopneumonia, dehydration or hypothermia). In a French study [27], it was found that 10 out of 48 elderly patients hospitalised after a fall had been on the ground for more than one hour. (DTI Report see Askham et al. [1].) From this evidence Doughty [10] observes, "It may be assumed that 'a long lie' may be as relevant to decreasing the chances of survival as a broken bone". Clearly the speed with which emergency help is alerted to a fall is crucial to the faller's health, especially when that person is older.

These demographics, along with the cost of residential care for older people, have encouraged research into the development of technology to support older people to remain in their own homes for longer, and the UK Royal Commission of care of the elderly reported that technological support for older people will become an economic necessity [25].

2.3. SMART homes, telecare and assistive technology

Williams et al. [30] comment that one of the major constraints on the design of telecare systems is the cost of telecare devices. As people become older, everyday tasks become more difficult and using a combination of care and/or equipment can reduce these difficulties. Personal and equipment assistance has been compared [28] and it is clear how often disability is reduced or resolved by such interventions. It was concluded that both personal assistance and equipment work, relieving dysfunctions for most people and alleviating them for many, however, equipment by itself is more efficacious than personal assistance. Equipment can release the time of both formal and informal carers, which is very relevant as it is becoming harder to recruit staff into caring roles due to competition from other sectors [23].

So, Assistive Technology may mean that scarce resources can be used more efficiently. For example, a

study of community nursing found that 15% of community nursing visits could be replaced with remote monitoring; this includes activities such as giving advice, monitoring compliance with medication regimes and routine physiological monitoring. Community alarms are low cost technology, and with over 1 million users in the UK, will continue to be very successful. Their major limitation, however, is that the user must be able and willing to initiate the alarm call. Porteus and Brownsell [19], recommend that passive systems are needed that can call for assistance without the need for the user to take action.

A survey of sheltered housing residents reported that 77% would welcome automatic fall detection while 68% would welcome lifestyle monitoring [7,12]. BT and Anchor Trust performed preliminary research into lifestyle monitoring using door opening/closing and pressure sensors in the home to compare current activity with recorded average activity profiles [2,19]. These could detect simple events such as "lack of expected activity" or "abnormal use of fridge". The "aware home" project [16] is investigating ubiquitous sensing in a home environment and wall-mounted cameras to track multiple people [24].

PIR sensors, door sensors and pressure pads enable room occupancy or presence in a particular area to be monitored [2,5,9]. Computer vision systems, however, can provide far more flexible sensors and current developments are making more detailed real-time monitoring in realistic indoor environments feasible [6,18].

Although the most reliable systems will use a combination of worn and embedded sensors [11], our work is primarily concerned with embedded visual sensors utilizing computer vision techniques. These have potential for detecting falls, inactivity, activity patterns, mobility and reduced mobility, room occupancy, proximity to or interaction with objects and environmental factors. These visual monitoring capabilities can be utilized for: passive alarms in response to events, detailing the nature of the event and possibly providing evidence for this information, monitoring and analysis of walking speed, duration, room usage etc., and prediction and prevention, e.g. risk assessment of falls, adjustment of alarm thresholds. They can also be used for retrospective analysis based on summary statistics, trajectories and where appropriate image data. Data gathered could also provide valuable insights into behavior and health for use by carers, social workers and psychologists.

2.4. Computer vision-based monitoring for telecare

The system we are developing uses ceiling-mounted, wide-angle cameras with vertically oriented optical axes in order to minimize occlusion by furniture. This is particularly important as older peoples' homes are often highly cluttered with belongings and furniture brought from former, larger homes. The system will operate in varying lighting conditions due to external windows and interior lighting controls and be robust in the presence of other moving objects such as fluttering curtains. McKenna and Nait-Charif [18] give a fuller discussion of the tracking system being developed.

Bonner [5], however, emphasizes that "wherever possible equipment should be integrated to blend in not just with the physical environment of the home, but also to take account of the individual needs of the end users". A user centred design methodology is central to this development [20]. Because of the importance of ascertaining the views of potential users of such a system, and the particular challenges of an older user population, we have developed a novel technique for the requirements gathering which we shall describe in this paper. The full scope of the project is shown in Fig. 1. As shown in the diagram the establishing of user requirements is an iterative process and this paper describes the first use of this method. A second set of scenarios that has been developed from results reported in this paper has been filmed and as of June 2003 the results of the second user group discussions are being analysed.

3. Methodology

3.1. Scenario development, filming and editing

A number of scenarios were developed based on the technical possibilities of the system, anecdotal stories and results from an initial focus group with older people. The scenarios were planned in discussion with the researchers and written by the Artistic Director of Foxtrot Theatre Company. Previous experience of interactive theatre suggested that five minutes of drama typically leads to about twenty minutes of discussion, and thus four short scenarios were written to give just under two hours for a group discussion based on them. The aim of the scenarios used was to provoke discussions about falling, about the risks that people perceived in their homes and to encourage discussion about the community alarm and how it currently works. Two sce-

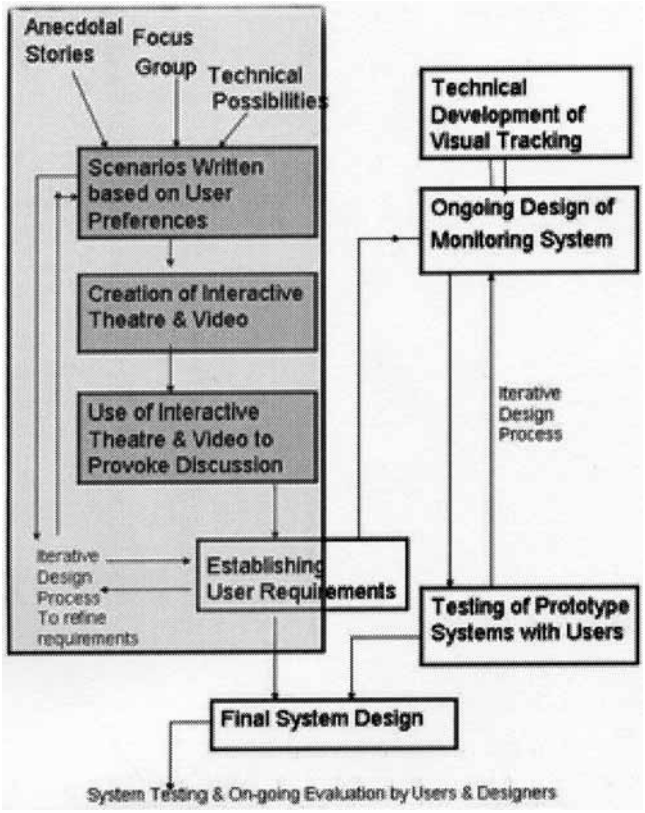

Fig. 1. The scope of the project with the areas addressed in this paper shaded.

narios were written in which an older person was seen falling and two in which carers were seen discussing a new monitoring system and how it worked. Professional actors then recorded these scenarios. Three actors were involved: a younger woman, an older man and an older woman. Both of the latter played both an older person falling and in other scenarios acted as carers. The filming was carried out with a Sony XM camcorder and natural lighting in two home settings over two consecutive days. The aim of the dramas was to stimulate interest and discussion and they were thus written, filmed and edited to be short and concise and did not aim to resolve situations or provide solutions. The issues of fall detection and movement (or activity) monitoring were both addressed. Stills from these videos are shown in Fig. 2.

3.2. Groups who have discussed drama-based scenarios on video

The groups chosen to view and discuss the videos represented a cross-section of older people, some in sheltered housing and some living independently. A range of health and support needs was evident across the groups, as was a range of levels of usage of the various community alarm systems. Almost every elderly person was, or had been, a carer for family, friends or neighbours; so they spoke with an awareness of others' needs and experiences. One group of professional carers was involved in this study and these people were wardens in local sheltered housing schemes. The groups were:

A. Frail elderly living in sheltered housing attending a day centre, plus some carers

This was the most fragile group who viewed the video. Fifteen older people (mainly in their 70s and 80s) and four carers were present. Of these older people some were slightly deaf, one was partially blind and some were in the early stages of dementia. One man and one woman were very fragile and a few reported falling quite often. Although this group was the most difficult discussion to facilitate, the responses from them were extremely useful as the group contained many people who currently used the community alarm and would benefit from a passive fall detection system.

Fig. 2. Example stills from the videos.

B. Mixed group of elderly people

The participants in this group were slightly younger (65 upwards) and less fragile than those in group A. There were two men and seven women and all were living in sheltered housing except for one woman who was in her own home. There was one carer with this group. This group was very chatty and full of anecdotal stories. The challenge was to discourage two or more people from talking at the same time so that the discussion could be effectively recorded and so that it was a group discussion rather than a simultaneous relating of several individual's experiences.

C. Retired group of professionals, living independently at present

This group included six women and one man between 75 and 87 years old. They were all living in their own homes and none were linked to the community alarm. They were very independent and, although two of the group and many of their friends had had serious falls, they had not considered joining a community alarm scheme. They saw themselves as carers for others, as well as possibly requiring some care themselves. As a by-product of the research, the videos, shared stories and the following discussion raised their awareness, of the risks of living alone.

D. Professional carers

Six sheltered housing wardens and the director of a local Housing Charity were involved in this meeting. This group was much more focussed and less chatty than the other groups. The wardens brought much useful experience and many helpful observations about the way people in sheltered housing live and their expectations of a system. The group was very focussed on the issue of falling and monitoring system designs. They were very thoughtful and experienced at caring for older people and they drew on both their professional and their personal experience.

The groups were each shown each of the four video clips. The presentation of each clip was followed by a discussion period of approximately 20 minutes. A researcher, who had had some training in audience facilitation in similar contexts, facilitated this. The discussions were videoed and a transcript was made from the video that was used to enhance the memory and brief notes taken by the researcher who was present in the audience.

4. Results of user discussions

The results of the discussions in the four groups have been divided according to areas of particular interest for the participants and for the researchers. Only when

a specific group made a particular point has the group been identified.

The many points raised in the discussions can be distilled into a few main issues.

- There is a perceived need for a passive fall detection system and its design can be broadly specified from stated potential user requirements (see 4.1 below)
- Discussions have given some insight into the details of the requirements for communication between a fall detection system and the "faller" and between the system and the "carer" or emergency services (see 4.2). We will be exploring the nature of this communication in future scenarios.
- There is the issue of errors in the system (see 4.3): what happens when falls are missed or when the system mistakenly reports a fall (a false alarm)?
- There are issues concerning the monitoring of activity, rather than simply fall detection (4.4).
- Potential users have anxieties about a system that detects falls and also may monitor behaviour (see 4.5).
- Careful consideration needs to be given to the relationship of the new monitoring system to other technology such as the door lock and the security system.

4.1. Fall detection system design

Broadly, the consensus among the potential users was that they would be pleased to have a passive monitoring system with a reliable fall detector, and they felt that it would provide reassurance for them and their families. They were content to have a monitoring device based on visual tracking provided that the output is only analysed by a computer. None of the participants wanted visual monitoring that allows other people to actually watch them in their homes. The carers group, D, specifically stated that falling is a major concern amongst older people and that passive fall monitoring would be very useful and acceptable.

Older people, especially those in group C who still live in their own homes, were not enthusiastic about carers having too much information about their activities except for the purposes of helping them in case of a fall.

The community alarm used at present in Sheltered Housing requires the person to activate an alarm, on a wearable pendant or pull cord on the wall that is linked to the warden in the daytime so that her voice comes through the system to ask if the "faller" needs help. Groups A and B suggested that a "voice" connection with any new system is expected and preferred. This needs to be explored further (see 4.2.).

Sheltered housing wardens, in particular, felt that the new monitoring system would need to be linked with the existing community alarm system, i.e. using same call centre as is used at present. It would be too confusing for tenants and carers if there were two systems in place. This approach would answer many of the anxieties mentioned by group participants (see 4.5. below) and, in particular, address the need for human contact with the system. Linking a new fall detection system with an established system may also provide a quicker route to developing an integrated support system.

The most likely places to fall were reported as the bedroom and the bathroom with going to the bathroom in the night being a particularly risky event for older people. The lobby was also said to be an area of risk. It was clear that there may be a need for passive fall detectors in common spaces in sheltered housing and in outdoor spaces such as a passage to an outer green or a passageway with dustbins. It was reported that these could involve uneven steps and dark passageways. It was interesting that a consideration of new technologies alerted users to hazards present in the everyday environment.

4.2. Communication with the monitoring system for the carer and the potential faller

Communication between the monitoring system and the users was felt by group B to be a very important issue. Participants said that the faller needs to know if the system has "seen them and what it is doing to raise help". They were also concerned that there should be means of telling the faller that the system was responding even if they were deaf and/or blind and both a flashing light and sound or voice communication was suggested.

Wardens commented that they had information about tenants (e.g. medical history and personality) which enabled them to prioritise care depending on likely urgency of need. It was suggested that a monitoring system should replicate this by having different settings: a slower response time if someone was normally healthy and active and a faster one if, for example, they had just come out of hospital.

Communication between the older person and the monitor was discussed both to cancel false alarms and

to ensure that the correct emergency service is called. Group C expressed a strong desire for a human-based system – "we do not belong to an age of computers and don't trust them or understand them the way that younger people do – I would be happier if I thought that there was a person there at the end of the phone". This group also felt that a lower technology option was better from the point of view of cost, privacy and reliability. A strong feeling was expressed that a self-activated, waterproof wrist watch type alarm linked to a central call system would be best. Concern was voiced by group D over the idea of a computer telephoning a carer as was shown in one scenario. All the groups said that they preferred more human-based systems. It was stated that the current personal connection and verbal communication between faller and warden/call centre provided an important and reassuring link.

Participants said that it was important that a tenant could not turn off the fall detection system completely. Groups B, C and D all gave examples of the pendant alarm being just out of reach when it was needed. Users, however, do need to be able to "clear the system" in the case of help being called unnecessarily. They also need to be able to activate such a system i.e. press a button to call for help if they are feeling ill and need help.

It was emphasised that the carer who gets the message that their family member or neighbour has fallen needs as much information as possible and/or needs to be able to communicate directly with the "faller". However, participants in Group C, who are still currently living independently, felt that the carer only needs to know is that there is an emergency to which they need to attend. These people felt that there was no need for images or more information and they perhaps valued their privacy more highly than the carer's peace of mind!

Participants referred to the simple technology of voice messages within elevators: simple technology which informs a user of position and progress. They also spoke of the sheltered housing system where the warden knows the faller personally and their medical history, and referred to the current community alarm where, thanks to the technology, the person at the call centre can refer to the alarm caller by name. So, from this experience groups A, B, and D thought that a human voice (via loudspeaker or telephone) was a natural way of communicating and one which fits elderly people's current experience and expectations.

4.3. System errors – false alarms and missed falls

An anxiety was voiced that, if carers are relying on the system to tell them if there has been an accident (and therefore, perhaps, ringing up or visiting less), it is very important that it works reliably. Participants were anxious about what happens when they have visitors such as lively grandchildren who may activate the system accidentally. If they are lying on the floor and the system is activated unnecessarily will it be possible to turn it off? Group D, the wardens, said that tenants do need to be able to "clear the system" in the case of help being called unnecessarily. Group B, who had experience of the current system, confirmed how important this was.

The issue of missed falls is more complex: if a person has an "emergency" they would want the alarm raised immediately. However, there are questions about how to define an emergency, and to how to characterise those events that a system could reliably detect. Potentially ambiguous situations, such as falling asleep in a chair or having a stroke while sitting down, were discussed as problem areas for an automatic visual monitoring system.

Research is required to explore further how the dangers of missed falls and the inconvenience of false alarms can be avoided and more scenarios are planned to explore these issues.

4.4. Monitoring activity

A non-invasive fall detector was felt to be useful, but anxiety about any system with a videocamera, was expressed and there was a reluctance, expressed most strongly by group C, to have any activity monitoring. Potentially, a monitoring system could build up a profile of the person's normal activity patterns and then alert a carer if the person was moving around less than normal, or using the kitchen less or the bathroom more than normal. Whether this was acceptable was explored in one scenario and generally it was felt to be too invasive.

It was reported that, in one local sheltered housing association, pressure mats had been taken out of flats because they were felt to be mechanically unreliable and too invasive. Group D felt that tenants would not want or accept activity monitoring. This group also reported that, when sheltered housing flats had been designed with frosted glass panels next to the flat front door, tenants often blocked the view through these panels by leaving the flat bathroom doors open. In contrast one of the Group D. participants felt that, in cases of

the onset of dementia, if the choice was between some monitoring in one's own familiar home and moving into institutional care, then monitoring, in this case, might be acceptable.

4.5. Potential users' anxieties about a new system

Group C in particular, as well as those living outside a sheltered housing scheme in groups A and B, expressed a general anxiety about the identities of the "carers": were they part of a remote, central system or were they neighbours or family? They said that family, friends and neighbours were also becoming elderly. Many people felt anxious about who they could trust with a key. A fall detector could link to the community alarm system as it is currently, but, there is still a need for someone that the occupant trusts to be given a key for entry.

Even when there is a trusted carer with a key at night, most elderly people worried about security, had chains on their doors, and often left a front door key in, in case of fire. In that case how does the "carer", once alerted, enter? Should the door lock system be linked to the fall detector so that a door lock is released to allow emergency services in once the monitoring system has called for help? This was suggested but led to security anxieties.

All the participants, but particularly Group C, were full of ideas about what technology could do for them and were prepared to pay for something that seemed to be useful to them. However, they did not want anything that they felt to be invasive, nor technology which was difficult to operate or understand. Those who were in group B felt that the monitoring system should be linked to other technology: fire alarm, burglar alarm, cooker controls, mobile phone (so that it can be used outside the flat) and to medical records.

Stories were told which suggested a lack of understanding by some tenants of the current community alarm system. For example, an elderly man would keep the pendant alarm in his slipper. When he got out of bed at night he would stand on it and the call centre would be alerted and would ask him if he was all right. So as "not to be a nuisance" he would keep quiet in the hope that they would not know it was he who had accidentally called. On receiving no answer, the centre assumed something was wrong and sent help. In another example a sheltered housing tenant had taken his pendant alarm on a weekend away, where it could not have worked, but was feeling falsely reassured by having it with him.

These, and other anecdotes, clearly show the importance of the user having a cognitive model of the system congruent with the way the system actually works. Creating a system that is congruent with users' expectations will minimise the need for training when a system is installed. Exploring the design of a system by pre-design user trials with actors on video is a way to discover what expectations are and to incorporate these in design. This will form the next stage of the development of this system.

5. Summary of results

Many interesting issues were raised and many anecdotal stories told during meetings which will be fed into the development of the system. The generic results from the current round of drama-facilitated discussions, which seem definitive, are as follows.

- No-one wants monitoring that transmits visual images to anyone else.
- Fall detection systems which are passive monitors are generally desirable and would be useful.
- For inside spaces in individual flats, the bathroom and bedroom are the most likely "emergency" sites, followed by the lobby.
- "Fallers" want to know what the system is doing – they need to be reassured that a system has "seen" them fall and that it has "done something" to get help. When they know that help is on the way they feel that they can relax.

Potential users also suggested areas where there could be a link with other technology such as the security system and other sensors such as the smoke alarm, bath temperature, gas detection or medical/physio support. The success of such monitoring is being investigated further at two sites in Scotland: Almondvale in West Lothian and Edinvar Housing in Mid-Lothian [5] where housing has focussed on linked technology for monitoring homes.

Several of the above areas would clearly benefit from further exploration via drama-based scenarios, for example, the form of communication between occupant and monitoring system and the form and type of communication between the carer and monitoring system. An important consideration is that the system should fit in with user expectations and be as simple as possible to use. Another important area for further exploration is how the system can be designed to minimise false alarms and missed falls.

6. Conclusions

Drama on video has been used to develop user requirements for a new monitoring system at the pre-prototyping stage. This has ensured that user requirements were explored effectively early in the design cycle.

The advantages of using theatrical techniques within a forum theatre context have been found to be that:

- Dramatized scenarios are an excellent way of setting a shared context for discussions between potential users and designers.
- Drama focuses discussion on specific scenarios of likely system usage.
- The experience of watching a video is very effective in provoking discussion of relevant details because elderly users can imagine themselves within the scenarios shown in the video.
- The use of video, rather than live drama provides a low cost way of using actors with many groups of users.

Drama was found to be an extremely useful method of provoking discussion at the pre-prototyping stage and provided many insights that we believe would not have been obtained without such techniques being utilized. It is also important to note that potential users found the experience interesting and enjoyable, and this undoubtedly assisted in the elicitation process.

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