Sensors on My Bed: The Ups and Downs of In-Home Monitoring

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Abstract. Australia's increasing aged population is associated with rises in health expenditure and residential care costs, creating a public health challenge. This challenge can be met with in-home monitoring systems that allow older people to live at home longer. There is, however, a dearth of knowledge on how Australians feel about being monitored. Here we describe an ongoing study conducted with elderly residents as part of a smart home pilot. We aim to identify perceptions of the sensor-based in-home monitoring system throughout the pilot, from conception to completion. In this paper, we provide our preliminary findings of initial reactions to the technology and contributions made by prospective residents at pre-pilot workshops. We found participants favoured system flexibility and enhanced family communication and that undesirable aspects could be circumvented or solved by our researchers. Much of the participant feedback was incorporated into the design of the pilot and the associated technologies.

Keywords: Smart Home, Assistive technologies, Home monitoring, End user engagement, Quality of life, Social inclusion.

1 Introduction

A post-war fertility boom, advances in healthcare and increased life expectancy have seen Australia's ageing population grow significantly over the last decade, with a greater percentage of people over 65 than ever before [1]. Female longevity is apparent with a ratio of 2:1 females:males in the 85–99 group and 3:1 in the 100+ group [1]. Associated with this 'silver tsunami' is an increase in health and residential care costs. Health expenditure rose from 7.5% of GDP in 1998 to account for over 9% of GDP in 2010, the majority of which was funded by the government [2]. At up to $50,000 per bed per annum [3], the cost of residential aged care services is also high, and is similarly subsidized by the government. As the number of aged Australians is predicted to continue to increase [4], there is a strong imperative to develop innovative assistive technologies to support and extend elderly home stay and therefore reduce costs associated with health and aged care.

Several countries have now introduced assistive technologies and smart homes to facilitate safe independent living [5]. The types of services and technologies differ

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depending on the aim of the project, and the needs of the elderly. Most of the technologies within the home are for use by the resident, however, some are designed for use by social workers and carers, particularly in homes designed for elderly people with dementia [6]. In general, most smart homes contain a combination of sensors and monitoring systems and an avenue for social engagement. An advance in wearable technologies has seen the introduction of actigraphs [7], sensorised clothing [8], and even air bags to prevent fall injuries [9]. Sensor-based in-home monitoring systems have the capacity to provide a safe environment for the residents, and the analysis of data derived from these devices has proven to be valuable in detecting changes in activity or routine that underpin health decline [7,10]. However, cultural and behavioural differences are likely to influence acceptability and uptake of both invasive and non-invasive monitoring devices.

In order to gauge the level of acceptance and determine the full range of benefits ensuing from the provision of assistive technologies to elders living independently, a qualitative component has been incorporated into studies conducted in the United States and Ireland [11,12,13]. In general, these qualitative studies have revealed that positive elements of home monitoring include an increase in peace of mind, safety and medical compliance; while negative aspects include technical glitches, privacy concerns, and the limitations imposed by a daily diary and wearable technologies. Wearable technologies were reported to have a further negative affect arising from a perceived increase in frailty and loss of personal autonomy [13]. Currently there is a dearth of knowledge of how Australian elders feel about being monitored.

In Australia, the Smarter Safer Homes project is being piloted in a group of elderly residents of an independent living facility. The primary aims of the project are to improve Quality of Life for the residents through social inclusion and to develop a decision support platform for care providers. This in turn will improve Family Quality of Life through increased contact and reliable health knowledge. As the Smarter Safer Homes project is the first of its kind in Australia, it is important to record the initial impressions of residents and their families. This will allow tailoring of services meet the residents' needs, and redesigning of elements perceived to be unacceptable.

Here we describe an ongoing qualitative study to identify perspectives of, and gauge reactions to, the sensor-based in-home monitoring system. Our study traces the pilot from conception and pre-pilot workshops, through implementation, activation and cessation. In this paper, we provide initial perceptions of prospective residents at pre-pilot workshops that were both positive (specifically, system flexibility and enhanced communication), and negative (flashing lights, cords and unfamiliarity with technology). Participant feedback was incorporated into the design of the pilot and the technologies to ensure that systems and services meet their needs and requirements.

2 Methods

The objective of the initial workshops was to gain an understanding from residents of an existing independent living facility of the requirements, desires and challenges to acceptance of this new sensorised, supported independent living technology being developed. To achieve this objective we met with interested parties in a regional town in New South Wales, Australia, to discuss technologies, services and the practicalities of becoming involved in the nine month pilot trial.

2.1 Participants

The pilot study is being conducted in accordance with Human Research Ethics approval (12/17), while the initial workshops received low risk approval under LR14/2012. Pilot participants (N=20) are residents of independent living units in a regional town in New South Wales, Australia. They are aged over 70 years, have access to fast broadband internet, are willing to use an iPad and have no home care arrangements in place. They must remain in the town for the duration of the study and have significant others who are located in another Australian location. Pre-existing conditions with compromised cognition are exclusion criteria. Pre-pilot workshop participants (N=11) are residents who have expressed interest in the pilot study and hence meet the inclusion criteria above (n=9) or family members (n=2). Pre-pilot workshop participation does not guarantee pilot placement.

2.2 Sensor-Based In-Home Monitoring System

The Smarter Safer Homes platform relies on broadband connectivity and is a combination of sensors, monitors, iPad and software. The platform will aggregate sensor information at environmental, cognitive, behavioural and physiological levels that can be accessed by relevant parties nominated by researchers and participants. An iPad will be provided to each resident to access the data and to facilitate video conferencing. The pilot participant's homes are fitted with a range of in-home sensors, including a GPS tracker fitted to a key ring to monitor external excursions (Table 1). None of these devices require participant training, maintenance or interaction. A suite of medical devices is also provided to residents on a needs basis together with training and instructions (Table 1).

Table 1. Examples of sensor type, placement and data gathered

Sensor type	Data gathered	Place of installation
Motion sensor	Motion within 5m	Ceiling in all rooms
Accelerometer	Bed movement	Under bed
Plug meters	Current draw of appliances and devices	Wall power outlets
Acoustic sensor	Fall detection; Presence of visitors	All rooms; Lounge
Temp/humidity	Temperature and Humidity readings	Kitchen Bathroom Living
Pressure sensor	Use of sofa/couch	Under sofa cushion
Reed switch	Open/close events	Doors, pill box
Security camera	Live video stream	Front door
GPS tracker	Outdoor trajectories	Key ring
BP and heart rate	Systolic/diastolic and heart rate	Medical station
Weight scale	Body weight, BMI, fat	Medical station
Blood glucometer	Blood glucose	Medical station
Sonomat*	Sleep quality, heart and lung data	On mattress

* Invented by Colin Sullivan, University of Sydney, Australia.

2.3 Procedure

Two workshops were held in the lounge room of a demonstration smart home prior to both implementation of sensors in the residents' homes and pilot commencement. Four residents attended the first workshop (3 females). Two of these residents (both female) returned for a second workshop along with five other residents (4 females) and two family members (both female). All female residents lived alone, while the two male residents lived in dual occupancy. An overview of the system along with selected demonstrations formed part of the pre-pilot workshops, followed by open discussion of the technologies and iPad applications. Workshops were recorded and transcriptions underwent content analysis to explore arising themes.

3 Results

Here we provide preliminary results from the pre-pilot workshops with prospective residents of the Smarter Safer Homes pilot study. The aim of these workshops was to demonstrate and discuss the smart home technology. We had a particular interest in determining unacceptable aspects of the technology and how these could be modified.

In general the demonstrations were received favourably by the participants who were curious about aspects of the technology and interested to know more. As they started to picture themselves using the technology, they began to question what the technology would do for them and what the implications of using it were (Table 2).

Most of the questions related to how the participants would use the technology and what information they would be provided by the sensors. Some of the residents queried, but did not seem concerned by, additional costs of internet provision or electricity usage. Similarly, participants were interested to know if the pilot was successful could it be applied to independent living units in other Australian regions, or to more dependent forms of aged living such as residential care or nursing homes.

3.1 Modifications Arising from End User Input

In most cases there was consensus over the acceptability of sensors. Pressure sensors, plug meters and reed switches were met with unconcern; however, participants did find some technologies unappealing. The units have illuminated devices, such as smoke alarms and emergency call buttons. Residents felt these provided enough light at night and were not keen on sensors with flickering lights. The accelerometers on the bed were the only sensors perceived to be a real invasion of privacy. While all participants felt alerts would be valuable, there were various views on the usefulness of specific alerts. One was keen for a 'running tap alert' to be activated in the bathroom, while another did not want this in the kitchen. Altruism emerged where participants accepted the technology on the proviso that their baseline data would benefit others, for example if we gathered data on typical running tap events, weight gain or sleep quality in their age bracket to use as a measure of forgetfulness, unhealthy weight gain, or dementia [14] respectively. Concerns raised by the residents and the solutions that resulted in design modifications are provided in Table 3.

Table 2. Indicators of participant curiosity of smart home technology

Topic	Question
Camera	So I can see and hear who's at the door? That's a good idea.
Cost	Will that raise our power bill or what extra will that cost in a home?
Detecting falls	[can it tell] if you had a fall? Would it go 15m outside? Who is monitoring it?
	If you knock over the ironing board do you ring and tell them?
GPS	So you mean that little machine would tell me how far I walked?
In-home monitoring	How widespread do you think you will go with this? Will it be in most homes of the aged? Is that what you're aiming at?
iPad	Would this thing be in a holder that you could pull it out and put it back in again? So it's got to go near somewhere which has a power point?
	What else can you do with one? Can you send emails? Read the news?
Medical portal	One of those things was a glucose level, that has a test. Who would use that?
	So for all those six health items, you've got indicators and graphs?
Pilot	When is this likely to start now? And where do we sign up?
	And when do you come around finding out where we want things, what we want measured and that? You put in all our information - we put it in?
	Do I need the internet on before you people start? Are you paying for that?
Video calling	What has my son got to have to receive my messages?
Weekly diary	And does that weekly diary then get read by you?

Table 3. Examples of end user concerns and modifications to pilot design

Context	Participant's concerns	Proposed solutions
Sensors	'More little flashing lights in our house?'	Cover lights on sensors
	'I'm too aware of them, yes.'	Unobtrusive placement
	'Do these gadgets need maintenance?'	Conduct maintenance
Automatic alert generation and receipt	'If something happened in the middle of the day, they would never know anyway.'	Tailor contact for alert type (Family, carer, GP)
	'I don't want an alert that the kitchen tap is running, I fill my watering can there.'	Allow alerts to be tailored to residents needs
	'An alert on the bathroom tap would be good'	
Technology	'My son gave me an iPad, I can't work it.'	Provide training
Recharging	'So it's got to go near a power point?''	Finding a suitable spot
Extension cords	'You trip over them. You get tangled '	Cords to run along walls

Most of the conversations around aspects of the pilot they did not want were based on practicality. Participants did not see the point in having motion or acoustic sensors if they did not alert you to an event, and they did not want alerts for events that they did not perceive to be relevant to them ('I don't leave taps running'; 'I only take two pills'; 'I know how I've been sleeping'). Participants felt they did not need to be

provided with irrelevant information which was 'meaningless' to them, such as data relevant to components of the project that aimed to assess for example, declines in cognitive or physical health. The participants were happy for this data to be collected, but did not feel it should be provided to the resident or their families.

3.2 Wish List Modifications

Participants were imaginative about the potential applications the technology could provide that would enhance their lives. Particularly if the technologies could warn someone that they were about to fall out of bed; or find objects they had misplaced.

3.3 Interacting with Technology

Much of the second workshop was devoted to demonstration of the iPad and its applications with a view to designing the interface in line with the resident's needs and preferences (Table 4). Participants were quite forthright and fairly unanimous in their preferences for the visual appearance of the iPad user interface. In summary, they expressed a preference for large font, blue or grey background, black print, sans serif font and buttons over blocks. These preferences were subsequently incorporated into the iPad user interface design. In terms of functionality, there was less agreement, and in general it was decided that information provision would need to be tailored for the individual. There were some functions on which there was consensus, such as a preference for audio over visual alerts; ability to change alert settings; ability to nominate which family members receive what data; and that family are advised that the participant is fine, but are not bombarded with medical and sensor data.

Table 4. Examples of participant contributions for the user interface of the iPad application

Feature	Specifics	Consensus and Additional Comments
Font	Size	Medium to large
	Type/ Colour	Sans serif/ Black
Layout		Selections in list on left hand side
Background		Blue or light grey
Tabs		Buttons over boxes
Alerts	Audio vs visual	Preference was for audio alerts
		Liked a list of devices left on
Family	Information sent	Basic info only, flexibility with nominations

Only one resident had family members present at the workshop, most were unable to join in as they either work during the day, or live out of town. None-the-less there was discussion on how residents and families would interact with the system. Participants felt families would be able to talk to them more often through the iPad and wanted to know what equipment families would need to have to do so.

Participants felt that information provision needed to be tailored for each family. For this reason, the configuration built into the iPad allows for individual family members to be added with three levels of information provision (none, basic, full) with the resident able to adjust these settings. Finally, participants did not feel alerts should go to families for three main reasons: not all family members had computers; most family members were busy during the day; and it would be too late by the time they got there or made contact. Hence alerts were configured to be sent to the resident or, in the case of extreme medical alerts, their care provider.

4 Discussion

An important aim of the workshops was to gain insight from the residents into how the technology and services could be tailored to their requirements. In fact, the participants provided a wealth of data that could be used by several of our researchers to inform and augment the pilot. Modifications were made to the design and placement of the sensors to reduce visibility; alert and information settings were configured to be tailored individually; and the iPad interface was designed on the basis of participant feedback.

Favourable comments were received around the flexibility of the system to be tailored to individuals, usefulness of alerts generated in response to taps or stoves left on, security afforded by a front door camera, potential for increased or easier family communication, enhanced peace of mind and the notion that others could benefit from the study. Several areas of discussion generated negative comments from the participants. Almost all concerned issues that were easily solvable, preventable, or pertained to existing devices or abilities, and thus not directed at the introduced technology. Participants were against equipment that had lights, extension cords or required maintenance and felt they would require training to use the iPad and medical devices. Apart from this, most of the undesirable aspects of the pilot were based on perceived usefulness of the data. If they could not see how the data could be used, they did not see the point in collecting it. This was keenly felt where the technology for data collection was considered an invasion of privacy, such as accelerometers on the bed or weight scales. Once it was explained that their information could provide baseline data on which to measure less healthy participants, they were much more accepting of the technology.

The wish list modifications were imaginative and intuitive but not unrealistic. It may well be possible to generate an alert based on bed accelerometer data that would warn someone about falling out of bed. The Gloucester Smart House [6] has a wall mounted locater device for frequently lost items. While not a part of this pilot it is conceivable that these devices could form part of a future Australian smart home.

All the discussion on families related to information provision – what they would like their families to know; and what the families would like to receive. In general it was considered that the families needed to know that the residents were fine, but not their personal or medical information such as daily patterns, weight, and so on.

More females than males attended the workshops, consistent with residential numbers at the independent living units and with female longevity noted in [1]. To ensure maximum participation, workshops need to be planned well in advance. Residents had a range of routine activities, like the weekly mah-jong tournament, that took precedence over ad hoc events. Small workshops worked well, as each resident had an opportunity to vocalise questions, qualms and opinions. It was favourable for the researchers too, as it allowed elements of the system to be thoroughly discussed and various perspectives gathered. In the first workshop, participants were distinguishable by voice, but this useful capacity was lost in the second, slightly larger, workshop.

The face to face nature of the workshops was extremely valuable in that the workshop facilitators could provide clarification and answers, both immediately, and after consultation with the research team. This communication was considered to ease the concern of the participants, make them feel they are being heard, and allow a smoother transition to in-home monitoring. Furthermore, the questions participants raised can now be addressed in a workshop for all residents prior to the pilot commencement. The participants spoke of an unfamiliarity with, and a reluctance to take up, new technology which will need to be addressed with training workshops in order to assuage concerns and ensure resident and family involvement.

The perspectives of prospective residents that we have recorded can now be used by researchers looking to develop technology based support systems that have been informed, in part, by the recipients. Understanding end user perspectives and communicating these to the wider community will help foster uptake of in-home monitoring services while providing peace of mind for families and carers. The inclusion of a qualitative component to smart home research will ensure that the delicate balance between service provision and preservation of dignity is maintained for these valuable community members.

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