Implementing Monitoring and Technological Interventions in Smart Homes for People with Dementia

Case Studies

Tim ADLAM, Bruce CAREY-SMITH, Nina EVANS, Roger ORPWOOD, Jennifer BOGER, Alex MIHAILIDIS

a Bath Institute of Medical Engineering, Wolfson Centre, Royal United Hospital Bath, BAI 3NG, UK.

b IATSL, Dept. Occupational Therapy, University of Toronto, 160–500 University Avenue, Toronto, ON, M5G 1V7, Canada.

Abstract. This chapter is about the application of behaviour monitoring technology in the context of a smart home for people with dementia. It is not about the design of technology, but about the application and configuration of existing technology in a specific context: in this case, smart flats for people with dementia in London and Bristol. Technology was installed and evaluated in a year long evaluation in London by a resident tenant. He was assessed throughout his tenancy using standardized outcome measures, by clinical professionals; and through the analysis of data collected by sensors installed in his flat. It was demonstrated that the technology had a positive impact on his life, improving his sleep in particular. This improvement had a positive effect on many other aspects of his life in the extra care setting where he lived. The Bristol evaluation is in progress. It is also an evaluation of smart home technology embedded in a person’s own home.

This chapter also describes two technologies being developed at the University of Toronto, in Canada. The first is COACH, a system used for the guidance of activities of daily living, and the second is HELPER, a fall detection and personal emergency response system (PERS). These technologies operate autonomously with little or no explicit input from the person using them, making them extremely intuitive and effortless to use. Practical experience and clinical results gained from the latest efficacy trials with COACH are presented and discussed. From the data collected though these trials, it seems that COACH has a positive effect on peoples’ ability to independently complete the activity of handwashing. It is hoped that monitoring technologies such as these will improve the independence and quality of life for people with dementia.

Keywords. dementia, monitoring, behaviour, technology, evaluation, guidelines, implementation, installation, sensors, measurement

1 Corresponding Author: Björn Gottfried, Centre for Computing Technologies, University of Bremen, 28359 Bremen, Germany; E-mail: bg@tzi.de.
Introduction

The monitoring of the behaviour of people with dementia has been implemented for several primary reasons.

Monitoring for safety: The continuous monitoring of behaviour in a person’s home can enable changes in behaviour to be detected that might indicate that a dangerous situation has occurred, such as the person having fallen or become suddenly ill.

Monitoring for long term trend prediction: Behaviour monitoring can also be used to detect long term trends in behaviour. It is thought that such long term trends can be used to detect potential health problems or changes in cognitive status for example through the measurement of specific parameters such as walking speed or more abstract parameters like activity levels and sleep patterns.

Monitoring for control and individualisation: Behaviour monitoring can be used to determine lifestyle related parameters that can then be used to customise the configuration of intelligent assistive systems. Customisation can either be manual, based upon human interpretation of the monitoring data, or automatic, based upon data interpretation by an artificial intelligence.

At this time, behaviour monitoring has been used widely in telecare systems for the detection of suddenly occurring problems. Networked sensors and communication systems installed in a person’s home are linked to a call centre, and when a problem is detected, a call to the centre is generated and a person is sent to the home to deal with the problem. Some systems such as those described in this chapter [1, 3] are taking a more intelligent approach to this application and are using artificially intelligent software agents to make judgements about the nature of the problem detected and then to

1. Technology in Bristol and Deptford

This section describes the technology installed in Bristol and Deptford flats. Both are part of Extra Care developments that provide a home and care for older people. The flats are similar in the facilities they provide, and the infrastructure upon which the smart systems are built is also similar. The Deptford flat is hard wired with some limited proprietary wireless systems for voice messaging. The Bristol flat employs a hybrid wireless and wired system but is mostly wireless, using off-the-shelf sensors and devices to deliver monitoring and interventional services to the user. A range of assistive devices [4] are installed in both flats that aim to support people with dementia to be safer and more independent; and to support care staff in their duties.

1.1. Infrastructure

The Bristol and Deptford flats have been built on the KNX buildings automation system. This is an off-the-shelf, standardised and highly interoperable system of devices for networking, sensing and controlling. Devices are available using wired and wireless communications. KNX devices are also available to link the system to remote communications, including webservers, gateways into TCP/IP networks and facilities for information distribution and control using GSM and the GSM Short Message Service (SMS).
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Location</th>
<th>Source</th>
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<tr>
<td>Passive infrared (PIR) motion sensors</td>
<td>All rooms</td>
<td>KNX supplier</td>
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<tr>
<td>Bed occupancy sensor</td>
<td>Bedroom</td>
<td>BIME</td>
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<tr>
<td>Smoke sensor (modified)</td>
<td>Kitchen</td>
<td>Hardware store</td>
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<tr>
<td>Door opening sensor</td>
<td>Front door</td>
<td>KNX device supplier</td>
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</table>

Table 1. A table of sensors installed in the Deptford and Bristol flats

KNX is based upon the European Installation Bus (EIB), the European Home System (EHS) and BatiBus. It is supported by many major device manufacturers who present a wide range of sensors, actuators and controllers suitable for use in commercial and domestic applications. Interoperability of devices from different manufacturers is excellent due to strict management of the standard by the Konnex Association.

The Deptford flat used wired KNX, which at the time of installation was known as EIB or ‘European Installation Bus’\(^2\). Control logic was provided with an ABB AB1/S logic controller installed in the flat on a DIN rail. The AB1/S is a programmable controller with up to a total of 200 logic elements available to the programmer for all programmes. The PC based programming software utilizes a crude graphical interface to link and configure logical elements.

The Bristol flat used a hybrid of the wired and wireless versions of the KNX standard, as well as some off-the-shelf proprietary wireless devices operating through a KNX gateway. Since the time of installation, the range of wireless KNX devices has been extended and it is no longer necessary to use proprietary devices in this way.

1.2. Sensors and Actuators

The Bristol and Deptford flats were similarly equipped with a range of sensors and actuators. The Deptford devices were installed in the flat in the six months prior to the beginning of the tenancy in April 2006. The actuators and sensors were sourced from KNX suppliers, electrical wholesalers, hardware stores and BIME.

The passive infrared motion sensors and the door opening switch were from the range available off-the-shelf from KNX manufacturers such as ABB, Gira and Siemens. The bed occupancy sensor was designed and built by BIME, and the smoke sensor was bought from a hardware store and adapted for use with a KNX binary input interface.

As with the sensors, the actuators used were a mix of off-the-shelf KNX devices and those designed and built by BIME. Both flats used standard KNX lighting actuators; and KNX binary output interfaces to control BIME devices such as the cooker isolator, the smart taps (Deptford only), and the warden call interface. The voice messaging was controlled by a KNX binary output interface linked to a BIME wireless controller and a network of message boxes in each of the Deptford rooms, and a standard off-the-shelf KNX device voice messaging system hard wired to speakers in each of the rooms in the Bristol flat.

\(^2\)The EIB standard was merged with the European Home Automation System (EHS) and BatiBus standards to form KNX: a new single European standard for buildings automation networks. KNX has since been granted an international ISO standard. See [http://www.knx.com](http://www.knx.com) for further information.
Table 2. A table of actuators installed in the Deptford and Bristol flats

<table>
<thead>
<tr>
<th>Actuator</th>
<th>Location</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td>Lighting control</td>
<td>All rooms</td>
<td>KNX supplier</td>
</tr>
<tr>
<td>Cooker isolation contactor and KNX binary output)</td>
<td>Kitchen</td>
<td>Electrical wholesaler and KNX supplier</td>
</tr>
<tr>
<td>Voice messaging (Deptford)</td>
<td>All rooms</td>
<td>BIME device</td>
</tr>
<tr>
<td>Voice messaging (Bristol)</td>
<td>All rooms</td>
<td>KNX supplier</td>
</tr>
<tr>
<td>Smart taps and KNX binary input (Deptford only)</td>
<td>Kitchen</td>
<td>BIME device and KNX supplier</td>
</tr>
<tr>
<td>Door opening sensor</td>
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Passive infrared motion sensors (PIR):  The Deptford PIRs were standard KNX sensors bought off the shelf from a UK KNX supplier. The specific devices purchased were designed to work as presence sensors, triggering after several motion detections have registered, and resetting after a short period of inactivity. These sensors were selected because they were ceiling mounted with a $360^\circ$ field of view. It would have been preferable to use wall mounted motion sensors designed for security applications, however the location of the KNX wiring installed at the time of build made this impractical. As a result the presence sensors did sometimes under-report movements through through the lounge if the person was moving quickly. This was not thought to be a substantial problem in practice as the tenant did not walk quickly.

The sensors were used for detecting the entry and exit of the tenant from the room. For this reason, they needed to be sited carefully, to prevent a sensor ‘seeing’ into more than one room and falsely triggering. Again, the incorrect positioning of the KNX wiring prevented this careful positioning from taking place, and there was some overlap of the lounge sensors into the kitchen and the bedroom.

Bed occupancy sensor:  A bed occupancy sensor was installed underneath the bed legs. The sensor weighs the bed and can detect if a person gets in or out of bed. A pressure mat by the bed can detect only if a person is standing by the bed and not whether they are getting in or out. The sensor was linked to the KNX bus using a binary input device.

Cooker minder:  A cooker monitoring system was installed that used a smoke detector to trigger a voice warning message if smoke was detected. If the smoke did not clear shortly after the message was played, then the system isolated the cooker from its electrical power supply.

Smart taps:  The kitchen was fitted with smart taps that could be used just like ordinary taps using their handwheels, but they also had a timer incorporated that turned off the water after a preset time. After the water is turned off, the taps remain usable and are not left in the ambiguous situation of being turned on but with no water coming out.

Voice messaging:  The messaging system was designed and built at BIME rather than being an off–the–shelf system. A message device was installed in each room and wirelessly linked to a controller installed with the bus system devices in a cupboard. A code sent from the KNX logic controller determined which message was sent to which room. A different off–the–shelf KNX system was installed in the Bristol flat which used a single message generating device and distributed hard wired speakers. Codes were delivered to the device using multiple binary output channels.
Front door sensor: A magnetically actuated reed switch was fitted to the front door to detect door opening. The was interfaced with the bus using a binary input channel.

Warden call interface: It was necessary to be able to alert the staff if a problem was detected that could not be resolved with a local intervention by the system. For this purpose a device was integrated into the warden call system that could generate a call when needed. The call system was linked to a DECT\(^3\). They operate in the phone handset that was carried at all times by the duty manager in the building. The Deptford flat had a single warden call channel available, so the call to the duty manager’s DECT phone did not distinguish between the channel being activated by the system or by the occupant pressing a button. The Bristol flat had two warden call channels, one of which was dedicated to to the monitoring system, thus enabling the duty manager to know whether the occupant or the system initiated a call.

Presentation of monitoring data: The data gathered by the monitoring system needs to be presented to the care staff and duty manager in a way that is understandable and useful to them. An example of raw sensor data is shown in Figure 1. This data, though it contains great richness and detail, is not useful in a care context without further interpretation and reformatting. Care staff do not need to know how many times a light switch was operated. Much more useful parameters might be whether the occupant is asleep or awake, or whether the occupant has been inactive for an extended period of time.

![Figure 1. A sample of raw sensor data from the Deptford evaluation. Each line is an event recorded in the log that might be a motion sensor trigger or a light switch being operated. The events are automatically time and date stamped.](image)

The Bristol and Deptford flats used slightly different approaches to data presentation. They both used alerts delivered to care staff based on realtime monitoring data using several different media.

Automatic staff calls The staff call facility incorporated into the smart flat was used to alert carers to situations which were likely to need their immediate attention. In this way they were able to target their attention at appropriate times. Staff calls were raised in the following three scenarios:

Unsettled night time behaviour: Bed occupancy and movement within the flat were monitored and analysed in real time and staff were alerted if unsettled behaviour was detected at night for a prolonged period. This was triggered on a number of occasions during the evaluation period and allowed staff to provide reassurance and reinforce daily routines. The tenant also had a tendency to become anxious when she had an appointment the following day, would wake early in the morning, and being disorientated about what time of day it was, would proceed to get ready.

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\(^3\)Digital Enhanced Cordless Telecommunications: A standard for cordless portable phones used typically for domestic and corporate purposes that permits the sending of voice and data.
The automatic staff calls alerted carers to the activity and upon visiting the flat could reassure the tenant of the time and encourage them back to bed.

**Wandering:** The front door contact was monitored during the night time ‘at risk’ period and staff alerted if the door was opened. Although the smart flat was located in a sheltered living environment, the family were anxious that there would be safety implications if the tenant left her door open late at night or early in the morning. During the evaluation period the tenant opened the door many times during the night time period. She was sometimes found outside her flat, particularly if she was anxious about making an appointment, however the majority of cases appeared to be due to confusion about the layout of the flat. In either case, the capability of the monitoring system to call staff when the door was opened assisted staff in providing reassurance and support to the tenant when it was needed.

**Difficulties in cooking:** The kitchen smoke detector was monitored and analysed in real time and staff were alerted if persistent smoke was detected. Cooking can be an important activity for people, preserving function and skills, providing patterns of daily living which help anchor in time and space, and, for some, helping to maintain identity and value. The tenant had a history of cooking at home, and continued to do some cooking once established in the sheltered living environment. Most of this occurred with one-to-one support from a carer, however she did attempt to perform a limited amount of cooking on her own. On five occasions during the evaluation period smoke was detected in the kitchen by the monitoring equipment and in four of these persisted long enough for staff to be called. In most care environments safety is considered of primary importance. The ability of the smart flat to monitor and respond to signs of danger in the kitchen resulted in carers being more at ease in leaving the tenant to cook for herself, ultimately allowing greater independence.

**Email updates** The computer within the Hillside flat was equipped with a mail server and this was used to generate emails in response to specific events within the flat. Primarily this was used to notify engineering support staff when faults occurred or when interventions such as verbal messages or staff calls were made. However, the system was also set up to notify the care manager of the time and reason for each automated staff call. As these calls were predominantly made during night time hours this enabled the care manager to gain a picture of the previous nights events upon arriving at work in the morning. This information complemented the written logs kept by the night staff.

Towards the end of the evaluation, the system was modified to allow the generation of more flexible summary emails. The intention was that these emails would be sent to carers and family if unsettled behaviour was detected at night and would contain a summary of information deemed relevant to the recipient. The information would include the bedtime and risetime of the tenant and any periods of sustained activity at night. If messages were played or staff were called the times of these interventions would be included.

The impetus for creating these summary emails was that the key family member was, from time to time, requesting feedback from the monitoring. This was predominantly to help them confirm information received verbally from the tenant about their night time experience. It helped paint a bigger picture of events that had occurred over previous nights in terms of restlessness and activity. This information had to be manu-
ally extracted and it was felt that automating this process would allow the family to gain
greater benefit from the monitoring. However, the automated provision of information
to interested parties who weren’t involved in the day-to-day, hands-on care of the tenant
raised some important questions. The overarching conclusion was that any sharing of
behavioural monitoring data must be done in a way that supports rather than undermines
the existing relationships between the people who have a strong interest in the wellbeing
of the person being cared for and those who are carrying out the person’s day-to-day
care.

The technology installed in the Bristol and Deptford flats was mostly off–the–shelf.
It did not have a high degree of intelligence and employed simple conditional algorithms
to determine its responses to situations detected using its array of sensors. However even
with these modest technologies, a strong positive impact on the quality of life of the oc-
cupant was demonstrated using sensor based and personal evaluation of the technology.
Some of the results of the use of this technology are presented in the results section of
this chapter.

Long term statistical analysis  Processing of data was undertaken by the research staff
to extract behavioural indicators of tenant wellbeing. Examples included hours in bed,
number and duration of out-of-bed episodes, day time room transitions, number and rea-
sons for staff calls. Graphs and statistics were presented to staff and family at reviews one
month after the tenancy began and then every 3 months until the end of the evaluation.
At the initial review data was used to inform which interventions were to be enabled. At
subsequent reviews the monitoring data was useful in highlighting the difficulties that
the tenant and/or staff may have been having and in prompting discussion about how the
technology might be modified to better support all parties. Each review led to refinements
of the system to better cater for the needs of the specific tenant and to accommodate
changes in her condition.

To be valuable to staff and family, the long term recorded data must provide in-
formation which is directly relevant to the tenant’s care. The challenge is in identify-
ing which parameters are most useful as indicators of the tenant’s wellbeing and then to
present them in such a way as to allow clear interpretation and comparison. The adop-
tion of monitoring data as a useful tool in the process of developing a tenant’s care plan
is most likely to be successful when a clear link can be made between the behavioural
trends shown in the data and existing measures of tenant wellbeing made through staff
observation.

2. Technology in Toronto

This section presents the COACH and HELPER systems. Both systems are autonomous
and are aimed at supporting different aspects of in-home living with little or no effort
from the people using the technology. The COACH system guides the completion of
activities of daily living while the HELPER system detects acute and long-term changes
in health. Both systems rely on artificially intelligent sensing, planning, and response.

2.1. COACH (Cognitive Orthosis for Assisting aCtivities in the Home)

The confusion and impaired memory functioning that accompanies dementia makes it
difficult for even mildly affected people to complete activities of daily living (ADL) [5].
These difficulties in ADL completion become more challenging as the condition worsens. It is not uncommon for a person with dementia to become disoriented part way through an ADL and/or not be able to remember what steps are required to complete the activity. The current solution is to have a caregiver supervise the person with dementia as they go about their day, something that can be difficult and humiliating for everyone involved. The COACH system has been developed to assist people to complete ADL independently from a human caregiver, easing caregiver burden and enabling greater independence of the person with dementia.

COACH monitors a person with dementia as they complete an ADL and provides prompts to the person if s/he appears to be having trouble with a step in the activity. While the goal is to support activity completion through the use of COACH, the intent is for the person with dementia to remain in control over the activity and to engage with their surroundings as much as possible. As such, prompts are only given if and when the person is having trouble with a step (e.g., confusion about the order of completion of steps, missing a step, or remaining inactive for a period of time). People with dementia are as unique as cognitively aware people; each individual has his or her own needs and abilities. Moreover, the effects of dementia are usually dynamic, causing changes in a person’s comprehension and execution capabilities that vary from day-to-day and generally degrade over longer periods of time. For prompts to be effective, they must not only be accurate, clear, and delivered in a timely manner (not too soon or too late), but also must be sensitive to a person’s capabilities and to changes in these capabilities, providing greater or less support as necessary. This requires the system to take into account the context of its environment, enabling COACH to react appropriately to the individual needs of the person using it. Aspects that need to be considered include: Where the person is in the activity? What is his/her preferred ordering of ADL steps? How responsive is the person to different kinds of prompts?

2.1.1. Infrastructure, Sensors and Actuators

As it is intended for use in the home, the design criteria for COACH included ensuring the system was affordable and simple to install. This resulted in the intentional development of a system with as few sensors and actuators as possible. The current system (version three of COACH) consists of a computer, an overhead camera, a flat-screen monitor, and speakers. An example setup of COACH can be seen in Figure 5. To test the efficacy of the system, it was configured to guide the ADL of handwashing, as this activity must be completed several times every day and steps are often missed.

Overhead camera: A video camera is placed over the area of interest, in this case the sink. Images from the camera are relayed to the computer, which analyses them for hand, towel, and soap positions in each incoming frame before deleting it. At the moment, the camera is the only sensor in COACH, although sensors such as a microphone will likely be added in the following version to enable increased perception (e.g., “hearing” when the water is on or off) and interaction with the person using the technology (e.g., basic speech recognition).

Computer: A single computer is all that is needed to analyse incoming images (sensing), make decisions about how COACH should react (planning), and to issue prompts to the person using the system (prompting). The particulars of how this is accomplished are discussed in more detail below.
Flat-screen Monitor and Speakers: The monitor and speakers are used to play audio and audio/video prompts that guide the person using the system to the next appropriate step in the activity.

Using the hardware listed above, the system guides a person through an ADL, in this case, handwashing. Handwashing can be broken into six steps, as shown in Figure 6. Any pathway from the Start to Finish nodes in Figure 6 represents a successful instance of handwashing. Using this representation, the system interprets images from the camera to determine where in the activity the person is and whether or not s/he needs assistance (i.e., if s/he has missed a step, is completing steps in the incorrect order, is leaving the activity before it is completed, or has been inactive for a period of time). If assistance is required, the system plays an audio or audio/visual prompt to guide the person to the next appropriate step. Prompts vary in specificity from minimal (e.g., a simple audio prompt asking the person to “Turn on the water”) to specific (e.g., “Tom, pull up on the silver lever in front of you to turn the water on,” accompanied by a video demonstrating how to turn the water on). Should the person remain unresponsive to the guidance given by COACH, the system will summon a human caregiver to intervene (e.g., via a pager). As such, COACH is not intended to replace the caregiver, but rather ensure the caregiver that s/he will be summoned if difficulties arise that prompting alone cannot handle. A novel feature of COACH is the dynamic history that the system maintains about each user. Each individual’s short- and long-term history is learned and adapted autonomously by COACH as it interacts with the person and includes his/her level of dementia, responsiveness, and number of times they have been prompted that day. By maintaining and automatically adjusting the history, the system can detect and respond appropriately to changes in daily and overall abilities. In an effort to keep the person using the device as involved and in control of the activity as possible, prompts are given at the minimum level that elicits compliance.

2.2. Health Evaluation and Logging Personal Emergency Response (HELPER) system

Falls, heart attacks, and other acute adverse health events become more prevalent with age. When an adverse event occurs, the affected person is often unable to summon help. This can result in many hours, or even days, before the affected person receives the medical attention they require, which in turn leads to higher rates of morbidity and mortality. To provide support and security, many people install a personal emergency response system (PERS). A PERS generally consists of a push-button that is worn on a bracelet or necklace and a speaker-phone base-station. When the button is depressed, a call is placed by the base-station to a call centre. The PERS client then speaks with a trained responder, who identifies the situation and, if required, dispatches the appropriate type of assistance. While PERSs can be helpful, many owners do not wear the push button because they forget to do so and/or they feel stigmatised. Thus many owners do not have access to the system when an adverse event occurs, cannot activate the system because of the adverse event itself (e.g., unconsciousness, broken wrist, etc.), or are afraid to activate the system because they perceive it as likely to result in long-term care placement. Additionally, this type of PERS is not suitable for people with dementia as it requires a reliable, explicit input from the owner (i.e., a button press), which is an unrealistic expectation of this population.

Building on the experience the research team has gained through clinical trials, a PERS has been built to operate more automatically and intuitively than conventional
The prototype, called HELPER, can autonomously detect adverse events and, using speech recognition software, has a dialogue with the occupant to determine what help the occupant needs. Depicted in Figure 2, HELPER consists of one or more ceiling mounted units that communicate with a central control unit. Each ceiling mounted unit uses computer vision and artificial intelligence to monitor a room and detect when an adverse event, in particular a fall, has occurred. In the case of an adverse event, the ceiling mounted unit determines the type of assistance the occupant needs through a series of simple, “yes/no” answer questions. If the system receives no response or cannot understand the occupant’s response, it will connect the occupant with a PERS call centre responder. Desired system response information is relayed to the central control unit, which dispatches for the appropriate type of assistance. Each ceiling mounted unit has other safety features, such as a smoke alarm that can automatically summon the fire department if it is not reset within a certain amount of time. In addition to contacting responders, the central control unit is responsible for coordinating the ceiling mounted units in an installation, keeping track of the occupant’s whereabouts, and building models of an occupant’s long-term living habits, which could be used to detect more gradual changes in health. Pilot trials with the HELPER system are set to begin in late 2009.

While this technology has been developed with independent older adults who are living at home alone in mind, it is not difficult to envision how the system could easily be adapted to monitor a person with dementia, detecting long-term behaviour patterns and notifying a caregiver if an adverse event occurs.

3. Practical Guidelines for Installation and Support of Monitoring Systems

Installing complex systems in the homes of people with cognitive disabilities needs special care and awareness because of the reduced ability of the occupant to adapt to the
presence of an unfamiliar person, for example an electrical contractor, in what would normally be a mostly private space. This section describes some practical guidelines that installers may find helpful. They are based on the experiences of the authors when conducting user evaluations of monitoring and interventional systems in the homes of people with dementia.

3.1. Guidelines on installation and support from the work in Bristol and Deptford

Survey the site prior to installation: The installer or another technically competent person should survey the site prior to installation to make sure that there are no unexpected problems that might arise such as the unavailability of a power supply or gas pipes that obstruct the installation of a device. The survey should be thorough and, where necessary, include measurements so that cable runs can be calculated in advance. The survey should enable the installer to plan the installation in advance of arriving at the person’s home with equipment and tools. This is to reduce the impact of the installation by making it as short and as efficient as possible.

Maintain good communication with the occupant of the evaluation site, another person that the occupant trusts, and care staff: The Deptford and Bristol evaluations were carried out in an extra care context where staff were available for 24 hours of the day. In both cases a family member was nominated as a ‘primary carer’ who would hold the occupant’s best interests uppermost.

In the Deptford evaluation contact with the carer was frequent and easy. The occupant’s daughter worked, but was happy to be contacted by email or phone, and made time to attend meetings and assessments when she was able to do so. The researchers became well known to the care staff even before the evaluation began as the researchers installed much of the technology in the apartment. After the beginning of the evaluation, there were some technical issues to resolve that required the attendance of the researchers in addition to the bimonthly review meetings held at the site. This frequent contact resulted in a good working relationship between the researchers, the care staff and the primary carer that contributed significantly to the durability of the evaluation when problems were encountered.

By contrast, the Bristol evaluation presented different communication challenges. The system was installed by a contracted KNX installer who efficiently and cost effectively completed the installation in a few days. There was no extended installation period prior to the evaluation so the researchers needed to work harder to build a relationship with the care staff. The main communication with the family was by email. This meant there was a lack of face-to-face contact, so at times it was especially difficult to know what were the family’s feelings about situations that were occurring. Delays that occurred in the evaluation might have been more swiftly resolved had more direct communication been possible.

Send two people and make sure one remains in the house: Always send at least two installers to install a system, and make sure that one if the installers remains in the the property until the installation is completed. This is especially important if the installation will be prolonged or require a complex installation procedure. This guideline follows experience with the ENABLE project where two installers visited the home of a person with dementia to install a cooker monitor. While in the middle of a complex installa-
tion with tools and materials distributed around the occupant’s kitchen, both installers simultaneously left the house to collect some additional materials from their van. They returned to the house to find that the occupant had forgotten who they were and was not willing to allow them access to her house. Fortunately in this case the woman’s son-in-law happened to visit at that time and persuaded her that she should allow the installers back into her house.

**Bring spares for key components, especially if they are vulnerable to damage in transit:** Bring spares for key components of the installation. When installing a cooker monitor in Lithuania, the ENABLE installers found that their gas isolation valve was damaged in transit, even though it had been carefully packed in a rigid case. Because the valve was damaged and no spare had been brought, the installation had to be abandoned and then reinstated later by a local gas installer.

**Installation standards may be different in different regions:** At the installation mentioned in the previous paragraph, the installer had to go out to modify a component to make it fit the cooker in the flat. When he returned to the small kitchen, the gas fitter who was installing the valve had removed the gas supply stop valve, stuffed a piece of rag in the end of the open ended pipe, and was trying to test the operation of the electric stop valve by inserting its wires into a mains power socket. The gas fitter had been selected for the job by a very senior person in the state energy company.

**Responding to technical faults:** When evaluating prototypes of complex technology that is still being developed, it is likely that faults and problems will emerge during the evaluation. People with dementia are less able to cope with fault conditions that people without dementia because of their impaired ability to reason, plan and adapt.

**Working with care staff:** Building an effective and robust working relationship with care staff in an evaluation of monitoring equipment is an important and challenging task that requires constant effort. Maintaining contact, communication and cooperation with the care manager is key to the success of the evaluation so that access to staff and facilities are easily obtainable, and that high level feedback about the impact of the installation on the working of the care facility and its integration into, for example, care plans and daytime activities.

The care staff should also be engaged with the project through good communication and involvement. They will be able to provide key insight into the effectiveness of a monitoring system and are users of the system just as much as the occupant of the accommodation.

**Implement and test new logic in-situ but off-line:** When working with people with dementia, it will be necessary to revise the control logic in use in their flat as their dementia progresses and their ability changes. In the Deptford flat and initially in the Bristol installation, revised logic was tested in the laboratory as much as possible, and then uploaded to the flat controller for immediate use. Inevitably there were some problems when the new control logic was faced with the complexity of a real person behaving unpredictable as real people do. Hasty changes had to be made to solve problems as they arose. In the later stages of the Bristol project, the new control logic was tested in the laboratory, then it was uploaded to the controller and enabled, but was not connected to the system actuators until it had been run for a week or so with only the sensors active. This enabled the
programmer to check the sensor input and control outputs with real live data, but without the risk of causing unwanted interventions in the occupant’s flat.

Guidelines around automatic staff calls and alerts: Feedback from carers indicated that the automated staff calls were useful in supporting them in providing appropriate care. Knowing that the smart flat would call them if a potential risky situation arose or behaviour indicated that the tenant was unsettled allowed them to target their care at times when it was needed most and allowed the resident greater independence in her day to day life. However, there were several key issues that were highlighted through the use of an automatic staff call system based on the monitoring and interpretation of sensor data.

1. Trust in the system by the carers is key to its success. Carers need to know that they will be notified consistently if a risky or unsettled behaviour is detected. However, they must also be relatively sure that if they are called it is for good reason. False alarms erode confidence and can lead to calls being ignored. This will be unacceptable in the long term and will undermine the technologies acceptance. False alarms can be due to inadequate algorithms which incorrectly diagnose situations or it may be due to unreliable sensor data. In either case, thorough testing is a necessary prerequisite before activating the system.

2. Carers may also ignore alerts if the automated system has been set up incorrectly. In the Hillside flat, the period over which the door sensors would trigger a staff call was set from eleven o’clock at night to seven o’clock in the morning. However, the tenant was an early riser and frequently got out of bed in the morning between six and seven o’clock. Due to her disorientation she would sometimes open the front door. Data logs showed that staff didn’t always respond immediately to calls during this period. This was due, in some part, to it being a busy time for staff. However, it may also have been influenced by the knowledge that this was not an inappropriate time for the tenant to be up and there was less risk to her if she did leave her flat during this period. Adjusting the settings so that opening the front door during this period did not trigger a staff call may have resulted in a more consistent staff response.

3. A knowledge of the reason for a call can assist the carer in knowing how best to respond. For staff calls initiated by the tenant the carer can use an intercom system to immediately find out from the tenant what assistance they need. In the cases where the smart flat has initiated the call the tenant is unlikely to know why the call has been made and interrogating them is unlikely to be beneficial. The Hillside installation did not include the facility to provide additional information to carers remotely once a call had been made; this would be a useful addition to the system.

4. The effect of staff calls on the tenant must be taken into consideration. Calls must be able to be made without alarming the tenant. In the Hillside installation calls initiated by the smart flat activated the staff call unit located in the hallway of the flat. This resulted in an audible alarm sounding in the flat, and continuing to sound until a staff member deactivated the call. The alarm caused the tenant distress, particularly as she was always conscious of disturbing others. If the tenant initiates a staff call herself then there must be some acknowledgement that this has been registered. However, where the calls are automatically generated thought
should be given to whether the tenant should be made aware of this, and if so, how this can be done without causing distress.

3.2. Practical guidelines from the work in Toronto

Other lessons were learned whilst conducting the work in Toronto described above. Three iterative versions of the COACH system have been installed and tested in three different long-term care facilities and evaluated with more than 30 people with moderate-to-severe dementia, established by a MMSE [2] score of 20 or less. While the following points reflect insights gained through daily, supervised pilot trials with a new system, many are applicable to permanent installations as well.

Get to know the Facility: As early as possible, the research team should get in touch with the Director / other management at the facility of interest. This will allow familiarisation with the facility and enable cooperation between the facility and researchers to determine interest in the system, appropriate (and, for prototype devices, dedicated) areas for the system, access procedures, and other matters of interest.

Obtain a Letter of Support: Before attempting to install the technology in the facility and/or apply for ethics regarding the study, obtain a letter of support from the director (or equivalent) of the facility. The letter should indicate the facility’s understanding of the purpose of the system, acknowledge their interest in having it installed, and (if applicable) their intention to participate in the research study.

Get to Know Your Participants: After obtaining appropriate ethics permissions, take the time to get to know the people who will be participating in the research study before it begins. Understanding the personal preferences and needs of the people who will be participating allows the research team to anticipate and avoid many difficulties before they arise. Not surprisingly, interacting with people in a way that respects their individuality will result in happier, more cooperative participants. It is vital that the person participates at a time that does not conflict with his/her schedule (e.g., meal times, nap times, social groups, etc.). Also, a little extra goes a long way. For example, one participant was an avid, lifelong painter. The research team brought watercolours and poster-paper, which were set up near the study location and made available to the participant after each trial. Very soon, she went from being an aloof to a quite keen participant (although her smile while painting was the greatest success of all).

Involving the Staff: Prior to installation of the system, the staff of the facilities were made aware of the purpose of the study and proposed execution plan at staff meetings. The team answered questions and asked for suggestions from the staff as to the most effective and least disruptive way to conduct trials. During the studies, researchers interacted with the staff often, answering questions and demonstrating the technology often. As the staff of long-term care facilities are often very busy, it is important that researchers continually work with the staff to ensure as little disruption to everyone’s schedules as possible.

Technical Support: Software/hardware support must be available and easily accessible at all times while the system is installed. It must be made clear to the people operating the device how assistance can be obtained and the response to technical difficulties must be timely. Enthusiastic and timely support will lead to greater interest and cooperation from the staff of the facility; if you do not take your responsibilities regarding your equipment seriously, you cannot expect others to do so.
**Continually Assess the Installation:** After installing a system, continually (remotely) monitor the operational status of the system and regularly assess the satisfaction of the people who interact with the system (e.g., staff, families of people with dementia, and the people with dementia themselves). Apart from asking direct questions, simply observing people interact with the system will yield significant information. This will result in many insights regarding the strengths and weaknesses of the installation as well as to ensure that any problematic situations regarding the system are addressed as quickly as possible and, in many cases, before they even arise. Be Prepared for the Reality of Working with this Population: Older adults with dementia are a frail and vulnerable population. Research trials must be designed in a way that is sensitive to peoples’ abilities and morbidities. Particularly with longer trials, days may be missed because of illness and in some cases participants may cease to participate entirely because of health concerns and, sometimes, in death. Not only should the methodology of the trials take this into account, but adequate support should be made available for the research team, who may very well be affected by changes in the participants’ health and well-being.

**Be Creative:** Ensuring that participants willingly and enjoyably participate in a study is important to most researchers. However, many conventional incentives are not appropriate for this group; monetary incentives cannot be given and it is inadvisable to offer food incentives because of the large number of dietary constraints. Be creative when devising appropriate incentives for participation. For example, during one set of trials, one of the researchers brought her small dog to the facility every day (after gaining approval from facility management). The dog stayed in a lounge area adjacent to the washroom where the trials were being conducted. Very soon after the dog’s appearance, people would come and go throughout the day to visit and play with the dog. Usually there were two or three people in the lounge area, some of whom were in the study and some who were not. The dog proved to be a wonderful addition to the research team, as she caused many participants to come to the trial area of their own accord, created an enjoyable place for socialisation, and became a conversation topic for the residents and researchers.

**Take the Time:** Apart from the performance of the system itself, taking the time to establish a good rapport with everyone involved in the study is the most important thing one can do to ensure a successful instillation. Participants, staff, management, and families all notice when a few extra minutes are taken to visit with the participant (e.g., chat a bit, help him/her to the room they wish to go to, etc.). While it takes more time, being a friend to the participants is not only personally rewarding, but is more than worth the effort for the trust, good rapport, and cooperation it yields. This positive relationship is especially important for trials that require many weeks or months to complete. This approach also fosters good long-term relationships with people, who will be keen to participate in future studies, greatly reducing the effort needed to find interested facilities, identify willing participants, and obtain consent from substitute decision makers. Setting up and maintaining good relationships will always pay off in the long run.

**Provide Recognition and Closure for the People Involved:** It is important to convey the closure of a study in a way that is appropriate for the people who participated. This gives researchers a chance to show their appreciation for peoples’ participation and provides closure for everyone. At the completion of the COACH trials, a “thank you” party with cake and juice was given for all the residents and staff in the wing and certificates were given to participants. Upon publication of the results several months after the completion
of the study, a pizza lunch with a 20-minute presentation followed by a question and answer period was held for the staff, management, and family members of participants. Getting the opportunity to see the impact of their participation not only resulted in a sense of satisfaction, but generated an excellent discussion with many observations the researchers plan to implement in the future.

4. Evaluation and Assessment

The assessment of the impact of assistive technology on the people for whom it is intended is not only important to determine whether it should be used on a larger scale, whether it is cost-effective, or whether it achieves the aims for which it was designed. Is it also necessary to assess and evaluate systems for their usability and usefulness during design and development phases so that the technology is known to be usable by its intended users and also useful to them. In these cases technology has been designed to be usable and useful to people with dementia and their caregivers.

4.1. Evaluation of the Deptford and Bristol Flats

The flat in Deptford was evaluated by a man who had moderate Alzheimer’s Disease. He moved into the flat from his own home, where he had been supported by community services coming into his home. He and his daughter agreed to participate in the evaluation programme. On arrival at the flat the participant had a Mini Mental State Examination (MMSE) score of 10.

The flat in Bristol was also evaluated by a resident tenant who agreed to be part of the research programme. The first tenant to reside in the flat was found to be unsuitable as a tenant by the housing association and was found alternative accommodation. This was not done because he was unsuitable as an evaluator.

The second tenant found for the flat in Bristol was a woman experiencing the early stages of Alzheimer’s Disease. She agreed to participate in the technology evaluation along with her daughter who was nominated as the tenant’s primary carer after the caregiving staff in the development. The woman’s immediate family did not live locally and maintained contact with her primarily using telephone. She was visited by family occasionally and went and stayed with relatives several times over the course of the evaluation period.

A variety of evaluation methods were used, including standardized outcome measures, qualitative methods and sensor derived parameters. These methods are described below:

Qualitative Measures

These measures form an unstructured and anecdotal record of the impact of the installed technological interventions. Due to the small scale nature of these evaluations, gathering sufficient quantitative data on which to base scientific analysis was difficult; the recorded views of the people using the technology became invaluable in assessing its overall value.
Interview: The participants, their key family member and the care facility manager (or her deputy) were individually interviewed at regular review meetings. In the Deptford case these occurred every two to three months; in the Bristol case an initial interview was conducted five weeks after she moved in and then review meetings were held 3-monthly. Notes were made from these interviews. These interviews took the form of a two-way dialogue, with research staff presenting observations and trends collected from the monitoring data, and staff, family and the resident giving feedback on the usefulness of the technology. The two-way nature of these interviews resulted in them being an invaluable setting in which changes to the technology could be discussed and agreed upon.

Care notes and event log: The notes made by staff relating to the participant were copied and collected at each review meeting. The staff also filled in a separate form recording calls made by the monitoring system and their responses the calls. In the Bristol case, these logs were of limited success due to poor compliance of staff. It may also have been due to night staff training being delivered by care managers rather than the researchers themselves, as was the case at the flat in Deptford.

Quantitative Measures
Two non-technological quantitative measures were used to measure parameters relating to the participant and the evaluation.

*Mini Mental State Examination (MMSE):* MMSE [2] is a crude but quick measure of cognitive function that is widely used to track the progression of diseases that cause cognitive impairment. MMSE was measured every 3 months throughout the evaluation.

The MMSE score of the Deptford flat’s participant was 10 upon arrival at the flat. This indicates moderate to severe dementia. After three months, at the assessment made just prior to switching on the interventions, his MMSE score had risen to 16. It subsequently decreased to 15 when measured at the six monthly review. It is thought that the increase in his MMSE score at the 3 month point was due to improved nutrition and basic care over the period after his arrival at the extra care facility.

The Bristol participant’s MMSE score was 21 on arrival. She had moderate dementia. Her MMSE score was not measured again during the evaluation.

*Individual Prioritised Problem Assessment (IPPA):* IPPA [6] outcome measure is designed to measure the impact of assistive technological interventions on a specific problem identified by a person (and his or her caregivers in the case of people with cognitive impairment). IPPA was measured at each review by the project occupational therapist.

Sensor Derived Measures
The monitoring and intervention system included a large number of sensors installed in the flats. Data from these sensors was collected and logged. Offline analysis of the data yielded meta-parameters describing aspects of the participants lifestyle and behaviour. Changes in these parameters were used as indicators of changes in behaviour and overall wellbeing.
Cumulative time asleep at night: This parameter was measured using the installed bed occupancy sensor. Time asleep was determined by aggregating the duration of continuous periods spent in bed of one hour or more. It was assumed that if the participant was in bed at night time then he was asleep. It is accepted that it is possible that he was in bed and was not asleep, however, determining his state of consciousness was beyond the scope of the technology used for this evaluation.

Figure 3 shows a graph of total time spent in bed day (24 hour day) from the Bristol evaluation. This type of long term data can be useful for detecting trends in health or progressive disease.

Number of exits from the flat during the risk period: This parameter was measured by identifying the number of times that the participant left the flat during the risk period. For the participant in the Deptford flat this was configured to be between 22:00 and 06:00; for the Bristol participant, between 23:00 and 7:00. An exit from the flat was defined as a trigger of the hall motion sensor, the front door motion sensor and then the front door sensor; without a subsequent trigger of the front door or hall motion sensors shortly afterwards.

In the Bristol flat this was measured slightly differently due to difficulties with the delay in PIR sensors resetting. The parameter recorded was the number of times the door was opened during the risk period. This was defined as a trigger of the front door motion sensor followed by the front door being opened within 30 seconds. Figure 4 shows an effective means of presenting this data that gives an overview of a whole night of activity.

Number of room transitions: Room transitions were measured throughout the day and night as a measure of activity. A room transition was defined as a trigger of a room motion sensor followed by the triggering of the sensor in an adjacent room.

Room transition data recorded from Deptford is shown in the tables below. It is thought that the number of room transitions occurring within a defined time-frame is a useful measure of activity levels.
Figure 4. A sample of data from the Bristol evaluation showing one night of bed occupancy and front door opening data. A downward transition on the bed occupancy trace indicates the tenant getting out of bed. A upward transition indicates the tenant getting into bed. An upward transition on the door opening trace indicates the door opening. A downward trace indicates the door closing.

<table>
<thead>
<tr>
<th>Daytime transitions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before switch-on (up to Aug. 15th)</td>
<td>217</td>
<td>445</td>
<td>348</td>
</tr>
<tr>
<td>After switch-on (after Aug. 15th)</td>
<td>199</td>
<td>535</td>
<td>367</td>
</tr>
<tr>
<td>November</td>
<td>258</td>
<td>599</td>
<td>357</td>
</tr>
<tr>
<td>December / January</td>
<td>157</td>
<td>536</td>
<td>297</td>
</tr>
<tr>
<td>February / March</td>
<td>201</td>
<td>694</td>
<td>385</td>
</tr>
</tbody>
</table>

Table 3. A table showing the number of daytime room transitions in the Deptford flat during periods between July 2006 and March 2007.

<table>
<thead>
<tr>
<th>Night-time transitions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before switch-on (up to Aug. 15th)</td>
<td>0</td>
<td>134</td>
<td>42</td>
</tr>
<tr>
<td>After switch-on (after Aug. 15th)</td>
<td>8</td>
<td>90</td>
<td>42</td>
</tr>
<tr>
<td>November</td>
<td>2</td>
<td>202</td>
<td>38</td>
</tr>
<tr>
<td>December / January</td>
<td>2</td>
<td>108</td>
<td>41</td>
</tr>
<tr>
<td>February / March</td>
<td>12</td>
<td>189</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 4. A table showing the number of night-time room transitions in the Deptford flat during periods between July 2006 and March 2007.

4.2. Evaluation and Assessment of COACH

The following presents selected results from the latest clinical trials with the COACH system. A single-subject design was used with two alternating baseline (COACH not used) and intervention (COACH used) phases with five participants who had moderate-level dementia (i.e., an MMSE score between 10 to 20). Each participant completed ten days of trials for each phase for a total of 40 trials per participant. During the baseline phases, a caregiver assisted the participant through the activity of handwashing in the conventional way (i.e., providing prompts, gestures, and physical assistance when the caregiver felt they were necessary). During the intervention phases, the caregiver stood outside the washroom and intervened only if COACH summoned her to do so. Data from the trials were analysed to determine the efficacy of COACH. However, "successful
device operation” does not mean the same thing to clinicians as it does to technicians. From a clinical point of view, a technology is successful if it achieves desirable clinical outcomes, in this case independent handwashing by the participant. From a technical point of view, the system is considered a success if it accurately captures the environment, interprets this information correctly, and gives reasonable prompts to the participant. Hence COACH’s efficacy was evaluated in two ways, with one examining clinical outcomes while the other focused on the technical operation of the system.

To reflect the importance of a person’s independence, the clinical assessment of COACH focused on: 1) independent step completion; 2) number of caregiver interactions; and 3) functional assessment scale (FAS). For independent step completion, participants scored one point for the first time s/he completed a step in a trial without any assistance from a human caregiver, up to a maximum score of five (one for each essential handwashing step). Number of caregiver interactions was the number of times the caregiver interacted with the participant and was considered to be any exchange between the caregiver and the participant related to activity completion, including verbal prompting, demonstration, and touching (either the participant or an object). The functional assessment score (FAS) is a modified tool for rating independence. For each trial, the FAS of the five essential handwashing steps were scored from zero (no attempt/refusal) to seven (complete independence), with an overall maximum of 35. If the participant completed the step in response to prompts provided by the COACH, a score of seven was given.

Table 5 summarises the results from the pilot study. From these results, it appears that the introduction of the COACH system leads to improvement trends in the three measures that were examined: independent step completion increased, caregiver interactions went down, and the average FAS increased. It is interesting that an individual such as S4 was able to obtain complete independence from a human caregiver when COACH was used. For people who are already relatively independent in handwashing, such as S3 and S6, COACH appears to serve more as a "maintenance” than guidance tool, with

Figure 5. Example setup of the COACH system when it is installed to monitor the activity of handwashing.
Figure 6. The steps required to complete the activity of handwashing. Note that “wetting hands” was a non-essential (optional) step in the activity as liquid soap was used in the trials.

no significant positive or negative effects (although positive effects would be difficult to detect using these methods as these subjects essentially had maximum score). In all cases, participants’ measures of clinical independence tended to improve when COACH was used.

Figure 7. Hits, misses, false alarms, and correct rejects made by the COACH system and participants’ responses during trials with five individuals who had moderate-level dementia.

To gain a better understanding of the device performance from a more technical point of view, how and when the device intervened was examined with respect to the
<table>
<thead>
<tr>
<th>Participant [Average MMSE score]</th>
<th>Phase</th>
<th>Mean number of steps completed independently (out of 5)</th>
<th>Mean number of interactions with human caregiver</th>
<th>Mean FAS* (out of 35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3 [15]</td>
<td>A1</td>
<td>5.0</td>
<td>0.0</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>5.0</td>
<td>0.0</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>4.9</td>
<td>0.2</td>
<td>34.8</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>5.0</td>
<td>0.0</td>
<td>35.0</td>
</tr>
<tr>
<td>S4 [12]</td>
<td>A1</td>
<td>3.6</td>
<td>2.6</td>
<td>29.9</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>5.0</td>
<td>0.0</td>
<td>34.7</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>4.5</td>
<td>1.4</td>
<td>33.9</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>5.0</td>
<td>0.0</td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>4.1</td>
<td>2.6</td>
<td>31.6</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>3.8</td>
<td>3.8</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>4.9</td>
<td>0.3</td>
<td>33.2</td>
</tr>
<tr>
<td>S6 [13]</td>
<td>A1</td>
<td>5.0</td>
<td>0.0</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>5.0</td>
<td>0.0</td>
<td>34.9</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>5.0</td>
<td>0.3</td>
<td>34.8</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>5.0</td>
<td>0.0</td>
<td>34.9</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>5.0</td>
<td>1.3</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>4.5</td>
<td>2.2</td>
<td>32.8</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>5.0</td>
<td>2.6</td>
<td>32.3</td>
</tr>
<tr>
<td>Mean score over phases</td>
<td>A1&amp;A2</td>
<td>4.4</td>
<td>1.7</td>
<td>33.2</td>
</tr>
<tr>
<td></td>
<td>B1&amp;B2</td>
<td>4.9</td>
<td>0.6</td>
<td>34.1</td>
</tr>
<tr>
<td>percent change**</td>
<td>11</td>
<td>-66</td>
<td>2.4</td>
<td></td>
</tr>
</tbody>
</table>

* Functional assessment score
** Calculated by \( [(B1+B2)-(A1+A2)]/(A1+A2) \times 100 \)

Table 5. Results from efficacy trials with COACH.

Table 6. Possible reactions of the COACH system to participant actions.

<table>
<thead>
<tr>
<th>Participant Action</th>
<th>Error</th>
<th>Hit</th>
<th>Miss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Error</td>
<td>False Alarm</td>
<td>Correct Reject</td>
</tr>
</tbody>
</table>

COACH Response

participant’s action. Each device intervention can be categorised as a hit, miss, correct reject, or false alarm, as outlined in Table 6. In addition labelling with these categories, (when applicable) data from the trials was also marked with whether or not the participant responded to the prompt given by COACH. These results can be seen in Figure 7. This data suggest that while the use of COACH may improve independence, there is still work to be done in improving prompting accuracy.

A more in-depth discussion of the results presented above can be found in [3].
5. Conclusions

The systems that are being developed in Toronto are designed to autonomously support people in their home, providing assistance only when it is needed and without any intentional input from the person it is supporting. Important features these devices are: 1) they do not require people to learn or remember how to use the devices as they will intervene automatically when needed; 2) interactions with the devices are intuitive (e.g., speech); 3) the devices learn about and adapt appropriately to the people using them; and 4) the person using the device remains in control of the situation, deciding his/her preferred course of action. As such, these devices are not specific to particular stages in aging or dementia, but can support a very wide range of mental and physical abilities, adapting to the person as his/her needs change. It is anticipated that monitoring technologies such as these will significantly increase the independence and quality of life of people with dementia in the not-too-distant future.

The behaviour monitoring technologies installed in these three examples (Deptford, Bristol and Toronto) have been shown to be beneficial to the individuals that evaluated it. These case studies clearly show that there is great potential for further development of such technology. However, if this future potential is to be realised, then methods and procedures for installation must be developed that take into account the particular needs of people with dementia. Design, installation, configuration and support must all be done with reference to the abilities and impairments of people with dementia and their carers, and in the case of configuration and installation, with reference to the specific abilities, preferences and impairments of the individuals for whom a particular system is being installed. Especially where more complex systems are being installed, it is not sufficient to bring a generic design to production and expect it to be suitable for all people with dementia without scope for individualised configuration.

Monitoring technologies such as those described in this chapter have the potential to transform the lives of people with dementia and their carers by providing greater independence; by allowing care to be more accurately tailored to an individual’s needs through the availability of high quality data describing a person’s lifestyle; and by reducing the anxiety and burden experienced by carers who need to check on the status of people with dementia, and worry about what may have happened to them when they are not there. Fully integrated user involvement in design and implementation is key to the success of such technologies because of the complexity and uniqueness of the people that use them, and the degree to which success of failure depends of how well the technology fits the individual user.

6. Future Research

This work has shown that monitoring of people with dementia can be of value to both professional and informal carers. However there has been very little implementation of this technology in the field except in a small scale technology evaluation context, such as the case studies described here. Further work is needed to develop a fuller understanding of the impact of these technologies on a larger scale, and to understand too how best to gather, analyse, interpret and present the data that the technology makes it possible to acquire.
References


