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The role of smart home technology in enhancing supported living for people with complex needs and challenging behaviour

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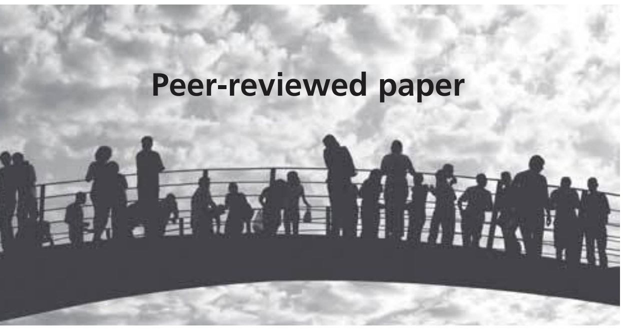


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# The role of smart home technology in enhancing supported living for people with complex needs and challenging behaviour

## Abstract
**This paper describes the role that smart home technology can play in enhancing the provision of supported living for people with complex needs and challenging behaviour. Intelligent building systems, or smart house technologies, offer a flexible environment that can be readily adapted and mapped onto the needs of service users and their carers. The effective management and presentation of information on the activity of service users can assist in planning care and facilitating responses to their needs in ways that promote individual dignity and independence. This paper describes how an approach was developed, using smart home technology, based on local experiences with previous technological solutions. Recommendations are offered towards the specification of a system within a design brief. The application of these recommendations is illustrated in the use of smart house technology within three contrasting local projects and the advantages of applying this approach are discussed.**

## Key words
**Learning disability; supported living; technology; smart home; benefit.**



## Introduction
### Policy
UK policy towards the care of individuals with learning disability was given a strategic priority and focus with the launch of *Valuing People: a New Strategy for Learning Disability for the 21st Century in England* (Department of Health, 2001) and *Same as You? a Review of Services for People with Learning Disabilities in Scotland* (Scottish Executive, 2001). Both of these documents enshrined in policy the requirement to increase the range of options available for such individuals to live with dignity and as independently as possible, and a key recommendation of both policies was the closure of long-stay hospitals and the resettlement of their residents into community-based settings. Both documents discussed the need to provide suitable accommodation to support such a strategy and *Valuing People* explicitly reported the fact that there was a lack of a suitable range of accommodation available. Guidance and funding was provided to facilitate these policies through the *Supporting People* strategy in England and *Change Funds* in Scotland.

In Scotland the *Same as You* strategy was implemented through a succession of Partnership in Practice (PIP) agreements, independently drafted within each local authority area, each covering a period of three years. This paper reports developments that took place within the local authority areas within Tayside,

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Scotland. During the first two PIP agreements standard technologies were gradually incorporated into projects, which were evaluated on an ongoing basis. The knowledge and experience gained during this process informed the decision to apply smart home technology in three projects during the third PIP agreement.

## Complex needs and challenging behaviour

The resettlement of people with complex needs and challenging behaviours from institutional to more individualised settings, preferably in their own homes, provides the challenge of maximising privacy and dignity while maintaining safety and security without the need for constant supervision by staff.

The accommodation choices comprised individual tenancies in dedicated blocks of flats, a section of a block of flats, or groups of attached, semi-detached or detached bungalows. Funding was primarily through the Housing Association Grant and funding stipulations meant that there was no allocation within the building programmes for the provision of communal areas. Care staff were to be based in one of the properties that was designated for that purpose, which could be converted to a tenancy at a later date if required, from which they provided daily support and emergency assistance to service-users. Staff to service user ratios were less than one and a typical model is presented in ***Table 1***.

A central goal is to allow these individuals, many of whom had lived large parts of their lives in shared ward environments, independence from perceived supervision. In this model a group of carers cross-support a number of service users at a distance. Daily routines will be well structured but there could be some unpredictability in behaviours and situations could arise with any individual, at any time, which might require a number of staff to respond. Moreover, more than one such situation could arise simultaneously or in close succession so it is important that the status of each individual is provided to care staff in an efficient and effective manner so that they can respond appropriately. Those being considered for resettlement within the period of the third PIP agreement represented a group of individuals who had previously been considered unsuitable for resettlement in community settings. Therefore it is the role that technology plays in supporting these individuals that is the focus of this paper.

## Introduction of technology

During the period of the first PIP agreement, basic alerting technology was considered and slowly introduced into projects. During the period of the second PIP agreement, the role of technology was given a higher priority and was expected to deliver significant benefits to the projects. This was reflected in the design briefs, which explicitly requested the incorporation of 'smart technology'. There was an assumption that contractors would understand what was meant by the term 'smart technology' and would deliver flexible, user-friendly systems that would integrate easily into the required care packages. Subsequent anecdotal reports indicated frustrations with the technologies, which were failing to deliver the expected benefits and therefore not being fully utilised. At this stage it was not clear what the issues were.

As a personal reflection the authors observe that stating a requirement for 'smart technology' did not lead to the incorporation of technologies that met the planning teams' expectations. Contractors received little guidance on definitions of 'smart technology' and were given an unreasonable level of responsibility for interpreting the needs of the service users and their carers, from the design briefs. Additionally 'design and build' contracts were used to manage the process, so the proposed solutions could not be evaluated until after completion of the projects.

## Smart home technology

In Scotland the use of technology to support independent living has proceeded in an ad hoc

**Table 1 Typical accommodation and support model**

| Accommodation | Service users | Staffing |
|---|---|---|
| Seven bungalows | Six individual tenancies | Five staff during the day |
| One or two bedrooms | Autistic spectrum disorders | Two waking and one sleeping staff at night |
| Kitchen | Complex communication and care needs | |
| Bathroom | | Staff respond directly to individuals |
| Living room | Challenging behaviour | |

basis within initiatives such as *Opening Doors for Older People* (Gillies, 2001) in West Lothian that concentrated on supporting older people with telecare; and the involvement of NHS Tayside and Dundee City Council within the CUSTODIAN project, where smart home technology was applied to individuals with acquired brain injury (Dewsbury *et al*, 2001). Technology did not become formulated into strategy until the Telecare Development Programme (Scottish Executive, 2006), which focused primarily on telecare technologies.

Smart home technology is taken to refer to intelligent building control systems used in a domestic environment (Allen, 1996). These systems are designed to operate in a variety of building environments and are capable of integrating traditionally separate building management system functions such as heating, lighting, energy and security within one holistic system. They are capable of handling large amounts of data, passing and processing it in real-time. Consequently they have the potential to provide interactive living and working environments to meet specific, individualised needs. The use of smart house technology to support independent living has been explored previously and has received attention at various times through a number of projects, such as the one supported by the Joseph Rowntree Foundation that developed the York Smart Home and the Edinburgh AID House (Gann, Barlow & Venables, 1999). There have been government reports, on technology related to disability, which included reporting of smart home implementations (Curry, 2001) and also focusing primarily on smart home technology (Poulson, Colette & Gelley, 2002). There have been scientific papers examining the relationship between smart house technology and telecare (Tang & Venables, 2000). Although the recent focus for technology to support independent living has been on telecare, developments in the use of smart home technology for more complex situations has continued (Orpwood, Adlam *et al*, 2008), as has general interest in such applications (Mann, 2005; Helal *et al*, 2008; Gentry, 2009).

# Methods and materials

## Experience and expertise

An informal, semi-structured approach was taken to reviewing the effectiveness of previous technologies, developing design criteria and proposing and applying technological solutions. This process was informed by the personal, practical experience of the authors. Jeremy Linskell has fifteen years experience in assessing for and providing Electronic Assistive Technology (EAT) for individuals with severe and complex disability. He also has ten years experience in exploring the role of smart home technology in supporting independent living, which commenced with participation in the aforementioned CUSTODIAN project. This project involved the development and validation of a user-friendly tool for the design of smart homes, which culminated in the creation of a demonstration site and a real-life implementation for an individual with an acquired brain injury (Dewsbury & Edge, 2001), within the City of Dundee. Jenny Hill has worked in Community Care for ten years and has spent eight years in Resettlement Development, developing accommodation with support for people with complex needs who are being resettled from long-stay institutions. Both authors have collaborated over a number of resettlement projects within the period covered by the three PIP agreements and worked closely on two of the three projects documented in this paper.

## Method

The authors worked with the project planning teams through the period covered by the first two PIP agreements and gained useful experience on the application of technology. The authors conducted reviews of the technological solutions that had been implemented, interviewing a range of staff from a number of projects. Staff members were approached from all operational levels, with projects chosen from a range of accommodation types. The interviews were informal and semi-structured, with staff asked to describe their roles; how they felt these roles impacted on the care of service users; the range of issues that influenced their roles; and, how the technology affected the performance of these roles. Staff were asked to demonstrate, as far as possible, the technology-related issues described. The authors recognised the importance of attempting to differentiate between technology that was poorly implemented or misused, and technology that lacked the capacity to effectively address the issues raised.

Following the interviews the authors collated the information, identified common themes and categorised them in order to develop a functional specification.

## Choosing a technology platform

The investigations of the authors into smart home technology began with the original planning of the resettlement programme, which led to the collaboration within the CUSTODIAN project. As a direct result of this favourable experience a substantial facility was developed within the City of Dundee, which afforded the authors the opportunity of evaluating the efficacy of smart house technology in detail (Linskell, 2006). On the basis of these experiences the commitment was made to develop a solution based on smart home technology. A search was conducted in order to establish which systems might be suitable for the proposed projects. Only systems commercially available in the UK, with UK-based representatives, were considered. A web search was performed using Hidden Wires (2010) as the initial point of reference and technologies were compared by reading the commercial literature and talking with company representatives. Once the technology platform was chosen the functional specification was applied to design a system, which was examined for feasibility using the chosen technology platform.

## System configuration

The capabilities and level of customisation of the system were discussed with stakeholders prior to final system configuration. After installation staff were introduced to the technology as part of the initial training, prior to service users taking up residence. Training was interactive, with possible scenarios discussed, and once staff gained an appreciation of the capabilities of the system they were encouraged to offer suggestions on how they would like the technology to operate to support specific individuals, which was implemented through further programming changes.

# Results

## System attributes

The following key system attributes were identified.

1. Adaptability
   - infrastructure – easy to reposition or incorporate additional sensors, control devices and reporting devices
   - configuration – easy to alter the relationship between system devices.
2. Tiered alert management system – multiple, adjustable alert levels for each service user.
3. Ease of use and flexibility
   - simple and intuitive interface
   - easy control of which alerts were active
   - inhibition of individual alerts without disabling activation of the source signal.
4. Real-time visual reporting - easy to interpret, real-time reporting of service user activity.
5. Mobile user interfaces - easy to use mobile devices for monitoring, remote control and communication.

## Technology platform

### KNX

The technology platform chosen was Konnex, usually referred to as KNX (KNX, 2010), and in the KNX variant chosen, the devices communicate via a twisted pair cable, referred to as a 'bus'. KNX cable routes were specified and supervised by certificated KNX installers who liaised with the other contractors to ensure compatibility with other systems such as fire and access systems. Cables were laid by the electrical contractor for each project, which was different in each case. Access to a demonstration facility allowed concepts to be communicated and discussed and assisted liaison with the electrical contractors.

### KNX devices

A number of KNX devices were used in each project, from a range of manufacturers. Only devices with unique properties will be specifically mentioned. An Application Unit (ABB, 2010), which is a sophisticated logic-processing module, was used to provide tiered alerting. General sensors such as bed sensors, pull chords, door and window contacts were connected using KNX binary input devices. Safety sensors such as flood and heat detectors were connected to KNX zone terminals. KNX output devices were used to control devices such as locks and mains supplies. Appropriate input and output devices allowed fire and access systems to be incorporated. Argus presence detectors (Merten, 2010) were used to monitor room occupancy and these devices incorporated infrared receivers, which when used in conjunction with infrared fob transmitters, provided location-specific attention calling for staff. A Multi Control Gateway (MCG) (IPAS, 2010) was included. This device is an 'IP gateway', which means that it can pass KNX data over a standard local area network (LAN), providing remote access and the integration of computers. A suite of Java-based programmes called ComBridge Studio Suite accompanies the MCG and allows web pages to be written for monitoring and controlling the system. Java (Oracle, 2010) is a programming language that can run applications on any type of computer and is widely used in programming for web pages. IPAS GmbH supported the project by developing Java-less versions of key programmes for use on handheld devices. A KNX LCD display panel was included, providing backup reporting and control facilities in the event of computer failure.

## General technical considerations

Each project required assessment for Wi-Fi coverage following completion. LAN cables had been laid for this purpose as a contingency and this proved essential as the construction methods used on all three sites led to very poor radio transmission. Each system has full power backup and on two of the sites included a broadband connection, for secure, remote support.

## Tiered alert management

The Application Unit was programmed to allow all the alerts within an individual property to be managed as a group. The system was designed so that the overall alert status of each service user's property is always in one of three states; green, yellow or red.

1. If no alerts are active then the overall status is green
2. If only yellow level alerts are active, then the overall status is yellow, and
3. If any red level alerts are active, the overall status is red

Core safety alerts, such as fire and flood are configured to be permanent red level alerts. Other alert signals such as bed sensors, door sensors, window sensors or pull chords can be configured to trigger either red or yellow alerts. If the overall alert level of a property is yellow and a contributing alert signal has its alert level changed to red, then the overall alert status of the property instantly changes to red alert and vice versa. Alert levels can be altered automatically based on time or other events. Staff with security access can manually override all alert settings. It is also possible to block alert signals, except for permanent red alerts, from contributing to the calculation of the alert level while still monitoring their activation in real-time. If any alert is enabled or disabled, or has its alert level changed, the system responds immediately to the new conditions without requiring resetting or reconfiguring in any way.

Any system activity can also be passed to a Microsoft Access database for later reviewing and reporting.

## Ease of use, flexibility and real-time reporting

User-friendly pages were created for monitoring and control. Alert signals are displayed on property floor plans, with easy to interpret signalling icons that clearly communicate their current status. Switching between summary views of the whole site and pages for each individual property is achieved using simple menu tabs. Monitoring, setting alert levels, resetting of alerts and control functions are available from relevant pages (***Figure 1***). Alerts or other predefined events can trigger the activation of multimedia files compatible with Adobe Flash Player (Adobe, 2010), which is a cross-platform browser-based application used to deliver multi-media content to web pages. This allows customised sounds or voice messages to be used to augment alerts. Context-specific windows can also be opened automatically to guide operators through specific situations, if deemed appropriate.

## Mobile devices

To extend the system philosophy to the carer-borne devices, these would have to be capable of displaying and controlling web pages in a user-friendly manner. Trials were performed using a number of WiFi-enabled personal digital assistants (PDA) running the Windows Mobile operating system, but these proved unsatisfactory. Firstly web pages could not be kept live, that is, they could not automatically update their content when the data on the server changed. Updates could only be obtained by refreshing the pages, which could be done manually or automatically every 60

**Figure 1 A screen from a control centre interface illustrating alert management**

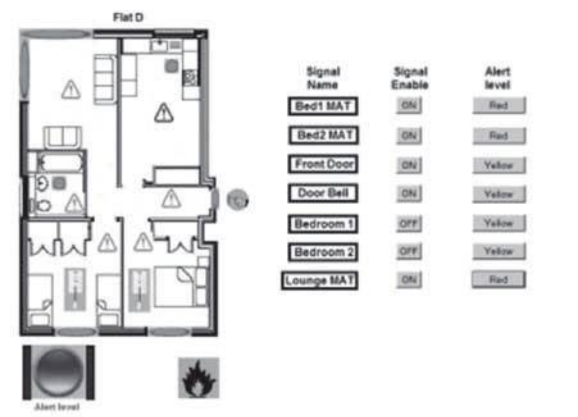
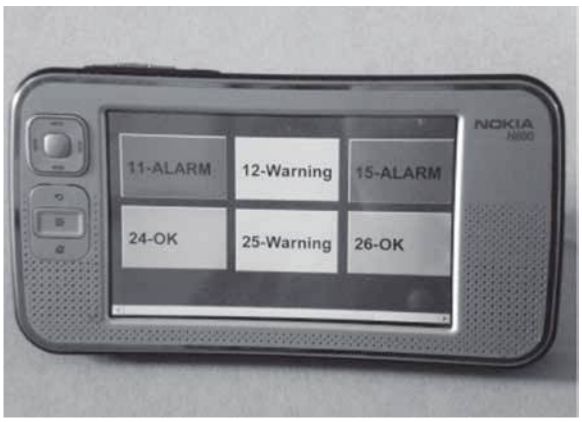



**Figure 2 Mobile device displaying summary of alert levels for a project**



seconds and was therefore not suitable for reporting time-critical alerts. Secondly neither Internet Explorer Mobile, the web browser that was bundled with Windows Mobile, nor the alternative compatible web browser, Opera, were capable of running flash multi-media files, which meant that multi-media alerts could not be generated. After further investigation a device was identified that could meet both these criteria, the Nokia N800 series Internet Tablet (Nokia, 2010), which runs the Maemo operating system (Maemo, 2010). This is a pocket-sized device with a four-inch touch screen, optimised for flash-enabled web browsing, with an integrated camera and a microphone for voice and video communication. Additionally the active elements of the web page, which report the status of alerts and events, remain active even when the display is in battery-saving display sleep mode, ensuring a practical battery life. The devices are Wi-Fi-enabled and connect to the system via a Wi-Fi LAN that was professionally configured for seamless connection across the sites.

A java-less variant of the software was developed for use with portable devices and a simplified format for data presentation was also developed. The web page displaying the overall status of a project displays each accommodation as a rectangular block, with the layout of the blocks chosen to reflect the layout of the site. The colour of each block is dynamically altered to match the current alert level of that accommodation, and an appropriate text descriptor is displayed within the block (***Figure 2***). Care staff can see at a glance, which properties are in either a yellow or red state of alert. Tapping any of the blocks opens a page that summarises the individual sensor values for that property, informing the staff of the exact source(s) of the alert status (***Figure 3***). Remote control, such as alert reset or door opening, is accessed through similar pages (***Figure 4***). Additional functionality can be applied, as in project three, where internal security camera transmissions can be viewed from the device.

## Three projects

Three projects were implemented at three different sites, with three different housing associations and two care providing organisations over a period of approximately one year. All projects have been operational, with service users in residence, for at least two years.

### Project one

This comprises the housing of six individuals in a mainstream block of flats, across two floors, supported by carers based in a seventh flat. Most of the service users had previously lived in a variety of settings and had a range of complex issues, including Prader-Willi Syndrome.

Safety sensors include fire and kitchen and bathroom flood alerts. Front door, all internal doors and windows are monitored and there are pull chords, all of which can have their alert levels altered. There is a facility for bed sensors if required. Monitoring of kitchen cupboards had been included at the planning stage but this was not implemented during the installation for unspecified reasons. There was monitoring and control of individual room temperatures and electricity supplies to kitchen utilities and all ring mains circuits can be monitored and controlled.

### Project two

This comprises the housing of four individuals in bungalows, within a mainstream housing development.

**Figure 3 Mobile device displaying alert summary of a property**

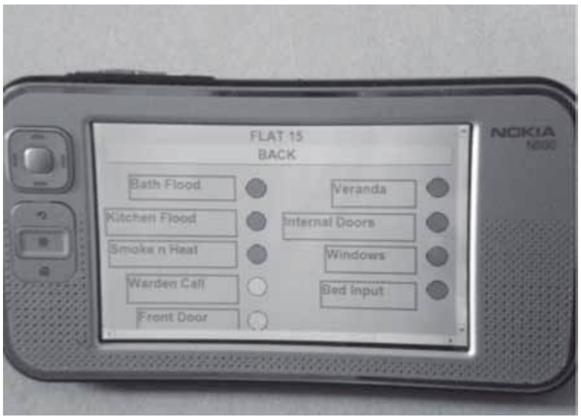
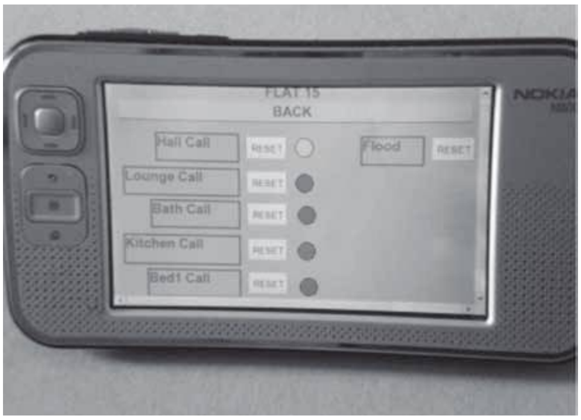



**Figure 4 Mobile device displaying an alert reset page**



The bungalows are grouped as two and three attached bungalows with the middle of the group of three bungalows for staff. The service user bungalows have controlled access and there are controlled access doors from the staff bungalow to each of the adjacent bungalows. All of the service users have been resettled from a residential ward and have histories of unpredictable behaviours, which may place their carers at risk.

Safety sensors include flood alerts, staff attention calling and an interface from the zoned fire system. Front and rear doors and windows are monitored and there is a bed occupancy sensor, and pull chords in each room, each of which can have their alert levels altered. Access control is by a KNX-based proximity card system that logs usage and can be programmed to initiate system functions on activation. Bed occupancy sensors are automatically set to red alert at 10.00 pm. One individual is allowed to smoke in the garden under supervision and to facilitate this there is a button on the N800 web page for their property that demotes the alert level of their rear door from red to yellow for ten minutes, which can be overridden at any time.

### Project three

This comprises the housing of six individuals in an access-controlled block of flats, on three levels with a staff flat on the top floor, and staff-controlled access to the block. Service-users are free to move within the block, including movement between each other's flats. There are known personality issues between some of the service users. All individuals have been resettled from a closed ward, may be a risk to themselves and their carers, and their interaction with the public requires monitoring.

Safety sensors include fire alert, flood detectors in the bathroom and kitchen and staff attention calling. Front door and doorbell to each individual flat are monitored, there is a bed occupancy sensor, and pressure mats under the carpets by all windows facing public areas, each of which can have their alert level altered. Front and rear doors to the block have sensors and there are presence and staff attention calling sensors in the corridors. Access control to the block is via a video entry system, which is situated in the staff flat. Exit from the building can also be effected via a wall pad on the inside of the main door, which has been fitted with a monitored ten second opening delay, following detailed discussion and agreement with the emergency services. Web pages for the N800s include a button for immediate opening of the main doors, for staff to quickly follow a service user making an unplanned exit. All common internal areas are monitored by a video system, which can be viewed on the N800s.

# Discussion

## Validity

The evaluation of previous projects utilised informal and semi-structured methods that have no independent validity. This paper reports the issues that the authors have identified from their experience throughout the three phases of resettlement. There is a limited knowledge base within the literature reporting the use of technology to maximise the independence of individuals with complex needs and challenging behaviour. Dewsbury *et al* (2007) reported on the overall design requirements of accommodation for people with complex behavioural difficulties and autistic spectrum disorder (ASD), including a summary of the technology incorporated within the projects. The authors are not aware of reporting of the application of smart home technology, as a generic solution, which in addition details the functional requirements for the specification of such a system. This paper describes a design ethos and demonstrates the feasibility of implementing it with off-the-shelf technology.

## System attributes

The experience gained by the authors from previous projects, combined with the knowledge obtained from the informal interviews with staff, led to the identification of a number of key system attributes. The implementation of solutions based on these attributes has been demonstrated using smart home technology in combination with other off-the-shelf technologies. The development of successful solutions is dependent on having a good appreciation of what is expected of the technology.

## Adaptability

Although many of the functions of a support technology for a particular client group will be generic, the needs of individual service users will differ and an individual accommodation may have to be reconfigured for changes in individual needs. There may be a number of reasons for transitions such as a change in occupancy or the evolving behaviours of a service user adjusting to living independently for the first time. The consequences of alterations in plans for occupancy, especially unexpected ones, had led in previous projects to problems associated with limitations in the technology. These have been due to restrictions placed on the positioning and/or introduction of sensors and actuators into the system, and the ability to reconfigure the system. It is particularly important that changes in behaviour that lead to changes in the care package can be efficiently reflected in changes in the technology used to support this process. Therefore easy and cost-effective alteration to the topology (physical layout) and configuration of a system is a prerequisite for effective contingency planning.

## Tiered alert levels

An issue that emerged from the previous projects was that it was hard to make effective use of alert information when all alerts carried equal value. The recipient had to take note and decide how to respond to every alert. There were robust protocols for dealing with vital alerts but the constant disturbance caused by having to acknowledge and respond to less serious, and at times irrelevant alerts, appeared to be undermining general confidence in the use of the systems. This had created a concern that a reduction in attention to vital alerts might develop. Flexible, tiered alerting allows each service user to have a profile of alert levels set to match their needs. This flexibility ensures that responses are optimised for the service users' needs and not the limitations of the technology. The availability of more than one alert level has proved beneficial and the ability to set the levels is used as required within the projects to assist in supporting service users. The logic programming of the Application Unit used to achieve this provided a template that can be applied to any sensors or devices that one might wish to incorporate within a system. The template was applied in its entirety to each project, even though the topology and the functions associated with each project were different. Larger projects could be developed by incorporating more application units. Any technologist with familiarity and experience with the KNX system could produce such a template for incorporation into a project using the Application Unit or an equivalent device from any KNX manufacturer.

## Ease of use and flexibility

There was a general observation that the systems employed previously were not particularly user friendly. On some sites only senior staff members were trained to use the technology with the consequence that the full functionality was often not incorporated into daily practice. There may well be times when senior staff members are not present so it is important that systems are designed to be user friendly and context specific so that they can be operated by all levels of staff who may need to do so. The system would need to control access to functions based on level of authorisation and these could be set according to agreed protocols. There was a strong emphasis within these projects on providing interfaces for staff that were intuitive and easy to use. For each project the short introductory guide provided at initial training proved to be sufficient documentation for routine management and use of the systems by care staff. This supports the view that seemingly complex systems can be operated with little training if they are appropriately designed, with the emphasis on being intuitive and context specific.

It was also reported by staff that there was some frustration at not being able to make changes to the systems as needs changed, in particular being able to disable alerts that were not relevant at that particular time. A simple illustration is sensors on internal doors during the day. One system did offer the option of disabling sensors, which was accessed from a scheduling page, requiring the timer to be unset every time to disable them. Additionally when an alert was disabled it could not be monitored or recorded, which is typically a problem with monitoring systems built around security-based technology. This sometimes led to alerts being disabled inappropriately or alerts not always being acknowledged. The value of being able to monitor the service users has assisted the carers in facilitating greater independence for them as discussed below. Therefore it is important that monitoring can proceed independently of alerting. The ability to easily control whether and when signals were enabled as alerts, independently of monitoring, was considered to be very beneficial.

## Real time visual reporting

The inclusion of a central monitoring station, from where the system was managed and data reviewed was recognised as a valuable resource. The availability of real-time monitoring of activity using pictorial representation of the properties has, for some of the service users, provided a valuable appreciation of their activity patterns. This has given staff confidence to pull back and give the individuals concerned more freedom and it was felt that this facility was particularly useful during the settling in period. Dewsbury *et al* (2007) have previously noted that risk management tools can additionally enable self-determination. The provision of real-time monitoring tools offers significant appreciation of the activity of service users. They also facilitate the involvement of care staff, who may struggle to interpret retrospective, time-based graphical reports, in the review process.

## Mobile alerting

Staff flexibility is vital to maximising independence for service users and ready access to relevant information helps to facilitate this. The previous projects had provided staff with pagers or Digital Enhanced Cordless Communications (DECT) cordless phones. DECT is the technology used in modern cordless telephones. Both of these device types can be configured to receive text alerts when sensors are activated. Pagers are small, robust devices and generally easy to use. DECT phones are bulkier but incorporate voice communication. DECT phones can also send control codes for performing functions remotely, such as resetting alerts or unlocking doors. This is achieved by sending commands via the keypad, usually prefixed with a hash key (#), and referred to as 'hash commands'.

Text reporting allows alert sources to be reported directly but the screens of both types of devices can be difficult to read and smaller screens only have limited space to display a message, although this situation has improved recently with advancements in the design of DECT handsets. Additionally the messages are stored sequentially, so when new messages arrive previous ones are displaced, and reviewing these messages requires the user to scroll back through the display. This is not a difficult task but it could be challenging to utilise the information effectively. If the recipient is required to scroll through them, in order to prioritise the information and make a judgment over which situations should be responded to, they must hold the alerts in memory, possibly in sequence, to establish their respective priorities. If the information relates to more than one situation, or if not all the messages are relevant to the recipient, priority setting becomes more complicated. It is a process that does impose significant demands on staff. These demands may cause the care staff to modify their response protocols to ones that are less information-dependent and therefore likely to be more intrusive from a service user's perspective.

The ability to use the N800 to compare the alert status of all properties and to review the source of alert signals in each property, assists staff in quickly obtaining an overview of the status of the site and the issues that require addressing. The device would benefit from having a vibrate facility and there are now a range of devices that could provide this functionality, along with the previously stated prerequisites. The introduction of the N800s as the standard mobile alerting device was probably the most novel aspect of the system. This may seem to be an inappropriate choice, as it could be perceived as expensive, fragile and both intimidating and difficult to use by care staff. This has not proved to be the case. The devices have a similar cost to large screen pagers and only one device has broken due to impact in the two to three years that the projects have been running. The device has been received favourably and there have been no reports of problems with its use. Its ease of use and user-friendly representation of the alerts is appreciated by the staff; many of whom have previous experience of using conventional mobile alerting technologies to support individuals with complex need.

The visual representation of multiple properties and their respective alert states, on a mobile device, has been demonstrated to be a positive development that facilitates the work of care staff. It has provided them with confidence to make extensive use of the alerting information available to them as an integral part of their care of their service users. The merit of such an approach is supported by a recent systematic review of the use of personal digital assistants (PDAs), (Prgomet *et al*, 2009). Although the review was in relation to hospital physicians it concluded that PDAs demonstrated '*the greatest benefits in contexts where time is critical and a rapid response crucial*'. It is reasonable to assume that any time critical decisions requiring judgements, involving multiple pieces of information, would benefit from using this approach and importantly it has been demonstrated to be practical in these environments and circumstances.

### Remote control

The extra bulk of the DECT phones, compared to pagers, which was commented upon was considered as a reasonable price to pay to be able to integrate alerting and communication within the one device. The incorporation of remote control functions was perceived as being a benefit and the ability to remotely reset alerts was felt to be a particularly useful function. However there was general dissatisfaction with the use of hash codes to perform these tasks, as all staff found it difficult to remember even a limited range of such codes, especially when under the pressure associated with a developing or even recently resolved situation. Therefore, very little use was made of this facility and care protocols were adjusted not to rely on them, thus again, not allowing the technology to enhance the care provided in the way that was initially envisaged.

### Communication

It was generally agreed a communication facility incorporating voice and video would be beneficial. Although discussed, IP telephony solutions, which allow integration of voice and video communications on a LAN, were not introduced into any of the projects. The incorporation of the internal security video system onto the mobile devices for project three showed that this can easily be achieved on a technical level and this facility has greatly increased the flexibility of staff usage, freeing up the individual who would previously have been assigned the role of manning the video security system. The integration of IP telephony, ie. telephone services over the LAN, into future systems would seem to be worthy of consideration.

## Lessons from using smart home technology

### Smart home technology

Smart home technology has the capacity to manage information on many aspects of a living space and facilitate the provision of integrated solutions to complex situations. In these projects the complexities lie in the efficient management and communication of information on individuals who have complex needs and unpredictable behaviours. The benefits of a flexible system to collect, manage and communicate the information has been demonstrated in the delivery of solutions that met the specification. The alert management logic provided by the Application Unit could also be utilised as part of an alerting paradigm that is fed to a conventional reporting system incorporating pager or DECT telephone systems. There is complete flexibility on how all elements of the system can be assembled. Similar arguments apply to the use of any intelligent building control system. There are economic benefits in investing in systems that have such flexibility, when the demands associated with a particular living space are complex and may change over time. These advantages may be further enhanced by potential energy efficiency savings and could contribute to policies relating to building construction and energy management.

## International standard and open platform

KNX meets both European and International standards for home automation and building control covering both interoperability and quality, and is supported by over 200 manufacturers. All devices that carry the KNX certification mark are guaranteed to be fully compatible with the system. There is a single, standardised computer programme for the design, programming and management of KNX systems and configuration files can be transferred from one copy of the programme to another without restriction. The KNX 'bus' cable may branch and be routed as required, including running alongside mains cabling, making it simple and economical to install, particularly at the time of building construction. Additional branches may be safely spliced on or removed as required at any time without having to disturb the electricity supply. With strategic routing of cables, devices may be changed as needed and compatible devices can be incorporated at virtually any point in the system. There is a large range of sensors, actuators and user devices available for the system with interfaces available for most external technologies. A KNX system does not require a central 'brain', with system intelligence distributed among all the devices, adding significantly to its robustness and stability. The intelligence inherent in the individual devices also offers economies of scale. For example a presence detector can simultaneously monitor the presence of an occupant; provide automatic control of lighting and heating based on occupancy; manage light levels based on ambient lighting conditions; and, act as a security sensor. The combination of reliability, flexibility, economies of scale, and a wide range of suppliers, identified KNX as the system of choice. Such an approach has been argued and applied previously (Adlam T & Orpwood R, 2008).

KNX is a royalty-free, open platform, which alongside its international standard, guarantees interoperability between all devices and little dependence on individual manufacturers. The standardised programming software ETS is another benefit providing a single configuration tool and a standardised file format allowing individual configurations to be shared between programmers. It is possible to copy a project and replicate it in its entirety. It is also possible to copy a project as a template, so that a project may be used to generate similar projects but based on an entirely different set of devices. This openness facilitates effective communication of knowledge and experience with the possibility of developing a repository of successful strategies and technology options for general reference.

## Other technologies

The KNX system is a distributed field network and there are a number of other systems in existence with similar benefits to those described above, most notably Echelon's LonWorks (Echelon, 2010). Both KNX and LonWorks come in versions that can communicate by twisted pair cable and over mains power cables and KNX additionally has wireless and local area network (LAN) protocols. There is also a range of wireless systems being developed such as ATLAS (Bose *et al*, 2006), which was implemented in the independent living environment the 'Gator Tech Smart House', and is now commercially available (Pervasa, 2010). KNX was chosen because of its compliance with international standards and the extent of support available within the UK. The bus version was chosen because of the high level of data traffic that was expected on the system, and the reliability that would be required to accommodate this effectively.

## Not a prescription

The authors have not reported their experiences as a prescriptive, technology-based solution as this would undermine the previous arguments for the benefits of using an open-platform technology. This paper has reported the attributes that a system should include and provides illustrative examples of how these can be implemented. The authors feel that this provides effective, general guidance to others wishing to follow a similar approach. It is necessary to have access to skilled installers, or system integrators as they are known, but there are an increasing number of such individuals available who are capable of being guided by a specification similar to the one reported here. The authors offer the opinion that the most likely source of difficulty in successful implementation of a project using a similar model is the possible misinterpretations between care provider and contractors on aspects of the design brief relating to the needs of service users and staff. They further proffer the opinion that some of these issues may be addressed by ensuring continuity of personnel involved across the planning and implementation stages of such projects.

## Conclusion

Assisting individuals with complex needs and challenging behaviour to live as independently as possible requires careful consideration of the environment, the support provided by care staff and the technology required to support both of these aspects. Technology that provides information effectively, so that staff can reduce the level of direct supervision that is required, will support this process and smart home technology has been demonstrated to be effective in fulfilling such a role.

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