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Supporting Safe and Independent Living: Findings, Themes and Concept Designs from a User-Centred Study on Digital Telecare

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Telecare technologies support people to live in the community safely. In the UK, the existing analogue telephone services for telecare will be switched off by 2025, as the telecommunications infrastructure is upgraded to digital connectivity. Internationally, analogue telephone services are also being decommissioned. The shift from analogue to digital presents a rare and major opportunity for new digital solutions that address current issues with adoption and use of telecare. This paper describes a user-centred study to design innovative digital telecare concepts. The main contributions are as follows: findings from user engagement activities, which identified issues that may be more important and less important to users; the synthesis of ideas generated through the design process, which identified four themes for future work in the field–community-based support, telecare you do not wear or notice, expand the use of telecare and introduce telecare earlier; and seven concept designs that illustrate how the themes could be approached.

RESEARCH HIGHLIGHTS

- A user-centred approach (Double Diamond model) was used to research and design seven innovative digital telecare concepts.
- The synthesis of user engagement findings identified issues that may be more important and less important to users when designing telecare.
- The synthesis of design ideas identified four themes for digital telecare solutions within the context of the analogue to digital switchover.

Keywords: older people; telehealthcare; assisted living technology; technology-enabled care; telecare; user-centred design

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1. INTRODUCTION

The delivery of health and social care is changing in response to a combination of factors including an ageing population and the associated increase in the numbers of people living longer with long-term conditions; increasing pressure on health and social health care budgets to 'do more with less'; and changes in models of health care from reactive to preventive, hospital-centred to community-based, clinician-centric to patient-centric and more recently, to consumer-centric. These changes are fuelling interest in the potential for technology, such as telecare, to support older people to remain safe and independent in their own home for longer and reduce utilization of health services.

A range of understandings of telecare exist. This paper uses the TEC Services Association (TSA) definition: 'Telecare services include personal alarms, a wide range of home sensors and activity monitoring. Alerts are monitored by remote control centres that can respond quickly to emergencies' (www.tsa-voice.org.uk/support-at-home). The TSA is the industry body for telecare services in the UK. Although telecare is the term used in this paper, other terminology is used in the field such as technology-enabled care, assisted living technology (ALT) and telehealthcare.

The most basic form of telecare comprises an alarm unit (hub); a pendant trigger worn with a neck cord, wrist strap or belt clip; and 24/7 alarm call handling. The hub incorporates an emergency alarm button and is plugged into the mains electricity supply and a home telephone line. Pressing the button on the hub alerts an Alarm Receiving Centre (ARC) that help is needed. Centre staff are able to talk with the caller through a speakerphone on the hub to decide on a course of action such as going straight to emergency services or involving those named on the caller's file such as a nearby informal carer (family member, friend or neighbour). Pressing the button on the pendant trigger also raises a call through the hub, provided it is within range (∼50 meters).

Enhanced telecare allows for automatic responses based on sensor information. For example, the following sensors can automatically raise an alarm call via the hub: a fall detector—an alarm is raised if the individual falls; a bed sensor—an alarm is raised if an individual gets out of bed and does not return within a pre-set time; and a property exit sensor—an alarm is raised when an individual's door is opened during pre-set times. A Global Positioning System (GPS) is used outside the home, often for people with dementia. An alarm is raised via satellite technology when an individual breaches a designated safe area and their whereabouts can be tracked.

Governments in most developed countries have telecare programs in place (Turner and McGee-Lennon, 2013). The UK has an estimated 1.7 million end users and over 240 ARCs (TSA, 2017). The main user groups for telecare are people with telecare equipment in their home (end users); informal carers who are involved in/affected by telecare arrangements; and health and social care (H&SC) professionals who support end users e.g. home care workers and community nurses. Usually, end users of telecare are older adults. However, telecare has to be designed to support adults of all ages with varying needs and capabilities e.g. young adults with learning disabilities.

In the UK, telecare is built on telephone line connectivity delivering voice and data. However, analogue telephone services will be switched off by 2025 as the UK's telecommunications infrastructure is upgraded to digital connectivity. Analogue systems using voice-band signalling will all be affected to some degree, including telecare. This shift presents a rare and major opportunity for a fundamental redesign of telecare, rather than a 'like for like' replacement. There are few examples of digital telecare deployments in the world (FarrPoint Ltd., 2016). There are deployments based on digital technology, but these are limited in scale and number, and tend to be standalone solutions separate from the main telecare systems. A successful digital telecare solution(s) is therefore highly desirable.

This paper describes a user-centred research study conducted in the city of Glasgow, Scotland, UK. The study was funded via a mechanism that enables public sector bodies to connect with organizations from different sectors to provide innovative solutions to specific public sector challenges. In this case, the public sector body was Glasgow City Health and Social Care Partnership (GCHSCP). Health and Social Care Partnerships are partnerships between the local authority and National Health Service. The challenge was to research and design new digital telecare solutions. The study team comprised a telecare manufacture, a Higher Education Institution (HEI) and an innovation centre that specializes in sensor and imaging systems and Internet of Things (IoT) technologies. This paper contributes to the body of work within HCI on telecare. The main contributions are as follows:

- Findings from user engagement activities, which identified those issues that may be more important and less important to users when designing telecare, to help ensure telecare is accepted and used.
- The synthesis of ideas generated through the design process, which identified four themes that should prove useful to other practitioners and researchers seeking to improve the acceptance and use of telecare: community-based support; telecare you do not wear or notice; expand the use of telecare; and introduce telecare earlier.
- Seven concept designs that illustrate ideas for how the themes could be approached.

2. RELATED WORK

A substantial body of research has shown that while many end users view telecare positively, many do not accept and/or use it as intended and many potential users are reluctant to take it up (Hamblin, 2016; Yusif, Soar, and Hafeez-Baig 2016; Stewart and McKinstry, 2012; Roberts *et al*., 2012; Clark and McGee-Lennon, 2011; Taylor and Agamanolis, 2010). Commonly cited barriers to the adoption and optimal use of telecare include: stigmatizing and conspicuous equipment; unattractive equipment; the equipment is too easily activated accidentally (false calls); the cost of services; reluctance to use the equipment to disturb ('bother') call operators or informal carers; forgetting to wear equipment; a lack of knowledge or awareness about telecare; a perceived lack of need; and concerns around personal and data privacy. Several of these problems were reported over 15 years ago (Blythe *et al*., 2005) indicating little has been achieved to address this challenge. This section briefly describes other related research.

2.1. AKTIVE project

The Advancing Knowledge of Telecare for Independence and Vitality in Later Life (AKTIVE) project explored how telecare can be developed to help older adults live a full and independent

TABLE 1. The obtrusiveness model.

Dimension	Subcategories
Physical	*Functional dependence*
	Discomfort
	Excessive noise
	Obstruction
	Aesthetic incongruence
Usability	*Lack of user friendliness or accessibility*
	Additional demands on time and effort
Privacy	*Invasion of personal information*
	Violation of the personal space of the home
Function	*Malfunction/suboptimal performance*
	Inaccurate measurement
	Restricted distance/time away from home
	Perceived lack of usefulness
Human interaction	*Threat to replace in-person visits*
	Lack of human response in emergencies
	Negative effects on relationships
Self-concept	*Symbol of loss of independence*
	Cause of embarrassment
Routine	*Interference with daily activities*
	Acquisition of new rituals
Sustainability	*Affordability concerns*
	Concern about future needs

life, and benefit those caring for them (AKTIVE). AKTIVE focused on two specific groups of older adults: those susceptible to falls and those with memory problems or dementia. The central study was called Everyday Life Analysis (ELA). ELA involved research visits over six to nine months with a sample of 60 participants aged 65+ years living in two localities in England, UK. The study explored how participants experienced telecare and used or under-used equipment, including barriers to adoption.

Hamblin (2016) used the data from the ELA study to examine how it corresponded to an American model of 'obtrusiveness' where obtrusiveness is something that is undesirably prominent. The obtrusiveness model was created by Hensel *et al.* (2006) in relation to ALTs and comprises eight dimensions, each of which has subcategories (Table 1). Hamblin found that the model is largely applicable to the UK context and identified two further issues that affect the acceptance and use of telecare: the degree of control an end user feels they have, and the information and support they receive in using their equipment. Hamblin concluded that the obtrusiveness model plus the additions (control and information) highlight important issues that can assist H&SC professionals in ensuring telecare is accepted and used.

Our study also analysed research data collected via user engagement activities using the obtrusiveness model, plus the two additions identified by Hamblin. The findings are presented in the Results and Discussion section. Our study builds on the work of Hensel *et al.* (2006) and Hamblin (2016) by applying the model to the Scottish context for the first time to our knowledge and finds that the model and additions are applicable. Our study found an additional factor affecting the acceptance and use of telecare: a fear or dislike of new technology. Although a much smaller study, our study also builds on the work of Hamblin by working with a general adult population rather than specific sub-groups within the population.

2.2. Athene project

The Assistive Technologies for Healthy Living in Elders: Needs Assessment by Ethnography (ATHENE) project aimed to produce a richer understanding of the needs and lived experiences of older people, and how they and their informal carers can work with ALT stakeholders—suppliers, health and social care professionals—to co-produce ALTs (ATHENE). The research team proposed that making successful ALTs relies on collaboration, involving not only formal carers but also informal ones, whose role has gone unnoticed by technology designers. In particular, the project focused on the role of 'bricolage' (pragmatic customization, combining new with legacy devices) by informal carers, in enabling ALTs to be personalized to individual needs. The research team concluded that a new research agenda is needed, focused on solving challenges of involving end users and their informal carers in the co-production of ALTs. Our study also employs a user-centred approach, involving user research and collaboration among telecare stakeholders including informal carers, to inform the design of products and services. However, our focus is on the opportunity arising from the transition from analogue to digital telecare.

2.3. The development of AAL systems

Hallewell Haslwanter and Fitzpatrick (2017) investigated the reasons for the limited number of Ambient Assisted Living (AAL) technologies on the market. AAL systems include sensor-based systems e.g. to monitor if a person has fallen and raise an alarm, and ambient systems e.g. to detect activity in the home. The authors focused on engaging with experts involved in the development of AAL systems, rather than end users, to understand the problems development teams encounter. A total of 71 issues were identified by participants. The most important issues included: not really understanding the needs of the user group; lack of overview of the players/which projects have been developed; and communication problems between project partners/stakeholders. Regards the first issue, the authors found the solution to be more complex than developers 'just

TABLE 2. Qualitative methods of design used in the study.

Method	Description
Focus groups	*Opinions, feelings and attitudes are gauged from a group of participants about a product, service etc.*
Observation	*Attentive looking and systematic recording of phenomena, including people, artefacts and environments*
Mind mapping	*Visually organizing a problem or a topic space in order to better understand it*
Affinity diagramming	*Research observations and insights are captured on individual post-it notes, and notes that share an infinity are clustered together, forming themes*
Personas	*Personas consolidate archetypal descriptions of user behaviour patterns captured into representative profiles*
Storyboards	*Visual narratives that generate empathy and communicate the context in which a product, service etc. will be used*
Scenarios	*A narrative that explores the future use of a product or service etc. from a user's point of view*
Simulation exercises	*Deep approximations of conditions, designed to forge an immersive, empathic sense of real-life user experiences*
Prototyping	*The tangible creation of artefacts at various levels of resolution, for development and testing of ideas*

being more user centred' e.g. a lack of access to older users was identified. Our study employed a user-centred design approach to better understand the needs of users, but similarly encountered a challenge with access to end users. Specifically, a concern by GCHSCP, who facilitated access to participants, about involving vulnerable older adults in research.

3. METHOD

The study employed a user-centred design approach. Specifically, it followed a Double Diamond design process involving four stages: Discover, Define, Develop and Deliver (Design Council, 2005). The study was conducted by 29 fourth-year MEng Product Design Engineering students (hereafter called designers) from the HEI, supported and supervised by the study team. In addition, a researcher at the HEI with experience in telecare helped to oversee the project and synthesize the study results into research contributions. The designers were grouped into seven teams and worked on the project for 1.5 days per week for 11 weeks, involving field research and studio-based learning and teaching. The main methods of design used in the study are listed in Table 2. Ethics approval for the study was obtained from the Research Ethics Committee at the HEI and informed consent was obtained for all participants.

3.1. Participants

Seventy-four adults representing the main user groups for telecare described in the Introduction section participated in the study: 13 end users (11 female, 2 male); 32 informal carers (29 female, 3 male); and 29 H&SC professionals (16 female, 13 male). In addition, the designers engaged with five individuals with severe learning and physical disabilities (two female, three male). These individuals did not use telecare, rather they represented extreme potential users; in considering their needs, the designers were encouraged and inspired to design solutions that are more usable by everyone. Participants were recruited via GCHSCP.

3.2. Design process

3.2.1. *Discover phase*

The Discover phase is about opening up—gathering inspiration and developing initial ideas. This phase began with a demonstration of telecare equipment by H&SC professionals with experience of prescribing and installing equipment, to support the designers to build knowledge of telecare and identify its strengths and weaknesses. Next, the designers engaged with telecare users. For logistical reasons, the designers formed into five research teams, with each team visiting one research venue. All the findings were subsequently shared among the seven design teams.

The first research team engaged with end users at a retirement housing community for older people, where homes are fitted with telecare equipment linked to the ARC in Glasgow. The next three research teams engaged with informal carers at three carer centres (one centre each), covering different areas of Glasgow. The centres provide a range of services including information, advice and respite care. The format of the sessions was focus groups within a communal space, lasting two hours. The fifth research team visited a day care service for adults with severe learning disabilities. The format of the session was semi-structured observation and discussion within a communal space. The research team observed members of staff interact with clients, clients interact with technology such as eye tracking software, and discussed clients' needs and capabilities with respect to telecare with staff. The Discover phase also included a visit to the ARC in Glasgow for the designers to experience the service first hand including a demonstration of receiving an alarm call. Additionally, the designers visited a technology demonstrator flat in Glasgow, set up to showcase the different ways older people can be supported to live independently in their own homes for longer, including through use of technology.

At each of these venues, research data were collected using field notes and photographs. Data were also captured using a storyboard method at the retirement housing community and carer centres. The designers sketched visual narratives of a day in the life of individual participants, based on their accounts, to better understand their experiences. To bolster the (first-hand) research data, a set of five personas was provided by GCHSCP. The personas were built on qualitative information and portrayed users of telecare with different needs. Each persona comprised a name, a (stock) photo, a short biography and description of their behaviours and the technology they use. Staff from GCHSCP's telecare team participated in a brainstorming session, involving the generation and discussion of multiple ideas in response to each persona. The data gathered during the Discover phase were analysed using design analysis methods such as mind mapping and affinity diagramming, and structured into problem statements and initial design ideas.

3.2.2. *Define phase*

The Define phase is about focusing down—synthesizing a mass of ideas into a reduced number of concept designs. During this phase, the design teams defined a direction (challenge area) to focus on from all the possibilities identified in the Discover phase and identified key ideas to develop further. The process was supported by generative design methods, e.g. scenarios, which helped the teams to carefully consider how their ideas could improve people's lives, as well as build consensus and understanding among the team members. The process included desk research and site visits to the collaborating innovation centre to investigate existing technological solutions for the areas the design teams wished to address. The Define phase ended with an interim presentation attended by members of the study team. Each design team presented their research findings and concept designs for constructive feedback and a steer on which design to develop further.

3.2.3. *Develop phase*

The Develop phase is about opening up—iteratively developing and testing the concept designs. The design teams revisited the retirement housing community and two of the three carer centres to gather feedback on their chosen concept designs. It was not possible to revisit the third carer centre due to scheduling difficulties. The sessions followed the format of the previous engagements (Discover phase). The designers also engaged with telecare H&SC professionals. The format of the session was a design critique within the design studios at the HEI. Participants were divided into small groups, then on a rotating basis, each design team met with each group of participants to present their concept designs for constructive feedback (Fig. 1). Participants comprised staff from GCHSCP, the carer centres, the learning disabilities service who were accompanied by three of their clients, the ARC and the technology demonstrator flat.

FIGURE 1. User engagement activity.

At each of these engagement sessions, responses to the concept designs were collected using field notes. The feedback was used to inform the iterative development of the design teams' concept designs using design methods such as prototyping and simulation exercises. For example, one of the design teams used an 'ageing body suit' located at the technology demonstrator flat to help develop their concept design. The suit restricts mobility, simulating the deteriorated agility e.g. stooped back and arthritis that is associated with aging. The Develop phase ended with a second interim presentation and critique attended by members of the study team.

3.2.4. *Deliver phase*

The Deliver phase is about focusing down—finalizing the resultant product, service or system. The design teams focused on final prototyping, branding, producing technical specifications and costings and preparing presentation materials such as three-dimensional models and information boards for a showcase event to share their research findings and final concept designs. The Deliver phase ended with the showcase, which was attended by stakeholders who had participated in the study. Following the showcase, each design team compiled a detailed report on the design process. Each report comprised ~100 pages (A4 size) of user research data, visualizations (e.g. mind maps, storyboards, scenarios) and design ideas.

3.3. Synthesis of findings and design ideas

As noted, a researcher with experience in telecare helped oversee the study. At the conclusion of the design process, the researcher synthesized the data collected/generated into research contributions. Specifically, the data that were synthesized comprised the findings from the user engagement activities and the ideas generated through the design process.

3.3.1. User engagement findings

User research data were primarily collected by the designers during the Discover and Develop phases. The data were analysed by the researcher using both deductive and inductive content analysis. Deductive content analysis was used because of the previous studies—namely Hensel *et al.* (2006) and Hamblin (2016)—dealing with the research topic and to test the obtrusiveness model and additions in the Scottish context. The deductive content analysis involved applying the conceptual framework (obtrusiveness model) by Hensel *et al.* (2006), plus the two additions (control and information) identified by Hamblin (2016) to the data. To begin, an Excel spreadsheet was created with a column for each of the codes (dimensions and subcategories) of the obtrusiveness model plus the additional codes 'control' and 'information'. The researcher then manually extracted all the user research data from the design teams' reports into the relevant codes (columns) in the Excel spreadsheet. The inductive content analysis involved using open coding to create any additional codes for data that could not be assigned to the predefined set of codes. Taking both a deductive and inductive approach enabled the researcher to clearly identify the most important issues relating to acceptance/uptake of telecare, as reported by participants.

3.3.2. Design ideas

Each design team delivered one final concept design i.e. there were seven concept designs in total. However, throughout the design process a multitude of ideas were generated and explored based on research. These ideas, expressed in words/phrases and images, were analysed by the researcher using affinity diagramming. To begin, the researcher re-read each of the design teams' reports several times. Each idea was then manually extracted (written) onto individual post-it notes, which were placed on a large sheet of paper. The post-it notes were then clustered based on affinity, which gave rise to the overarching themes. Finally, the theme categories were named and summarized, and checked with other members of the study team.

4. RESULTS AND DISCUSSION

4.1. User engagement findings

This section presents the synthesized findings from the user engagement activities. Unless reported, participants did not describe any issues relating to particular dimensions or subcategories.

4.1.1. Physical dimension

A few participants reported issues related to excessive noise. For example, one participant commented '*I don't like the noise of the alarm*'. Several participants reported issues related to the aesthetic incongruence of telecare, in particular its unattractive and jarring appearance and '*medical aesthetic*'. One participant commented that the pull cord is '*ugly, outdated and a monstrosity*'.

4.1.2. Usability dimension

Lack of user friendliness or accessibility was a major issue for participants. The majority of problems related to activation of devices due to physical or cognitive conditions, or learning difficulties. For example, one participant with arthritis commented '*My fingers don't work well sometimes and I can't press the button*', and one participant with early stage dementia commented '*I forget why it's there and press it out of curiosity, then throw it into the bin when it I don't see it do anything. When the responders arrive, I get angry and confused*'. Participants also reported that they often forgot to charge their GPS device and wear it when leaving home, and that devices were easily activated by accident (false calls). For example, one participant commented '*The pendant goes off all the time and it takes the alarm forever to shut off*'. The main accessibility issue related to the standard practice of installing a single hub in an end user's home. Participants reported they cannot always hear the hub and/or be understood by the ARC if they are in another room. A couple of participants reported that additional demands on time and effort were needed to charge GPS devices daily.

4.1.3. Function dimension

Many participants reported problems with false calls from inaccurate measurement of devices, particularly from property exit sensors, fall detectors and smoke alarms. For example, one participant commented '*the smoke alarm goes off so often that I have cakes and biscuits ready for the firemen!*'. In terms of restricted distance or time away from home, many participants reported that the pendant trigger only works within range of the hub limiting its usefulness in large houses/gardens or away from home. A few participants reported a perceived lack of usefulness. For example, one participant from the retirement housing community who had deactivated their telecare system, commented '*I don't feel that I need it*'.

4.1.4. Human interaction dimension

A single participant reflected that asking for help from friends and family had negative effects on relationships by making her feel that she was '*no longer an equal*'. Of note, staff at the ARC in Glasgow described a number of issues related to a lack of human response in emergencies. Originally, there were four call centres in Glasgow, all serving local communities where staff and residents were familiar to each other. The centres then merged into a single centre, serving the whole of Glasgow where staff no longer have the same local knowledge of residents or geography of the area. Consequently, staff are less able to make decisions based on being knowledgeable about the client, which other research has also found to be important (Proctor *et al*., 2016), and travelling (response) time is longer.

4.1.5. *Self-concept dimension*

Self-concept was another major issue for participants. Many participants viewed the uptake and usage of telecare as a symbol of loss of independence. For example, one participant reported that her family had organized the installation of telecare, i.e. it wasn't her choice, and that made her feel '*less independent, I'm not dead yet!*'. Participants also described telecare as a cause of embarrassment. For example, participants commented that the pendant trigger '*screams I am vulnerable*' or '*shouts I need assistance*', and that it makes them feel like '*an inconvenience*' to ARC responders and emergency services in particular, especially in instances of false calls, as '*they have more important things to do*'.

4.1.6. *Sustainability dimension*

Many participants raised affordability concerns. Historically, local authorities have provided telecare services free of charge, however many have now introduced charges. In 2013, GCH-SCP introduced a weekly charge (£3) for its telecare service, which sparked a strong negative reaction: ~3000 (30%) of its service users cancelled the service. Some participants commented that they could not afford the service e.g. '*it's a luxury I can't afford*'. Others commented that they are paying for a '*safety net*': something that they pay for all of the time, which they might only need some of the time in an emergency. For some, this was not worth the cost benefit.

4.1.7. *Control and information and support dimensions*

The control dimension was cited by a single participant as a concern, whose family had arranged for telecare to be installed in their home. This had made them feel '*inferior, it's a constant reminder of my condition*'. The information and support dimension was also an issue for some participants. For example, some participants were unclear on how to use the equipment and where it works and does not work. Many of the carers were unaware of the products that could help them support the person they cared for to live independently, indicating the need to improve awareness of existing products and services through health and social care channels, and consumer channels.

Overall, the findings of the user engagement activities indicate that the model of obtrusiveness by Hensel *et al*. (2006) plus the additions identified by Hamblin (2016) are applicable to the Scottish context. An additional issue was identified: a fear or dislike of new technology. For example, one participant commented '*I have an iPad, but I haven't opened it and I don't have any desire to*', and another participant with a basic (non-smart) phone commented '*I don't like touchscreens*'. Although a much smaller study, our findings are broadly similar to the study by Hamblin (2016). Neither study identified significant issues with functional dependence on telecare or obstruction, invasion of personal information, threat to replace in-person visits or interference with daily activities, suggesting these dimensions may be less important to users when designing digital telecare. Conversely, both studies identified issues with the other dimensions, in particular the usability and self-concept dimensions.

4.2. Themes

Four themes were identified from the synthesis of ideas generated through the design process:

- Community-based support
- Telecare you do not wear or notice
- Expand the use of telecare
- Introduce telecare earlier.

This section presents each theme, illustrated with at least one of the design teams' final concept designs, as an example(s) of an approach that could be taken. NB: each of the final concept designs relates to more than one theme; we chose the concept design(s) that best illustrates the theme. All of the designs emphasize attractive and less stigmatizing products and services to address issues of aesthetic incongruence and self-concept and utilize low-cost technology to address affordability concerns. For example, several of the designs use LoraWAN, a wireless networking standard to support the IoT that offers long-range connectivity and low power operation cost (LoRA Alliance).

4.2.1. *Community-based support*

The first theme is that of utilizing community-based support to make telecare less reliant on traditional organizational requirements such as ARCs. Arguably, successful telecare relies on the existence of social networks and the availability of hands-on care. Indeed, other researchers have noted a key paradox of telecare is that while it is intended to work at a distance and to be of particular value to people who do not have robust networks of co-present caring others, it will only function well when they are situated within such networks (Proctor *et al*., 2016). The AKTIVE project proposed that support networks for telecare users that draw on neighbours, friends or people known through local associations (e.g. a church group) give some strength to relatively 'weak ties', which are theorized as especially productive of social cohesion (Yeandle, 2014). Further, for policymakers and practitioners, ensuring older people have the opportunity to sustain and develop networks of weak ties may be important for future planning of support systems capable of assisting large numbers of frail older people to live safely and independently in their communities (Yeandle, 2014). A comparable conclusion of the UK Government's Whole System Demonstrator programme—the largest randomized control trial of telecare and telehealth in the world—is that organizational requirements around telecare, such as arrangements for monitoring and responding to alarm calls, requires review if it is to become cost-effective (Newman *et al.*, 2011).

The value and potential of community-based support is illustrated in the CommuniCare concept design. CommuniCare envisions the creation of 'connected communities' where people are embedded within local networks of support for telecare. Each participating household has a Beacon (hub) and a set of Seeds (pendant triggers) that can be placed around the home or on the body (Fig. 2). The Beacon has a screen, speaker and microphone. The Seeds come in a choice of five different attachments: magnetic, adhesive, suction pad, key ring and clip. The Seeds communicate with the Beacon and each Beacon communicates with the other Beacons in the network and with the ARC via LoRaWAN and GSM SIM technologies. The more Beacons the stronger the network of support. The Beacon has two main alert settings: non-emergency and emergency communication. The settings are operated using a scroll-wheel interface, and the current setting is visualized using green (non-emergency) and red (emergency) colour coding on the screen and an LED strip on the body of the hub. In an emergency, the end user raises an alarm via the Beacon by selecting the emergency communication option or by pressing a Seed. While the community network fulfils the primary responder role, the ARC will monitor all calls and respond as necessary. The Beacon may also be used for non-emergency communications with other Beacons in the network. For example, seeking companionship or help with practical tasks. Such communications are not monitored by the ARC and could help older people combat issues of loneliness and isolation, which can be especially prevalent in the elderly and vulnerable. With reference to the obtrusiveness model, CommuniCare particularly addresses issues of human interaction, where staff from ARCs may be less knowledgeable about the client and travelling (response) times may be longer, as well as aesthetic incongruence. CommuniCare also addresses affordability concerns by reducing demand on ARCs, especially in areas with clusters of telecare users, which is also important given that health and social care budgets are under significant pressure in most countries.

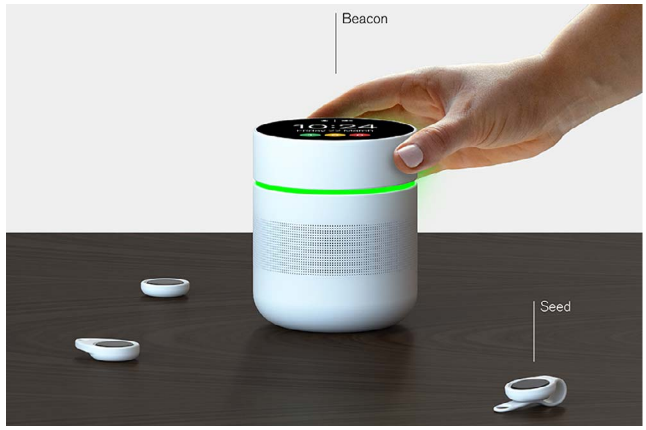

FIGURE 2. The CommuniCare Beacon and Seeds. Image credit: Alistair Byars, Robert Mueller, Steph Parker and Samuel Watson.

4.2.2. *Telecare you do not wear or notice*

The second theme identified is telecare that does not require the end user to wear anything e.g. a wrist-worn pendant trigger, and/or telecare that is less noticeable (obtrusive), in order to encourage acceptance and usage. Several of the design teams concluded that an intrinsic problem with the most common form of telecare equipment, the pendant trigger, is that end users need to be willing to wear it. However, as noted, the findings of this and other research has indicated that many end users choose not to wear their pendant trigger and/or other wearable device (e.g. a fall detector) or they forget to put it on. In response, several of the design teams explored two directions: ambient and voice sensing technologies—removing the need for end users to be wearing a device and/or to be capable of pressing a button when help is needed; and interoperability with mainstream home technology products connected to the Internet such as smart speakers e.g. Amazon Alexa and Google Home—to help remove the noticeability of telecare equipment and encourage people to consider purchasing consumer technologies rather than a telecare equipment package from their local authority.

The value and potential of a non-wearable solution is illustrated in the Evolve concept design (Fig. 3). Evolve is an unobtrusive home-based system, comprising the vHUB, vSENSE, vSPEAK and vSMARTPLUG equipment. The equipment is intentionally designed to be 'boring' e.g. using plain colours and simple shapes, to be less conspicuous. The vHUB is the hub that connects all the equipment and connects to the ARC via cellular data (eSIM). The vSENSE is a PIR array that uses low-resolution imaging to discreetly monitor (track) the activity patterns of an individual(s), as well as room temperature. vSENSE is installed in the corner of a room and includes a fisheye lens for maximum coverage. vSENSE uses low resolution imaging rather than a camera to address potential privacy concerns about 'spying'. vSENSE automatically raises an alarm call to the ARC via the vHUB if human activity is not detected within a pre-set time, or vSENSE detects a fall or extreme (dangerously high or low) temperatures. vSENSE aims to detect falls more accurately than current technologies through analysing the end user's motion to detect the characteristic dynamics of a fall, and monitoring their inactivity and comparing it with a map of acceptable periods of inactivity in different locations in the field of view. The vHUB, vSPEAK and vSMARTPLUG are designed to utilize existing infrastructure in the home—a plug socket—as an everyday object that is less noticeable. The vSPEAK is a plug with a built-in speaker/microphone and voice recognition that allows users to voice-enable an alarm call to the ARC and communicate with Centre Staff. The vSPEAK can be installed in as many rooms in the property as desired. The vSMARTPLUG is a plug with a built-in speaker that connects

FIGURE 3. The Evolve vHUB (right), vSENSE (bottom), vSPEAK (top left) and vSMARTPLUG (bottom left). Image credit: Rebecca Jones, Isobel Leason, Africa Perez and Christopher Welch.

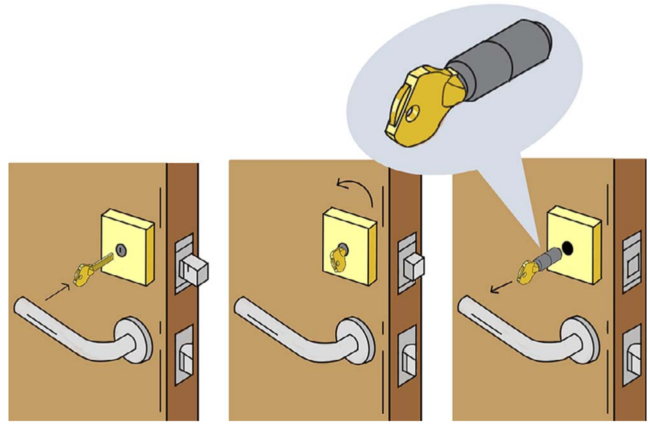

FIGURE 4. The Typic Find-Me Key. Image credit: Morven Graham, Corrie Grant, Gregor Mackay and Louis Slorach.

to vSENSE to detect when the end user is exiting/entering the property. vSMARTPLUG alerts the end user to take their GPS device with them, or to plug it in for charging, when they exit or enter the property respectively. In this way, vSMARTPLUG tackles the problem of end users forgetting to take their GPS device with them or to charge it. Finally, Evolve is a Zigbee and 869 MHz radio-enabled platform allowing Evolve equipment and smart home technology to be connected. With reference to the obtrusiveness model, Evolve particularly addresses issues of aesthetic incongruence (aesthetic sensibilities and integration into the home), lack of user friendliness or accessibility (not always hearing the hub and/or being understood by the ARC if in another room), inaccurate measurement and cause of embarrassment (false calls from fall detectors), and privacy (use of cameras).

Following the study, the team member (Managing Director) representing the telecare manufacturer, moved to a new assistive technology provider. This provider subsequently offered an internship to two of the designers—one from the CommuniCare team and the other from the Evolve team—to work within their R&D (research and development) department on the themes of connected communities and working as a community to combat loneliness, and linking to the smart home for improved services, indicating the desirability and feasibility of the community-based support and telecare you do not (wear or) notice themes.

The value and potential of telecare that you do not notice is also illustrated in the Typic concept design (Fig. 4). Typic comprises the AmbiNet (ambient sensors and hub), the Find-Me Key and the Typic app and picture frame display. In the interest of space, we focus on the Find-Me Key. The Find-Me Key helps address the issue of end users not always remembering to wear their GPS device when they leave home, and the issue of false alarm calls from property exit sensors. H&SC participants in our study reported that the number of false calls is as high as 73% for this particular sensor. This is due to a standard property exit sensor sensing when a door has been opened, but not whether it has been closed from the inside or outside, and therefore whether the end user is safe at home or not. This is important due to the cost to services to respond to calls in instances of uncertainty. The Find-Me Key comprises a key, barrel and lock. The device replaces the lockset on the front door of the end user's home, and is designed to retrofit to any standard lock. The barrel includes a GPS sensor, a Near Field Communication (NFC) RFID chip, a LoraWAN module (for communication with the hub), an inductive charging coil receiver and a rechargeable battery. The battery is wirelessly charged in the lock and addresses the issue of additional demands on time and effort to charge GPS devices daily. The lock is wired into the main electricity supply and includes an NFC RFID reader, an inductive charging coil transmitter, a LoraWAN module and a backup battery. The end user uses the key to lock/unlock their door in the usual way. When they unlock their door using the key, the GPS barrel attaches to the key; (the door auto-locks) and when they unlock the door, the GPS barrel detaches back into the lock. Through cross-checking data from the AmbiNet sensors, and in particular an infrared camera that monitors movement, with the status of the Find-Me Key, Typic can better support a course of action by the ARC. With reference to the obtrusiveness model, the Typic Find-Me Key particularly addresses issues of additional demands on time and effort (charging GPS devices daily), inaccurate measurement and cause of embarrassment (false calls from property exit sensors) and acquisition of new rituals (no changes to daily routines).

The value and potential of telecare you do not wear or notice is also illustrated in the WaveSense concept design (Fig. 5). WaveSense comprises the WaveCore, WaveBand, WaveTrack and WaveCam equipment, plus the WaveSense app for users to install on their smartphone. WaveCore is installed in each room in the home, and uses advanced radio technology to image

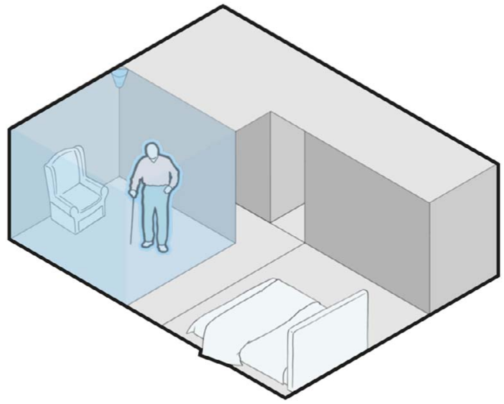

FIGURE 5. The WaveCore antenna. Image credit: Catriona Brown, Alex Duff, Emma-Marie Magro and Angus Wilkie.

the room, using an antenna (with sensor array) and hub (with chip). In particular, WaveCore senses the location, movement and posture of people. The hub processes data from the antenna and automatically raises an alarm call to the ARC if a lack of movement is detected indicating that the end user may be unwell, or a sudden change in posture is detected indicating a potential fall. The antenna contains a microphone and speaker to help ensure that end users can hear and/or be understood by the ARC. WaveTrack refers to wireless motion sensors that can be placed around the home and on domestic appliances to track daily activities such as what time the end user usually gets up or boils the kettle. Data are communicated to the WaveCore hub and displayed on the WaveSense app. The app is also accessible to informal carers, e.g. family members, and the information can be used to help manage care needs or detect potential problems. WaveCam helps address the issue of end users, typically people with dementia, not remembering to wear their GPS device when they leave home. WaveCam comprises a camera paired with a contact sensor on the entrance door that captures a photograph of the end user when they leave home (as detected by WaveCore). The photo (plus exit time) is sent to the ARC as a visual aid to finding the end user if needed. Finally, WaveBand is a wrist-worn trigger available in a range of designs and colours. WaveBand operates both within and outside the home, addressing the issue of a standard pendant trigger only working if within range of the hub. WaveBand includes an alarm button and a GPS sensor. In the event of an emergency, pressing the button alerts the ARC that help is needed via the WaveSense app on their smartphone, and their whereabouts can be tracked if needed. With reference to the obtrusiveness model, WaveSense particularly addresses issues of lack of user friendliness or accessibility (forgetting to wear GPS devices; not always hearing the hub and/or being understood by the ARC if in another room), restricted distance/time away from home (pendant trigger only working within range of the hub); and privacy (use of cameras).

4.2.3. *Expand the use of telecare*

Currently, telecare is aimed at people experiencing more severe declines and/or much older people, and is therefore addressing a relatively small population. The third theme was the potential to expand the use of telecare beyond those who are normally thought of as typical users. Several of the design teams explored new products and services that are desirable and functional for everyone, irrespective of age or ability. For example, the use of telecare for overnight support (sleepovers) was explored. Sleepovers are designed to meet a range of needs including support where a person: has a significant mental health problem or learning disability that means it is difficult for them to be alone overnight; needs a call/conversation to reassure or check-in; or might wander or leave their home. In the UK, the cost to employ a social care worker for sleepover hours has increased markedly due to a change in legislation around how staff are paid, representing a ripe opportunity area to potentially introduce telecare.

The value and potential of telecare for sleepovers is illustrated in the Snooze Safe concept design (Fig. 6), which removes the need for sleepover staff to stay overnight at the user's home. The system comprises a bedside device (the hub), a property exit device and a mobile application (app) for sleepover staff to install on their phone. The property exit device is connected to the bedside hub via short-range wireless (Z-Wave) technology, and the hub is connected to sleepover staff via cellular technology/the app. The bedside hub uses XeTHru sensor technology to detect breathing rate and movement in order to determine whether the user is in bed, and issues that are more common in people with learning disabilities such as epilepsy and sleeping problems. The bedside hub also incorporates a screen, a camera (mounted so that is only visible when being used to reduce potential privacy concerns) and video calling to enable a conversation with sleepover staff as a means to provide reassurance or to check-in, or for sleepover staff to assess a potential emergency. For example, if the end user is feeling anxious, they can make a video call and staff can offer reassurance and a human response. The property exit device comprises a magnetic sensor placed on the front/back door, which uses a reed switch to detect if the door is open or closed, and works in conjunction with an infrared motion sensor placed on the adjacent wall, which detects movement in the hallway, to infer if the end user is in/out the property. The Snooze Safe app provides a facility for sleepover staff to view and respond to the data collected by the beside hub and property exit devices, with the aim of keeping the user safe in their homes for longer. The main functionality is a user profile, alerts (notifications and history), sleep tracking data and video calling—the app connects to the bedside hub. In the event of a potential emergency, e.g. the end user experiences a drop in breathing indicating a potential seizure or has exited the property at night-time, an alert is sent to the sleepover staff via the app on their phone, who can take appropriate action. With reference to the obtrusiveness model, Snooze Safe particularly addresses

FIGURE 6. The Snooze Safe bedside hub (left) and property exit sensors (right). Image credit: Jemma Brown, Scott Neill, Michael O'Donnell and Jessica Vinnels.

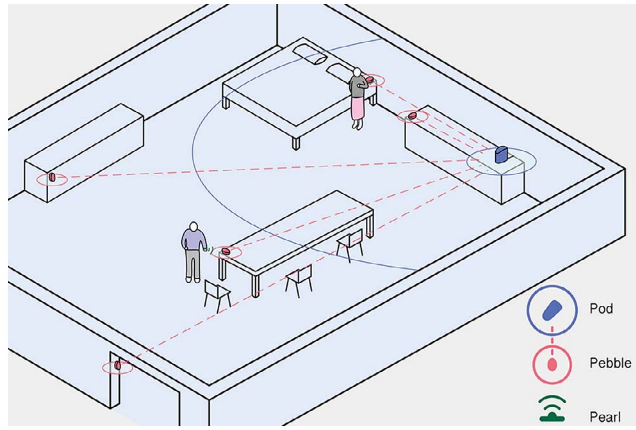

FIGURE 7. The aWear system. Image credit: Molly Akers, Kieran Kay, Penny Morton, Cathel Robertson and Caroline Tougher.

issues of affordability concerns (high cost of services), symbol of loss of independence (regaining independence) and aesthetic incongruence (aesthetic sensibilities).

The value and potential of expanding the use of telecare is also illustrated in the aWear concept design (Fig. 7). aWear is a discreet system that monitors and records activities of daily living (routines), including how often an end user enters a particular room e.g. bathroom, or uses a particular domestic appliance e.g. kettle. aWear alerts the end user if anything unusual is detected. Emergency calls can also be raised to the ARC. aWear expands the use of telecare through targeting individuals who could potentially benefit from support with safe and independent living, but are not yet experiencing a severe decline etc., as well as those more typically assessed as needing telecare. Accordingly, there are two versions of aWear: aWear Daily provides monitoring capability only; and aWear Emergency Care additionally connects to the ARC. Both versions include the Pod (the hub), the Pearl, the Pebble and an app. aWear Emergency Care additionally includes the Pearl Plus and Pebble Sound. The Pod, as the hub, compiles the monitored data for viewing via the app and raises alarm calls. The Pearl is a wrist-worn device available in a range of colours and sizes that uses Bluetooth to connect to Pebbles in order to monitor activity. The Pearl Plus additionally incorporates an emergency alarm button. Pebbles are placed around the home and besides/on appliances as required, and also use Bluetooth to connect to the Pod. The Pebble Sound additionally incorporates a speaker and microphone, addressing the issue of end users not always being able to hear the hub and/or be understood by the ARC if they are in another room. The app visualizes the data collected by the Pearl/Plus and Pebble/-Sound devices, and alerts users to irregularities to daily living (routines) that could indicate possible issues including the need for enhanced care. For example, taking the scenario of an older person who has difficulty in drinking due to forgetfulness, the app can signal a possible risk of dehydration due to particular appliances (e.g. tap) not being used and thereby prompt a more regular routine of drinking to maximize health. The app is also accessible to informal carers, e.g. family members, to provide reassurance or to support care giving. With reference to the obtrusiveness model, aWear particularly addresses issues of self-concept (desirability), acquisition of new rituals (positive changes to daily routines), and lack of user friendliness or accessibility (not always hearing the hub and/or being understood by the ARC if in another room).

4.2.4. *Introduce telecare earlier*

The final theme relates to the earlier introduction of telecare as a pro-active choice rather than in reaction to a crisis (a 'push' situation). As described in the previous sections of this paper, there are a range of factors that affect the acceptance and use of telecare, including a fear or dislike of new technology. Some older adults are reluctant to adopt new technologies in later life that they are not familiar with, particularly when implemented in response to a time of crisis. In response, several of the design teams explored two directions: technology that end users want to acquire earlier in the life course, with a focus on prevention—so that in the event of a crisis, users are already engaged and familiar with the technology should additional equipment be required; and the concept of modularity, where the technology is flexible enough to suit the changing needs and abilities of end users as they age.

The value and potential of more modular solutions is illustrated in the Exila concept design. Exila is a personal trigger that comprises a ring, an armband, and a smartphone app. Exila operates both within and outside the home, addressing the issue of a standard pendant trigger only working if within range of the hub. An alarm call is initiated by gesture: by bringing the ring, which includes a passive RFID antenna and chip, in close proximity to the armband, which includes a RFID reader. The

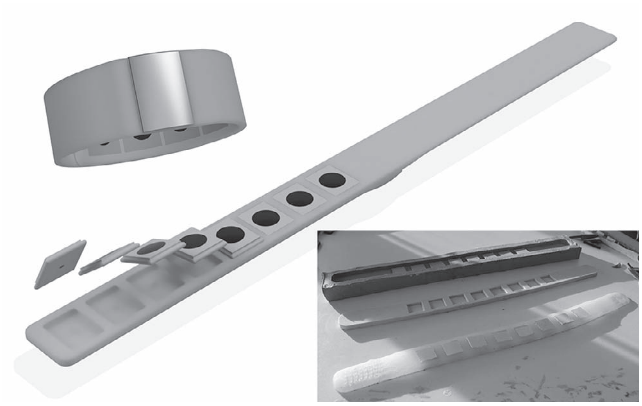

FIGURE 8. The Exila armband and early prototypes (right). Image credit: Jay van den Hoven, Rachael Hughson-Gill, Joe Pollard and Chiara Rossi.

armband is an adjustable strip of silicone with eight recesses (slots) for sensor modules (Fig. 8). The armband is available in a range of colours and can be worn/operated beneath clothing e.g. to address the fear of stigmatization for needing such a device. By default, two slots are dedicated to the RFID reader, and a CAT-M1 SIM card and Bluetooth sensor. The armband also incorporates a microphone and speaker. Once initiated, an alarm call is raised to the ARC via (CAT M1) cellular technology, and the end user can talk with Centre staff via their armband. In the event of a connectivity issue, and if the end user is carrying their smartphone, an alarm call is raised via Bluetooth/the Exila app and the end user can talk with Centre staff via their phone. The modular design of Exila allows telecare to be tailored to the end user's specific needs, with the remaining five slots on the armband capable of accommodating a range of sensors. Examples of options for these slots, as prototyped by the designers, include a GPS sensor for locating the end user in an emergency, a heart rate sensor, a temperature sensor, and an accelerometer. The Exila app visualizes the data collected by the sensors, which can support end users to take preventive action where needed to remain safe and independent in their own home. The app is also accessible to informal carers, e.g. family members, to provide reassurance or to support care giving. With reference to the obtrusiveness model, Exila particularly addresses issues of self-concept (desirability) and restricted distance/time away from home (pendant trigger only working within range of the hub).

While other countries are planning digital telecare deployments, there are currently very limited examples of digital telecare internationally. Thus, there is very limited best practice and availability of digital solutions on the market (FarrPoint 2016). However, the decommissioning of analogue telephone services internationally means it is likely that a significant number of countries will need to start deploying digital telecare. This presents an important opportunity for the field of HCI to help address this immense problem and improve the acceptance/use of telecare. The four broad themes identified through our study, illustrated with the concept designs, should prove useful to other practitioners and researchers seeking to improve the acceptance and use of telecare.

4.3. Limitations

A limitation of the study is the gender imbalance in participants, where only 5 of 45 (11%) participants across two of the user groups—end user, informal carers—were male. This is largely due to the very small number of men who participated in events at the retirement housing community and attended the carer centres. Therefore, the results of the study may be less representative of the target population than is desirable. However, a roughly equal number of male and female H&SC professionals participated in the study. Ideally, the study would have included more end users to increase its validity. However, as suggested by Hallewell Haslwanter and Fitzpatrick (2017), a set of personas built on user research was provided to the designers to supplement their own user research.

5. CONCLUSION

Telecare plays an important role in enabling people to remain safe and independent in their own home, and most developed countries have telecare programs in place. Telecare has traditionally used analogue connectivity; however, internationally, there is a shift to digital connectivity. This presents a rare and major opportunity to fundamentally redesign telecare, address current issues with adoption and use, and support more people to live in the community safely. This paper describes a user-centred study on digital telecare involving key stakeholders. The main contributions to the field of HCI are findings from user engagement activities, which identified issues that may be more important and less important to users when designing telecare; identification of four themes that should prove useful to other practitioners and researchers seeking to improve the acceptance and use of telecare: community-based support; telecare you do not wear or notice; expand the use of telecare; and introduce telecare earlier; and the presentation of seven concept designs that illustrate ideas for how the themes could be approached.

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