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Older Adults' Perspectives of Smart Home Technology: Are We Developing the Technology That Older People Want?

Abir Ghorayeb^{*,1}, Rob Comber², Rachael Goberman-Hill¹

¹ Bristol Medical School, Faculty of Health Sciences, University of Bristol, Bristol, UK.
Rachael.Goberman-Hill@bristol.ac.uk

² Dept. of Media Technology & Interaction Design, KTH Royal Institute of Technology, Sweden.
rcomber@kth.se

**Corresponding Author*

Abir Ghorayeb: Abir.Ghorayeb@bristol.ac.uk

Abstract

New technology and smart homes have the potential to improve quality of life, safety, and care for older people. However, we do not yet know how older people's perceptions of these technologies may vary, in particular how views based on experience of actual use may differ from those related to anticipated use. We also do not know how older people living independently might view technology that may be of future rather than current value to them. This paper explores older people's views of smart home monitoring technology and compares these between people with direct experience and those without. Four focus groups were conducted with six older people recruited from the community with no smart home experience and seven drawn from a large-scale Interdisciplinary Research Collaboration that is developing a sensor platform for health and lifestyle at home. For the seven participants, the sensor platform was installed and operated in their homes for eight to twelve months before the current study.

The study found that participants in each group had some similar and some different understandings of smart home technologies. Among participants who had already tried the smart home monitoring technology, acceptance increased over time and with use. They expressed fewer concerns than non smart homes participants regarding privacy, trust, usability, and more concerns about utility. Non smart home participants focused on the extent to which this technology might increase household's vulnerability and they considered the technology somewhat intrusive and noticeable. It appeared that the more positive views of participants who had direct experience of smart homes related to the degree of trust between them and the researchers who installed and maintained the smart home system. Both groups of participants shared views about the technical feasibility, affordability, impact on relationships, and about the engagement and competencies of those who would view the monitoring data. They suggested that the technology would be more acceptable if it was possible to customize functionality and features. These findings have implications for development of smart home technologies so that they are appropriate and acceptable to older people who are living independently.

Keywords

Home Healthcare, Smart homes, Older people, Technology Acceptance.

1. Introduction

Increased longevity is often associated with frailty (Crews and Zavotka, 2006; Ghorayeb et al., 2006). With current trends in population demographics, the need for support, social and health care for older people is growing (Ghorayeb, 2007; Robineau, 2016). In the UK, the National Health Service (NHS) provides care that is free at the point of receipt. With an ageing population, two-fifths of the NHS budget is spent on healthcare for people who are aged 65 years and over and there is a pressing need to find solutions that provide high quality care without increasing costs (Robineau, 2016). Most older people want to continue living in their own homes (Boldy et al., 2011; Woolhead et al., 2004). Home may be a 'safe haven' and people may have developed strong feelings of attachment to their homes, particularly if they have lived there for many years (Wiles et al., 2012). Living at home may also enable existing links with family and friends to continue, enabling older people to stay socially active. The desire to remain at home is influenced by a variety of factors including health status, burden on others, and loneliness (Wiles et al., 2012).

Assistive technologies may empower older people to maintain their independence and to improve their safety and wellbeing (Baecker et al., 2014; Schatorjé and Markopoulos, 2015). This form of technology generally involves interaction with a remote monitoring centre and complements rather than replaces support from the healthcare system, with such systems described as “smart homes”. Smart homes are often designed as a mean to sustain ageing in place, through support for home-based tasks such as cooking and cleaning as well as assistance in monitoring and maintaining health status. Helping these technologies be as acceptable as possible has been the subject of research, which indicates that placing emphasis on the benefit of technology can increase its acceptability to older people (Mitzner et al., 2010). However, a systematic review by Peek and colleagues highlights an absence of research about technology acceptance by older people living in the community (Peek et al., 2014) and there are few studies that investigate how older people’s perceptions of smart homes may change over time when living with the technology (Lee and Kim, 2019; Turjamaa et al., 2019). In a recent systematic review that focused on acceptance of technology for ageing in place in the post-implementation phase, Tsertsidis and colleagues found that the older people’s perception of technology changed between the pre- and post-implementation stages. Some concerns that emerged in the pre-implementation stage changed to positive features over time and with use (Tsertsidis et al., 2019). Due to the shortage of research studies that investigate older people’s views during the post-implementation phase, the researchers suggested that there is a need for more longitudinal studies that are able to investigate the same technology over time and with use. They also highlighted that future research needed to take place in participants’ own homes (Tsertsidis et al., 2019). This accords with Lee and Kim’s view, who suggested that: “It is necessary to investigate the problems that can occur while older adults are residing in the smart space themselves”(Lee and Kim, 2019). Together, these provide a research challenge that may help to inform future development of approaches to enabling acceptance of technology in this population with full attention to the nuance of such experiences. In this paper, we describe a study that compares the views of older people, living at home in the community, with experience of smart homes with the views of those without such experience.

1.1. Older People’s Perspectives on Smart Homes and Monitoring Technology

Published literature highlights an increasing number of smart homes developed to support and monitor older people’s health. However, older people do not necessarily see benefits of having a smart home and feel that such technology is intended for people who are less healthy than them (Peek et al., 2014). In two recent systematic reviews, the authors conclude that there is an absence of literature that investigate older people’s experiences of living with smart home technology or involves them in the design of the technology (Lee and Kim, 2019; Turjamaa et al., 2019). Of these, Lee and Kim highlight the importance of attention to psychological as well as physical independence and Turjamaa and colleagues highlight the absence of research that involves older people in the design of the technology. In another review, Tsertsidis and colleagues highlight that older people’s views of smart home technologies change between the pre- and post-implementation stage (Tsertsidis et al., 2019).

A range of concerns have been identified as possible barriers to adoption of smart home technology. These include usability, accessibility, reliability, trust, stigma, control, privacy, lack of human response, burden to others, lack of perceived need, and affordability (Coughlin et al., 2007; Demiris et al., 2004; Peek et al., 2014; Tsertsidis et al., 2019). For instance, Mann and colleagues found, in a survey conducted with 661 older people with chronic physical conditions, that 56.3% of them did not think the smart home technology would be beneficial to them, and 59.3% were not interested in buying such a system (Mann et al., 2007). Coughlin and colleagues conducted a workshop and focus group with 30 leaders in ageing advocacy and ageing services. They reported that monitoring technologies have a positive impact on older people’s feelings of safety but that dependence on technology might present a threat to older people’s dignity (Coughlin et al., 2007). Similarly, Demiris and colleagues, who conducted focus groups with 14 older people, found that a video sensor was thought to be invasive and undesirable, despite the view that it would be useful in health emergencies (Demiris et al., 2008a). The sense that technology has value for safety is echoed by findings from Pigni et al. who found that older people viewed a personal health system to be useful for monitoring health and therefore improving security and safety (Pigni et al., 2017). Finally, not all systems are designed to address health directly, with some focused on social connections, but findings related to acceptance area similar to those found in relation to systems designed for health. A systematic review by Morris et al. on the effectiveness of smart technologies in improving social connectedness of older people living at home highlights a need to explore how technology may be effective and how social connectedness, mediated by technology may provide health benefits (Morris et al., 2014; Peek et al., 2014). In an empirical study, acceptance of smart home technology designed to connect older people with support networks was found to be higher if cost, usability and information security were addressed (Cosco et al., 2018; Morris et al., 2014).

Many studies of older people’s perceptions of smart home technology have taken place in laboratory settings or have been performed in early phases of technology development such as the user requirement or evaluation phases (Lee and Kim, 2019). These studies have mainly conducted brief evaluation sessions using presentations or scenarios to explain or demonstrate the technology to the participants, followed by semi-structured interview or focus group (Peek et al., 2014). In such evaluation sessions, potential users are asked to provide their opinions about the technology that they have just learned about and have had the chance to try for a short period of time in an experimental setting. These methods depend on the users describing how they would be most likely to feel about the technology, and these views tend to be positive and may not reflect how they would view the technology if they had the opportunity to use it in ‘real life’ (Lee and Kim, 2019). In addition, living in a smart home can trigger new behaviours may be different from those that are part of routine life without such technology. Thus, it is possible that there is a difference between views of those who have previously used technology compared with those who are potential

users (Venkatesh et al., 2011; Yang et al., 2018). Understanding and characterising the details of these differences may provide vital information for future development of technology that is acceptable.

Few studies have explored use of smart home technologies in real environments over periods of time, even though doing so would enable investigation of how perception of smart home technologies may change with use (Peek et al., 2014; Tsertsidis et al., 2019). For most studies, privacy, confidentiality, lack of human contact, usability and loss of autonomy, and obtrusiveness are an issue for smart home residents (Chernbumroong et al., 2010; Chung et al., 2016). For instance, Demiris and colleagues evaluated the technology implemented in the apartments of nine participants living in an independent retirement facility. They concluded that without video sensors as part of the system, older people with smart home technology forgot about the existence of the monitoring technology, which did not interfere with their daily lives or cause privacy concerns (Demiris et al., 2008b). Similar findings were described by van Hoof and colleagues who interviewed 18 older people with a high demand for care after they had autonomous surveillance and videophony systems installed in their homes (van Hoof et al., 2011). These participants reported an increased sense of safety and security, and privacy was not a major concern for them. In a feasibility study, Bock and colleagues deployed a system consisted of multi-sensors to capture data on motion, temperature, luminosity and humidity in the houses of 11 residents for three months. In this study, privacy was not a concern for older people as long as the collected data could be used only by family members, caregivers or physicians (Bock et al., 2016). In addition, some research studies report that smart homes helped some participants to remain active (Lie et al., 2016; Pol et al., 2016). Another aspect of the experience of smart home technology is ‘trust’ between users and monitors. For instance, Lie and colleagues found that safety is closely linked to the notion of trust therefore the system depends on the relationship between the older person and the person or people who are monitoring from a distance, and that these relationships should be based on “affective bonds of trust” (Lie et al., 2016). Some health oriented studies investigated older people’s perception of a telehealth medication devices after few months of use (Chen et al., 2014; Giger et al., 2015; Reeder et al., 2013). Over time and with use, participants found the technology to be increasingly useful and they felt more motivated to use it. The high rate of the perceived utility and acceptability can be understood as related to the health status of the participants (Boise et al., 2013; Chen et al., 2014; Giger et al., 2015; Reeder et al., 2013).

Few studies have investigated users’ perception of commercially available smart home devices (Georgiev and Schlögl, 2018; Giger et al., 2015; Tsertsidis et al., 2019; Yang et al., 2018). Homes were mostly equipped with heating devices, security cameras, smoke detection and some media and entertainment devices. Most of older participants expected that smart home technologies would be introduced gradually and found it difficult to live in a new smart home with different functions (Van Berlo, 2011). For most of these research studies, privacy and security were still the main concerns of users, and these were in addition to the lack of interoperability, complexity, cost of use and lack of perceived utility (Lee and Kim, 2019). Table 1 summarises some of the key literature.

The high level of acceptance of smart home technology in these studies may be related to participants’ awareness of their own vulnerability and need for help to maintain independence (Pol et al., 2016). However, many studies have included highly selected participants, and in most the participants were frail, with high demand of care, and were recruited from a retirement community or home cares (Boise et al., 2013; Courtney, 2008; Demiris et al., 2004; Lie et al., 2016). The relatively high level of support already received might influence the perceived utility of new technology. In other studies, participants were experienced volunteers who had already taken part in other research studies (Chen et al., 2014; Lie et al., 2016), which may also have impact on the findings and their generalisability. Further research is needed to investigate whether older people who consider themselves as able to live independently are also keen to accept smart home technology (Burrows et al., 2018; Lie et al., 2016; Morris et al., 2014; Peek et al., 2014; Pol et al., 2016).

Overall, there is a need for more research that focuses on older people’s experiences as smart home users. Importantly, there is a lack of research that explores the experiences of older people who are living independently with little support in place and comparing their experiences with those of people who have not lived with technology. Characterising and comparing views about smart home technology may provide a foundation for future development of approaches that enable people to accept technology, and that may help technology design to take account of views during its design.

Study author	Laboratory Settings/Short Evaluation Sessions	Home Settings	Commercial Devices	Participants	Evaluation Methods	Location	Duration of the trial of technology
Courtney, 2008	X			14 older people, Community dwelling older people	Focus group and interviews	Residential care facilities	Participants did not try the technology

Demiris et al., 2008a	X			14 frail older people	Focus group sessions	Retirement community	Participants did not try the technology
Demiris et al., 2008b		x		9 older people	Interviews	Retirement community	4-6 weeks
van Hoof et al., 2011		x		18 older people with high demand of care	Interviews and observation	Users' homes	8-23 months
Reeder et al., 2013			x	96 frail older people	Survey	Participants' homes	9-12 months
Chen et al., 2014		x		5 participants with disabilities, 45 years or older	Interviews and weekly diaries	Participants' homes	3-6 weeks
Pol et al., 2016		x		11 older people with different comorbidity levels	Interviews	Senior residence or in the community	Few months
Pigini et al., 2017	X			13 older people with cardiac diseases. 15 healthy older people	Survey	Smart home of the Occupational Therapy Service department	Evaluation sessions
Georgiev and Schlögl, 2018			x	10 participants, age not defined	Interviews	Participants' homes	Not described

Table 1 Summarised selected literature

1.2. Objectives

Our main objective is to understand older people's views of smart homes and how their experience can influence these. In this study, we focus on the views of those who have been living in a smart home for a period of eight to twelve months as well as those who have not. The study aimed to explore experiences of people who were living independently in the community. Our study was designed to explore these objectives and to inform future work to inform to design of smart home technology that accounts for older people's voices.

2. Method

This is a qualitative, focus group study conducted with older members of the public who had the opportunity to try SPHERE (a Sensor Platform for HEalthcare in a Residential Environment) technology in their homes and people those who had not had that opportunity. This study received research ethics approval from the University of Bristol, Faculty of Health Sciences Research Ethics Committee (FREC).

2.1. The SPHERE System and House

The EPSRC-funded SPHERE Interdisciplinary Research Collaboration (IRC) is developing a system of home-based sensors that will collect information about everyday behaviours and use of the home, with the ultimate goes of identifying any change in health or wellbeing status

(Zhu et al., 2015). The system is currently in development stages and does not yet collect information that is used for health or social care purposes, as such the SPHERE system provides a means to explore and understand how people perceive smart home technology.

Non-medical sensors installed in the SPHERE house include environmental, video and wearable sensors (Diethe, 2018; Zhu et al., 2015). The environmental sensors include humidity, temperature, air quality, noise level, luminosity, occupancy, door contacts, water and electricity consumption. The video sensors (Diethe, 2018), called “silhouette sensors”, generate black-and-white silhouettes of the inhabitants and are placed in the living room, kitchen, corridor/hall and staircases, focusing on activities recognition through data analysis. The wearable sensors are custom-developed and ultra-low-power (Diethe, 2018).

To test and develop the system, the sensors were installed in a fully furnished, two-bedroom residential property: ‘the SPHERE house’. Once refined, the current system was then installed in more than 50 homes in a large UK city to test and develop the system further. The SPHERE system uses a bespoke app, the “SPHERE Genie”, which runs continually on an Android tablet provided to each SPHERE household. This application was designed largely as a consent tool for the SPHERE study and is not delivering a service, intervention or supporting assisted living. The Genie allows household participants to view the battery level of their wearable, pause the collection of data, or delete periods of the data that has been collected.

2.2. Participant Recruitment

Older people who had experience as participants in SPHERE and who therefore had experience of the SPHERE smart home technology were identified and approached about participation in the focus group study. Participants without experience of smart home technology were recruited in collaboration with a local community engagement centre. Through this collaboration we attended older people’s gatherings including an older people’s forum, dancing, knitting and film clubs. Participant information booklets were also made available in two public libraries and we contacted local charities that support older people to seek their help in the recruitment processes.

We approached all potential participants by sending out recruitment packs (invitation letter, participant information booklet, reply slip and freepost envelope). We tried to achieve a heterogeneous group of older people, across different ages, education, health status and interests. Table 2 presents the characteristics of the recruited participants. We recruited a total of thirteen older people over the age of 65 (range 65 – 89 years of age). Five out of the thirteen participants self-identified as male and two identified as belonging to minority ethnic groups. This demographic approximates the population in the city, with 15% minority groups and 54% female in the most recent data (Council, 2020). All participants were living independently in their own homes. At the time of data collection, eight participants were living alone and five lived with partners. Both groups were broadly equivalent for age, gender education and other technology experience. Seven participants held postgraduate degrees, three of whom obtained these degrees when aged over 40 years. Another two participants held a bachelor’s degree or equivalent. Four participants had school education. Beyond experience of SPHERE technology, most participants had some experience with smart technologies although these were limited to smart mobile phones and/or tablets. Two participants had landline phones while another individual had never used a phone or a computer. One participant had a smart watch and a rain sensing automatic window.

We noted the relatively high education level of seven participants and the later age that three of them had achieved their postgraduate degrees. We are aware that this may have impacted on the type of information that the study collected, and we think that further research is needed with a more educationally diverse population. As the population ages it is also likely that familiarity with technology and educational attainment of older people will continue to increase. The sample, to an extent, may reflect the future generation of older people compared with the current older population (Cho et al., 2013)

The sample size was guided by the achievement of saturation (Guest et al., 2006) in which no new themes were identified in ongoing data collation such that we determined that sufficient participants and data had been included in the study. The study as a whole was designed in light of the concept of “information power”, meaning that the “more information the sample holds, relevant for the actual study, the lower amount of participants is needed” (Malterud et al., 2016). Based on the depth of the information that we collected, the study achieved information power. All participants provided their written, informed consent to take part in the study.

	Number of Participants	Male	Female	Age Range	Postgraduate Qualification	Degree level Qualification	School Qualification	Experience with:		
								Smart phone and/or tablet	Smart utility meters	Other smart gadgets
NP	6	2	4	66-88	3	1	2	5	2	

SHP	7	3	4	67-89	4	1	2	5	3	1
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Table 2 Participants' characteristics

2.3. Focus Groups

Focus group discussions enable discussion and conversation. We used this method to foster participants' confidence in their ability to be creative and useful when talking about technology. Seeing other older participants and sharing thoughts together provides a starting point for discussion (Ghorayeb, 2007; Wilkinson, 2004). When working with older people, it is important to implement practical steps that can enable inclusion and there are several known strategies to achieve this. These include small group size, ease of access to the focus group location, carefully paced sessions and session length, and some flexibility in the way in which they are run (Barrett and Kirk, 2000; Seymour et al., 2002). Small groups enable better communication and interaction, help the facilitator to investigate ideas more closely with all participants and allow the researcher to deliver more detailed analysis of each participant's experiences, for instance to understand any link between views about smart homes and personal experience.

We conducted a series of four focus group sessions (with a maximum of four people per group) to explore older adults' perceptions and expectations of smart home technology as well as their beliefs about the ways in which technology could help to improve their daily lives. Each focus group was formed of mixed gender participants with different levels of qualification. Two focus groups comprised seven older members of the public who had the opportunity, prior to this study, to try SPHERE technology in their homes for eight to twelve months. The other two focus groups comprised six older members of the public who had never been in contact with SPHERE technology before. Focus groups were held at the SPHERE house to give participants the opportunity to visit the house and see the technology in situ, which meant that discussion was focused on real-world examples. Each focus group lasted about two hours and included a comfort break for refreshments and light lunch. The researcher who facilitated the groups (the first author) worked to ensure that all voices were heard, and that each person could share their views and experiences. Participants had the opportunity to seek information from one another and to feel at ease in sharing any challenges or issues with technology, and they said that they found the focus groups to be pleasant and interesting. Participants received clear details of where and when each focus group would take place and how long it would last. Participants who travelled to attend had their travel expenses reimbursed.

The focus group activities were divided in three phases:

1. Phase 1 (20 minutes): At the beginning, the researcher welcomed participants, explained the purpose and context, and made introductions. Participants could ask questions or clarify any concerns before signing the consent form to participate in the study. One copy of the informed consent form was given to participants and a second copy was kept with the researcher and stored securely on University premises. Participants were informed that audio-recording would be used for data collection and provided consent to this.
2. Phase 2 (40-60 minutes): New participants were shown the sensor prototypes distributed in the SPHERE house and the researcher explained the purpose and the functioning of these sensors to them. SPHERE participants who already have the technology installed at their houses were asked to describe their understanding of each sensor. The participants were asked to: i) discuss freely their opinions about the technology, ii) express any concern they have, iii) share any experience using similar technology, and iv) discuss pros and cons of this kind of technology.
3. Phase 3 (30 minutes): SPHERE and wearable technology was used to provoke discussion about privacy and safety and how to address these concerns.

Audio-recordings of the focus groups were sent to an approved specialist company for transcription. For brevity, we use 'SHP' to indicate people who were living in smart home (Smart Home Participants) and NP (Non-Smart Home Participants) for people who did not have SPHERE technology installed in their homes and so were seeing the technology for the first time during their visit to the SPHERE house.

3. Findings

The focus group transcripts of NP and SHP were analysed using inductive thematic analysis (Braun and Clarke, 2006). The coding and development of themes was conducted by the first and the senior author together. We conducted ongoing data meetings in which the material and the analysis, including coding and then thematic development, were discussed and refined. To do so, we read and re-read the transcripts and then assigned codes to the data and grouped these codes into themes and categories. The codes were developed inductively from the data and the analysis was discussed between the first and last author to refine the interpretation and development of the themes (Barbour, 2003). As analysis progressed we began to find that the same themes were recurring and as such we assessed the sampling and data collection and concluded that we had achieved an appropriate degree of saturation (Guest et al., 2006). Based on the codes, we grouped the data and themes into different categories as shown in Figure 1 below. First, we present separately specific findings that emerged from the focus groups of SHP (Category 1) and could not be compared to any of NP findings, then we analyse systematically the common findings between the different groups and discuss similarities (Category 2) and differences (Category 3).

Figure 1: Findings categorisation

3.1. SHP specific findings

Four themes were specific to people who had experience of the SPHERE system in their own homes and could not be compared to any of the NP findings. Over time and with use, participants seemed to request more interaction with the system and attached more importance to aesthetics and positions of the sensors. They were not always able to remember the functionalities of the different sensors and some of them found it challenging to tell their visitors that they were entering a telemonitored house. Table 3 summarises the findings that were specific to SHP.

SHP Specific findings	Detail of the findings
Towards more interaction with the system	Participants expressed interest in receiving information from the different sensors as well as a desire to be informed of who would be able to access data. The way in which the system can best communicate the information was a source of concern for them.
Aesthetic appeal and sensor position	The SHP were particularly focused on the aesthetics of the smart home technologies.
Curiosity about the system	SHP were curious to know about each sensor in detail, how the data would be analysed, and how a decision to send an alarm would be made by a future system.
Need for information	SHP asked for guide books for the smart home. However, all had been provided with guide books at the beginning of their involvement in the study. Their request indicates that they were in need of further guide book style information.
Making visitors aware of the smart home	Some participants had not been turning off the monitoring system or asking visitors to provide their consent.

Table 3 Summary of SHP specific findings

3.1.1. Towards more interaction with the system

Participants described interest in receiving information from the smart home system as well as a desire to be informed of who would access data.

SHP3: I am just looking at a blank face all the time [when looking at the screen on the Genie interface].

SHP4: My grandchildren saw it [the Genie Interface] and said, 'Wow!' I said, 'It doesn't do anything else.

SHP1: What we've got at the moment is purely passive, taking in information. It's not giving us information.

In the present study, we did not aim to evaluate the "Genie" interface as it was still in development. At the time of the study it functioned to allow participants to control data transfer and to check the level of the wearable battery. Instead of evaluation, we used the Genie to trigger discussions and elicit participants' views about what they would wish to have access to in any future smart home technologies.

In addition, a future system is likely to be more interactive. The way in which the system can best communicate the information to older people is ripe for investigation, as illustrated by the following quotation:

SHP3: But if you're saying to them, 'Right, you have to do your exercises.' I can see a Big Brother way of saying, 'It's 10 o'clock. Everybody do their exercises.

3.1.2. Aesthetic appeal and sensor position

Some of the SHP said that they would want sensor technology in their home to be more aesthetically pleasing. They also queried the position of the sensors. SHP thought that placement of sensors depended on the user's house size and attachment to their homes. This may be a major

factor in whether smart homes are acceptable. Older people may have a strong attachment to their homes, having lived in their homes for many years.

SHP2: People are very sensitive about where they want things put in their own house ... it hadn't really been taken into account that you might not want to have a camera or not.

SHP1: I feel there are quite a lot of things around the house but again, it doesn't impinge on my consciousness much; certainly not aesthetically.

SHP7: I am not keen on the one in the bathroom to be perfectly honest.

SHP4: I think it will depend on the personality and the house.

3.1.3. Curiosity about the system

A) Curiosity: Although SHP had experienced smart home technology for more than eight months, they still had many questions to ask about the SPHERE technology when they visited the SPHERE house for the focus groups. Some participants seemed to have clear understanding and knowledge of the functionality of most of the sensors, but many were unable to articulate the functions of the sensors, even though they had received this information about this when the system had been installed in their homes. The visit to the SPHERE house gave participants the chance to ask questions and we found that they were curious to know about each sensor in detail, how the data would be analysed, and how a decision to send an alarm would be made by a future system:

SHP4: Oh, I didn't know you can tell how much we were using water. I thought it was just signaling that we were using it.

SHP5: That is only just to monitor the humidity and the movement.

SHP7: Oh, is it? You know, are you sure?

SHP1: Does it show the number of people in the room as well as whether they're moving?

SHP6: How does the artificial intelligence decide when it is sufficient to trigger an alarm?

In addition, two participants said that they sometimes lost the wearables:

SHP3: I've lost two of these [wearables] because I can't remember where I've put them. They show up about a week later and then I have to keep wearing.

They suggested that a future smart home system could send some sort of prompt to help them find the wearable when misplaced.

NP who were visiting SPHERE house for the first time and who had received explanations about each sensor at the visit were able to discuss the functionality of the sensors with more ease than the SHP.

B) Need for information: Lack of instruction and guidance can be a barrier of technology adoption by older people (Vaportzis et al., 2017). Ageing can be accompanied by some visual or cognitive changes, which can vary between individuals. Participants described their interest in reading and learning about new technology, which they related to their familiarity with books as a ready source of information:

SHP3: My biggest problem is I forget and so every once in a while, I get an email saying, 'Can you charge your wearable?' Sometimes I remember how to do it and sometimes, I don't and they have send me a little diagram. I think I probably do need a proper little book, particularly for people of my generation and older who are used to pieces of paper and books; if it doesn't work or how it works, so that you've got something to look at and also to give other people to reassure them about what it's doing.

As the participant proposed in the previous quotation, an instruction leaflet or guide book is essential to improve the usability of smart home technology. Provision of a guide book in printed format provides clear information and is accessible. Such a guide book can include information about risks and benefits as well as practical guidance to the system. SHP were all given guide books at the beginning of their involvement in the study, although our study indicates that they may have not continued to use these over time.

3.1.4. Making visitors aware of the smart home

For ethical reasons it is appropriate that visitors to a smart home are made aware that they are entering into a space that has monitoring technology in place. However, SHP found that ensuring visitors' awareness and understanding could be challenging for a variety of reasons and some participants had not been turning off the monitoring system or seeking consent of visitors. Others said that they turned off the system when they had visitors or had asked them to sign a consent form, provided by the SPHERE study, stating that they agreed to be monitored during their visit.

SHP3: Actually, most people assume it's something to do with home security, I think, or something like that. I often say, 'It's only monitoring me and not you, so don't worry about it.' I've never turned it off.

SHP1: When people just come normally, we just turn off the system.

Living in a smart home triggered this new behaviour, which can only be observed in the post-implementation phase.

3.2. Concordance between NP and SHP

Our thematic analysis identified five key themes, with some subthemes in which there was concordance between NP and SHP: (1) Technology failure, feasibility and affordability, (2) Impact on human relationships, (3) Engagement and competencies of those who provide monitoring, (4) Gradual introduction of smart home technology, (5) Expectations and recommendations. We discuss each of these themes in turn. SHP and NP' quotations are presented to illustrate each theme. Table 4 summarises these findings.

NP and SHP findings	Detail of the findings
Technology failure, feasibility and affordability: Concerns and familiarity with technology	Both NP and SHP raised technical concerns relating to the system and many demonstrated their familiarity with technology.
Technology failure, feasibility and affordability: Concerns about affordability and public policy	Most of the SHP and NP expressed some reservations about the affordability of the smart home technologies. They questioned how this technology would be financed and rolled out in the future.
Impact on human relationships: Socialising outside the home	NP and SHP discussed the potential impact of the smart home technology on socialising and related loneliness and activity.
Impact on human relationships: Burden on others	SHP and NP did not want to be monitored by their children or family members in order not to be burdensome.
Impact on human relationships: Replacing humans	SHP and NP believed that smart home technology should never replace carers or social interactions but could facilitate engagement with carers and create new opportunities where they can meet new people.
Engagement and competencies of those who provide monitoring	Some NP and SHP expressed concern about the level of engagement and competencies of people who will monitor their health status, when receiving an alert.
Gradual introduction of smart home technology	SHP and NP wished to choose the functionality in relation to their own needs, would not necessarily want the smart home technology as a complete package and instead would value gradual introduction.
Expectations and recommendations	SHP and NP had many positive views about smart home technology and proposed additional functionalities that they would find useful, depending on their individual needs.

Table 4 Summary of findings showing concordance between NP and SHP

3.2.1. Technology failure, feasibility and affordability

This category contains two themes: 'Concerns and familiarity with technology' and 'Concerns about affordability and public policy'.

A) Concerns and familiarity with technology. NP and SHP raised technical concerns relating to the system, including in relation to how it would monitor more than one person, levels for an alarm and ensuring that the system is provided with sufficient information about a person's presence or absence from the home.

NP2: I can see how it all works in a home for a person by themselves, but what if there's more than one person in the house, how does it know who is who?

SHP6: But we know that one of the big problems about analysing this sort of data, is that you've got to determine at what level you trigger the alarm.

SHP4: The new factor is, artificial intelligence is and the scope for mega data processing is a very new development.

NP3: If I go out to the shops and I have an accident and I'm taken to hospital ... or maybe you have to tell the technology I am going on holiday [to justify the user's absence].

SHP2: Can you imagine the number of false positive triggers being set off.

Participants were aware that monitoring technology was available to purchase. They spoke about plug-in devices (usually kettles) that send signals when changes in routine are detected and discussed relatives and friends who used personal alarms, reflecting on advantages and inconveniences. Most of the participants had tablet computers and 10 out of 13 had smart phones, which they used to go online and to keep in touch with family members and friends. Some of them used the phone's reminder function or apps to do so.

NP2: I have an app on my phone that tells me I've got to take my medicine.

During focus groups many participants used technical or alternative words to describe some sensors even though the sensors were introduced in non-technical language. For example, some described the “Genie” interface as a “tablet” and the “silhouette sensors” as “cameras”:

SHP4: The Genie?

SHP3: No, I call it a tablet.

SHP1: iPad.

SHP3: Yeah, a tablet.

The familiarity and regular use of technology echoes Ofcom’s report into the UK’s population’s technology use, which noted: “striking growth in older people’s use of technology between 2015 and 2016”: 48 per cent of over-75s were using tablet computers and 39% of people aged 65-74 were using a smartphone in 2016 (Ofcom, 2017). However, not all participants used such technology, for instance one SHP described herself as “technophobe”, saying that digital technology “is going to be just wiped [out]”. She did not have a smart phone and wrote letters instead.

B) Concerns about affordability and public policy. Participants questioned how home technology would be financed and rolled out. They discussed how to make the technology more affordable and accessible to individual older people as well as for care systems more widely. Cost of the technology remains a significant barrier for many older people and has an impact on their ability to adopt technology.

NP2: I can’t envisage anyone paying for it to be done unless there was some commercial use ... but when it’s used in real life, no-one will have the money to pay someone to look at it.

SHP5: Trouble is nobody’s got the money to pay anyone to look over the CCTV camera ... and it’s the same with this, they won’t have the money to pay.

In three focus groups, people questioned whether recommendations would translate into public policy and related actions. For instance, this is shown in the quotation below, from a participant who had worked in the policy arena:

NP3: I have worked in the public sector and the independent sector in terms of policy and we’ve seen, well I was asked to write many reports for the council and I came up with lots of obvious conclusions and I presented it to councilors and they said oh yes, very interesting, and nothing was ever done, so that’s why I think...

Despite these misgivings, participants still thought that smart home technology will enter the market:

SHP1: You can just see, it will become a commercial thing you know.

3.2.2. Impact on human relationships

NP and SHP all placed emphasis on the potential impact on socialising outside the home, place burden to others and replace humans.

A) Socialising outside the home. While smart homes may promote safety for people who have health issues, some participants suggested that they can decrease their activity level and increase their loneliness. In their opinion, people need real in-person interactions to socialize and complete daily tasks.

NP2: They’ve developed technology so far that they see fewer and fewer people now because everything is robotised, they even have robots that talk to them when they feel lonely! It makes them see fewer and fewer people [giving example of Japan].

NP3: I know that is very scary.

SHP7: Yeah, I think it keeps them more at home, the technology, you’ve got to get out, whatever the weather.

SHP6: Buy a dog.

SHP5: They’ll get you out, much better than a monitor!

B) Burden on others. Other research indicates that older people decide to move to residential care in order not to become a burden to other family members (Stilwell and Kerslake, 2004). Concern about the possibility that adult children of family members may be burdened, either emotionally or practically, was a reason why SHP and NP would not want to be monitored by their children or family members.

SHP2: I’ll share that with them in my own time. I don’t want them to be dipping in or even feeling that they haven’t dipped in and they feel guilty. I just don’t want it to introduce guilt to my children because they didn’t know what was going on. I want it to be under my control.

SHP2: you do not want them to be worrying unnecessarily, do you? ... make them feel guilty.

NP2: I mean if I got so old I wouldn’t want my children worrying because the worst thing that I remember about my parents getting old was the background worry all the time.

Others thought that their children or relatives were too busy or are not willing to help.

NP3: I trust my son not to misuse it, I mean, it might be a way of keeping in touch! Getting him to respond!

NP2: They are very busy aren’t they?

SHP6: Oh, they don’t want to know.

SHP7: They wouldn't want, no, they don't want to be bothered with us.

D) Replacing humans. SHP and NP thought that a smart home system had the potential to help older people when carers are away or by sending reports or alarms. However they also thought that technology should never fully replace social interactions but facilitate and create new opportunities where they can meet new people or stay in contact with their friends and neighbours.

NP2: An addition to the fact that a warden can only visit people once a week, depending how many people.

NP2: I mean I think these things if they are used to enhance and monitor human performance they are better if they are used to substitute for human performance and it's the humans who are supposed to check on the technology, that's the way round these things go, but it's much better for the humans to do the caring and the technology to do with the tech and safeguards you know but it won't be like that.

SHP6: I think I prefer to spend money on a human being.

NP3: I think what worries me is that if it's going to replace human beings going and checking on people then that's not good entirely, but it has its uses technology, sure.

SHP3: but I wouldn't want it to replace human beings.

3.2.3.Engagement and competencies of those who provide monitoring

SHP and NP also spoke about the need for trust in the level of engagement and competency of those who will monitor their health status through information collected by any smart home system. When talking about such systems they drew on their sense of what it would be like if others were monitoring the health status of the participant, which the SPHERE system had not been designed to do.

NP2: Even if there were people paid to look at it [the information], they'd be reading their books and playing computer games

SHP6: We know that human beings, don't react very well. That's the problem.

Some expressed concern about the speed in which a person monitoring the information might react if a response was needed, for instance they suggested that people are much slower than machines and can be distracted easily. Despite the suggestions in the literature that older people may be more trusting than their younger counterparts (Boise et al., 2013), participants in our study expressed concern about competencies and engagement of people monitoring their health status. Mistrust can have negative consequences on the acceptability of monitoring technology and needs to be taken into account when designing smart home technology.

SHP and NP alike all expressed some mistrust in the speed of a person's reaction to an alarm, but SHP, as detailed in the paragraph 3.3.1 did not describe any worries about data security or in having sensors at home.

3.2.4.Gradual introduction of smart home technology

SHP and NP thought that people may wish to customize functionality and might not necessarily want the smart technology as a whole or complete package:

NP5: I don't think I would want all of this technology. I wouldn't want movement sensors and everything going on, but I could say that there are points in my house, like maybe the stairs, that I would like to say ... if I fell down the stairs, it would trigger something. I don't see the need to monitor me moving about the house.NP5: You identify the need and then say, 'I would like somebody to keep an eye on that bit' or 'Remind me of that.' I can't see me having the whole fitted out with all this technology.SHP2: If I want my children to check that I'm not lying in a heap at the bottom of the stairs, I'd just need the camera, don't I? It's not rocket science. Why do we need this complicated system?

Our study found that smart home technologies may work best if designed to enable gradual adoption by older people. Key to this is provision of the ability to select the features needed and then to add further features in the future. Older people wish to have control over the transmitted data, such as the ability to turn the technology off or pause it for a short period.

3.2.5.Expectations and recommendations

SHP and NP also discussed the utility of the smart home technology for people with disabilities or after hospital discharge. Most participants did not think that they needed the technology at the moment but would wish use this technology if they became older or frailer.

SP6: I mean it's very specific for people with particular disabilities.

SP7: Cause of health issues, yeah.

SP3: I suppose that if I was going to have it there all the time, I would think there needs to be a reason; either I'm falling regularly or I'm becoming very forgetful ... I think that diabetes might be an area that they could look at because there are so many diabetics.

NP5: I think some of it would have been useful.

NP4: I suppose I'd like to think that I'm still young and I don't need the technology.

NP3: Yeah I pick and choose.

NP1: I mean I don't know, at the moment I wouldn't want to live in a smart home because I think I'm quite capable of looking after myself but ... There may come a time when I think it would be useful.

NP5: I think some of it would have been useful ... I mean the idea of a movement sensor is quite good really.

NP2: But you probably wouldn't get this until you were housebound.

Participants thought that well-designed smart home technology could improve social interaction, increase levels of exercise, or improve lifestyles. They thought that it was crucial that technology should be customized based on their individual needs. SHP and NP had many positive views about smart home technology and proposed many functionalities that they would find useful, depending on their individual needs. They also tried to identify factors that would enhance the acceptability of smart home technologies. In Tables 6 and 7, we summarize some of the desired features and functionalities that participants thought would encourage older people to adopt smart home technologies.

Expectations	
1.	Design better retirement accommodation and control the equipment and appliances at home, locally or from distance, such as switching the heat on before getting home.
2.	Monitor vulnerable people (parents, friends or neighbours). Helping them with their activities daily living. Preventing falls and assisting with visual and hearing impairments.
3.	Remind them of where they put their car keys, of their appointment times, when their medication is due and when they need to change batteries of alarms. Highlight when they have left the water running, an open window or door, etc.
4.	Detect moldy foods in the fridge.
5.	Trigger social activities and exercise to raise the activity level.
6.	Facilitate an early discharge from hospital and reassure family members when there is need.
7.	Manage their health status and offer them the opportunity to monitor their life parameters, blood sugar, blood pressure and different other parameters chosen personally depending on the personal needs.

Table 5 Participants' expectations

Recommendations	
1.	The technology must be unobtrusive. Older people must be able to know how, where and what kind of information is transmitted.
2.	Older people need to see the benefit of the technology, to be able to customize it and to have control over it.
3.	The technology needs to be able to be 'self-taught'. Any new technology needs to promote communication, exercise and social interaction
4.	Family members, children, and carers may influence older people's adoption of new technology and could be included in discussions about it.

Table 6 Participants' recommendations

3.3. Discordance between NP and SHP

There were two main themes in which the views of NP and SHP were discordant. People who had experienced smart home technology for long periods of time were less aware of the functionality of each sensor. Furthermore, they presented fewer concerns about privacy, trust, and usability. Instead, they expressed more concerns about the utility of the system. Table 7 summarise the findings in which there was discordance between NP and SHP.

NP and SHP findings	NP	SHP
Increasing household vulnerability vs no privacy concerns	NP raised privacy concerns and focused on the extent to	Over time and with use, concerns about privacy seemed to disappear

	which technology might heighten vulnerability of the household.	and even some of them asked for the technology to collect more information. SHP appeared to have relationships of trust with the researchers.
Intrusive technology vs unobtrusive technology	Most of NP thought that the technology in the SPHERE prototype house was too noticeable or intrusive.	Most of the SHP have forgotten about the sensors after few weeks of installation at their homes. They found this technology to be unobtrusive.

Table 7 Summary of discordant findings between NP and SHP

3.3.1. Increasing household vulnerability vs. no privacy concerns

Although NP raised concerns about the sharing and security of data collected by smart home technology, concerns about privacy seemed to disappear once people had experienced the SPHERE technology for few months. SHP seemed to become comfortable with the technology and some even asked for it to collect more rather than less information:

SHP4: I'm not doing anything I'm ashamed of' [not worried of being monitored].

SHP5: No, I've not got, when you think about it, no I've got no concerns at all. My only concern would be the other way round I think it's not intrusive enough.

SHP3: I would not put any condition on it at all [to have a silhouette sensor in the bathroom].

SHP1: I have no concerns at all. As some of the others have said, you can see quite a few things around the house which I don't find too intrusive or aesthetically annoying.

Related to this, NP particularly focused on the extent to which technology might heighten existing vulnerability of the household, for instance to potential burglars or hackers.

NP1: It's all intelligent data which they collect and all this data it is so easy to identify the vulnerable people and I think that's where my problems would be ... I mean if it got in the wrong hands then what would happen is lot of people would realise that this person is vulnerable and lives on his own and you know what happens with vulnerable people!

Other NP confirmed:

NP3: So if you have this technology in your house, eventually ... and it measures many things ... what's to stop somebody developing a van that goes round detecting all these vulnerable people, like TV license detector vans.

NP4: For the data to be misused.

Participants provided the example of their receipt of marketing materials from companies as evidence that their personal data was already in ways that they were not comfortable with:

NP3: I turned 50 and I got Saga brochures for holidays, no, because somebody somewhere...

NP2: I get funeral plans now!

NP3: Yeah! so yeah somebody somewhere knows, they know because of the census.

This contrast between NP and SHP may reflect an association between trust and privacy. Over the months of their use of the technology, SHP appeared to have developed relationships of trust with the researchers. This led to reduced concerns about privacy and confidence that information collected by the smart home system would be well protected.

SP4: No, I don't [have any concerns]. It doesn't interfere with me. Any information they've got [the researchers], I'm quite happy for them to have. I know that it won't be used for an ulterior motive. Nobody would bother with it, unless it was beneficial. I've got no problems with it.

Another justification that may explain the difference between NP and SHP regarding privacy concerns is that some SHP were unable to articulate the functions of the sensors, as shown in section 3.1.3. At the beginning of their visit to SPHERE house, SHP and NP were provided with information about the sensors and had the opportunity to ask questions about them. While discussing any considerations that they might have about privacy, all the participants were aware of the sensors' functions. This indicates that it was their experience of living with the sensors (or not doing so) rather than awareness of the sensors functions that accounted for the difference between SHP and NP.

3.3.2. Intrusive technology vs unobtrusive technology

For NP, usability of the technology was a concern, which echoes findings in other studies (Peek et al., 2015). They thought that the technology in the SPHERE prototype house was too noticeable or intrusive. In part this relates to the SPHERE prototype house, in which sensors in the

SPHERE house are clearly visible to enable technical developments. When installed in people's own homes, SPHERE technology is more hidden.

NP4: [user comparing smart home technology to smart phone] ... I don't think people have been educated to use mobile phones. It's a self-taught technology.

NP6: I agree ... I think I would find it far too intrusive at the moment. Particularly because there has been so much concern about data and what's done with it, I do think that's really important. We have to be very clear about protection of people's privacy and who sees that information and how it's controlled.

Although participants noticed the need for enough electricity sockets for the technology, most SHP had forgotten about the sensors after few weeks of the installation at home and found them to be unobtrusive. Some found the wearable uncomfortable, particularly if they did not usually like to wear a wristwatch. They found the home technology unobtrusive and did not make any change in their lifestyle or daily behaviour or activities even for whom who suggested that they would want smart home technology to be more aesthetically pleasing. This is illustrated by the participants SHP5 and SHP1 in 3.3.1 section and in the following quotation:

SHP4: Mine is in a chest of drawers in my conservatory and I don't notice it at all. I certainly don't notice it's there. None of the things interfere with me at all or anybody else.

There was one SHP who had a different view, finding the technology intrusive and preferring not to have the silhouette sensors at home. This individual referred to the silhouette sensor as a "camera":

SHP2: I don't think I was quite prepared for quite how intrusive some of this stuff was. Maybe it's the fact that the people putting it in don't necessarily have discretion about where in the room you want it...

4. Discussion

There is an absence of post implementation studies with older participants, who consider themselves independent and non-vulnerable, to investigate how perception of smart home technology changes over time and with use. Previous research has studied the views of selected groups of older people often in experimental contexts and who are mainly frail, with high care needs or recruited from a retirement community or home cares. These factors are likely to influence views about utility of the new technology. Our research is novel because it has investigated older people's perceptions of smart homes while they are still independent and residing in their own homes. Furthermore, we sought to compare perceptions of people who had experience of the SPHERE smart home platform for eight to twelve months with views of people drawn from the community. The aim of this research was not to evaluate SPHERE technology, which is still in the development and refinement phase. Instead, the SPHERE technology served as means to explore the experience of smart homes and, for those recruited from the community, to explain the concept of smart homes to elicit their expectations and preferences.

4.1. NP and SHP perceptions of smart homes

On the whole, NP and SHP expressed positive views about smart home technology and were fascinated by its potential to support older people. However, whether in the NP or SHP groups, most did not think that they needed smart home technology themselves, but all would be willing to use it if and when they became older or frailer. Our findings were consistent with the literature (Cosco et al., 2018; Morris et al., 2014; Peek et al., 2014) and can be explained, as the participants suggested, by the fact that older people are not always aware or willing to acknowledge changing needs until somebody else, such as a family member or a carer, presents the change to them.

This resistance to smart home technology is also related to societal views about ageing, and older people value their social image and autonomy (McNeill et al., 2017; Peek et al., 2015). All participants suggested that monitoring technology could be stigmatizing and signify frailty. This reflects wider societal views about technologies that are specifically designed for older people (Wu et al., 2015). While most participants would not wish to have a functioning smart home at the moment, they proudly described having smart phones, tablets, smart utility meters and similar connected technologies. These smart gadgets, which are designed for the general public, serve to increase confidence in their ability to learn and helps them to feel more rather than less capable. Conversely, technology explicitly described as for the benefit of older people is seen as less acceptable. We believe that technology that is described as designed "for all" would be more attractive and possibly exciting to older people.

As found in other studies (Callejas and López-Cózar, 2009; Portet et al., 2013) another concern about smart home technologies was that too much assistance could increase older people's dependence on others and decrease autonomy. Participants preferred to maintain their levels of physical and cognitive activity and looked forward for technology which can help to maintain or increase these as well as connect them with others in their social worlds.

Some SHP and NP said that living in a smart home was more acceptable if they were able to customize the technology to select the functionality and features. They did not want to have the smart home technology as a complete package. Related to this, participants wanted their concerns to be considered; concerns that were shared by all participants in the study were impact on socialization outside the home,

burden on others and replacing human interaction. Trust in smart home technologies and monitors is another key factor in the adoption of smart home technology (Ziefle et al., 2011).

Participants considered the future, including the affordability of smart home technology. For instance, they thought that SPHERE technology would be important technology of the future, and they also wondered about the cost to individuals and the need for commercial or business involvement. They also wondered about whether this type of technology would be more available to wealthy people, and a signifier of wealth and luxury. This perception was described by Wilson and colleagues as a significant barrier to technology adoption (Wilson et al., 2017). A strong sense of social responsibility and desire for connectedness appears to be one of the reasons why older people reject smart home technologies. They were concerned that this technology will take the place of carers or nurses. Another concern, which can be a barrier of technology adoption, is that people are concerned about the whether there would be competency in the human input required to assess the information collected by the home technology.

This suggests that making smart home technologies appealing for older people means ensuring that it address their needs, will not replace social interactions, does not substitute carers and nurses, and does not make them feel old. If possible, this technology needs to facilitate new social and community events where they can meet people. The relationships between older people and their monitors need to be based on trust.

4.2. Change over time in views about smart homes

Experience of living in a smart home influenced views about the technology itself. One of the considerations in relation to smart home technology, highlighted in other literature, is privacy and security of transmitted data (Coughlin et al., 2007; Demiris et al., 2004; Peek et al., 2014). While NP wanted to protect their information and to be confident that the technology would not make their household or home more vulnerable, SHP who had experienced SPHERE technology for long periods of time became less concerned by privacy issues as time passed. Most of the SHP said that they did not feel watched by the sensors and that they forgot about the sensors' presence after a while. Our findings extend some previous research (Demiris et al., 2004; Lie et al., 2016) and contrast another (Boise et al., 2013). The participants in Boise and colleagues' work were frequent users of computers and the authors described them as having "sufficient knowledge to fully understand the risk of sharing personal data" (Boise et al., 2013). Furthermore, in contrast to some previous studies (Chernbumroong et al., 2010; Chung et al., 2016; Hawley-Hague et al., 2014), usability was not a major concern for SHP as the SPHERE system is fully automated.

There may be a need to consider how best to balance the need for understanding and awareness of the presence of the technology with comfort and ease in the home. This would ensure that older people are protected and remain fully informed. This contrast between NP and SHP may be related to their different experiences of smart home technology as we noted that SHP described relationships of trust with the research team that had deployed and serviced the SPHERE system in their homes, which provided them with confidence that their data would be curated appropriately. This finding is crucial and appears to explain discordant views between NP and SHP. This may be transferable into a non-research context, in which ensuring high levels of trust in the service provider would be key to acceptance. Our findings extend the work of Lie and colleagues who believe that the system depends on the relationship between older people and their 'monitor' (Lie et al., 2016).

We found that after few weeks of the installation at home, with the exception of one person, most SHP had forgotten about the presence of the sensors and found the technology to be unobtrusive and that it did not cause them to make any changes in their everyday behaviour. The views of NP were in contrast to this as when they saw the technology in situ at the prototype house, they found the technology intrusive and too noticeable. While in part this can be explained by the fact that in the prototype house the sensors are clearly visible to enable technical developments, this can largely be explained by the relationship between duration of use and feelings about the technology and shows that acceptance increases over time and with use.

4.3. Research insights

For older people, systems that are designed to remotely monitor their health and activity patterns require careful design to ensure their acceptability and utility. Our study found that smart home technology may work best if designed to enable gradual adoption. Key to this is provision of the ability to select the features needed and then to add further features in the future. Older people wish to have control over the transmitted data, such as the ability to turn the technology off or pause it for a short period. They also wish to participate in decisions about sensors' placement and aesthetic. The ability to pause the technology may satisfy the need for "emotional release", which has been described by others as vital for the wellbeing of users (McNeill et al., 2017).

Our study found that older people may not wish to share information about their health status with family members or friends for fear of burdening them (Robinson et al., 2009). They are usually more comfortable sharing this information with health professionals or carers. Designers should respect such preferences, and it may be prudent to provide older people with the option to select or change their choice of the trusted contact. Affordability and implications for the jobs of carers were concerns in this study as in other studies like (Bostrom et al., 2013). Carers and family members are part of the decision process and can promote telemonitoring technology acceptance by older people.

If sensors cannot be hidden from view inside the home, then careful attention should be paid to their appearance. Although SHP became accustomed to the “silhouette sensor” over time, there was still the potential for it to seem intrusive, this was the case for one participant, and for others it took time for them to become accustomed. It is likely that the appearance of the sensor was the reason for the sense of intrusion, as it was shaped somewhat like a camera despite its ability only to generate black-and-white silhouettes. Future designs could reflect the need for a sensor to look different to a camera.

As discussed by Herczeg (Herczeg, 2010), interaction with smart home technologies is a key factor in technology adoption. The more automated the system is, the more the interaction is essential, but some users would prefer a completely automated system and would trust the technology more easily than others. Such “active” users need to interact with the system and to choose when and with whom to share the data, achieving this serves to increase their autonomy (McNeill et al., 2017).

To improve the acceptability of smart home technology to older people, it must be designed as an addition and not a substitute for people. It is essential to raise awareness of its usefulness and focus on its potential to promote independence, social interaction and safety. Control is important and it is vital to “enable the user to present the image that they want to convey to others” (McNeill et al., 2017). As described by Burrows and colleagues, smart home technologies should be reliable and allow personal control of data and information flow (Burrows et al. 2018). Accurate and robust technology can help to ensure that people think that their data is secure and that they are protected. Furthermore, ensuring that those who are making use of the data in telemonitoring tasks are fully trained helps with confidence and trust.

Designers would benefit from looking at older people in the same way they look at themselves, which participants in our study described as “young in our mind”. Although health monitoring may be of crucial importance, social life is equally important and connectivity may be of benefit to health, although more research is needed (Morris et al., 2014; Peek et al., 2014). In our focus groups participants were clear that smart home technology may be more acceptable if it were to offer smart ways to have fun, play online games, do shopping, connect securely with other people, help other members of the family, as well as other social functions.

4.4. Limitations

We conducted the study with participants from one UK city and many of the participants had a high level of educational attainment. We are mindful that future research could seek to include people living in a variety of contexts, for instance people living in rural settings that might be more isolated may have different views about the value of smart home technology for older people. Furthermore, although the education level may not provide a ‘representative’ sample of the generation, their experiences may foretell the experiences of future generations who will age with more experience of technology and possibly higher levels of educational attainment.

In addition, the sample size of 13 people is modest by quantitative standards, but for a qualitative approach the size of the sample and the use of small focus groups provided us with the chance to achieve depth and “information power” (Malterud et al., 2016). Information power was also operationalized by attending to the point at which saturation was reached (Guest et al., 2006) which was enabled through the team and expertise-based approach to analysis (Barbour, 2003). Together, this gives us confidence that the findings are robust and provide insight into views of older people that are likely to resonate with others.

5. Conclusion

Our study responds to an absence of research exploring independent older people’s views and experiences of smart home technology over time and with use. We have presented a systematic analysis that compares views of six participants recruited from the community with the views of seven who had experience of living with smart home technology within the SPHERE study. Our findings may inform future research, which could explore how best to raise awareness of the functionality of the system. Future research should also identify and characterise expectations of health care professionals and caregivers. Immediate next steps could include design of a user-system interaction, including identification of the information that older people would most like to have to and to share with others.

Finally, our study provides insights that can help in the design of technology that would be acceptable to older people living independently. This has implications for how technology can be designed and produced to enable maximum appropriateness and acceptability to enable and facilitate ageing in place.

6. Acknowledgments

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References

- Baecker, R., Sellen, K., Crosskey, S., Boscart, V., Barbosa Neves, B., 2014. Technology to reduce social isolation and loneliness, Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility, Rochester, New York, USA.
- Barbour, R.S., 2003. The newfound credibility of qualitative research? Tales of technical essentialism and co-option. *Qualitative Health Research* 13, 1019-1027.
- Barrett, J., Kirk, S., 2000. Running focus groups with elderly and disabled elderly participants. *Applied ergonomics* 31, 621-629.
- Bock, C., Demiris, G., Choi, Y., Le, T., Thompson, H.J., Samuel, A., Huang, D., 2016. Engaging older adults in the visualization of sensor data facilitated by an open platform for connected devices. *Technology and Health Care* 24, 541-550.
- Boise, L., Wild, K., Mattek, N., Ruhl, M., Dodge, H.H., Kaye, J., 2013. Willingness of older adults to share data and privacy concerns after exposure to unobtrusive in-home monitoring. *Gerontechnology* 11, 428-435.
- Boldy, D., Grenade, L., Lewin, G., Karol, E., Burton, E., 2011. Older people's decisions regarding 'ageing in place': A Western Australian case study. *Australasian Journal on Ageing* 30, 136-142.
- Bostrom, M., Kjellstrom, S., Bjorklund, A., 2013. Older persons have ambivalent feelings about the use of monitoring technologies. *Technology and Disability* 25, 117-125.
- Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 77-101.
- Burrows, A., Coyle, D., Gooberman-Hill, R., 2018. Privacy, boundaries and smart homes for health: An ethnographic study. *Health and Place* 50, 112-118.
- Callejas, Z., López-Cózar, R., 2009. Designing smart home interfaces for the elderly. *ACM SIGACCESS Accessibility and Computing*, 10-16.
- Chen, K.-Y., Harniss, M., Patel, S., Johnson, K., 2014. Implementing technology-based embedded assessment in the home and community life of individuals aging with disabilities: a participatory research and development study. *Disability and Rehabilitation: Assistive Technology* 9, 112-120.
- Chernbumroong, S., Atkins, A.S., Yu, H., 2010. Perception of Smart Home Technologies to Assist Elderly People, The 4th International Conference on Software, Knowledge, Information Management and Applications (SKIMA 2010), Paro, Bhutan.
- Cho, M.E., Kim, M.J., Kim, J.T., 2013. A Smart Workspace Supporting a Healthy Life in Pre-elderly Households. *Indoor and Built Environment* 22, 280-288.
- Chung, J., Demiris, G., Thompson, H.J., 2016. Ethical considerations regarding the use of smart home technologies for older adults: an integrative review. *Annual review of nursing research* 34, 155-181.
- Cosco, T., Soar, J., Yusif, S., Elers, P., Hunter, I., Whiddett, D., Lockhart, C., Guesgen, H., Singh, A., 2018. User Requirements for Technology to Assist Aging in Place: Qualitative Study of Older People and Their Informal Support Networks. *JMIR mHealth and uHealth* 6.
- Coughlin, J., D'Ambrosio, L.A., Reimer, B., Pratt, M.R., 2007. Older adult perceptions of smart home technologies: implications for research, policy & market innovations in healthcare. Conference proceedings : Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference 2007, 1810.
- Council, B.C., 2020. The population of Bristol.
- Courtney, K.L., 2008. Privacy and senior willingness to adopt smart home information technology in residential care facilities. *Methods of information in medicine* 47, 76-81.
- Crews, D.E., Zavotka, S., 2006. Aging, disability, and frailty: implications for universal design. *J Physiol Anthropol* 25, 113-118.
- Demiris, G., Hensel, B., Skubic, M., Rantz, M., 2008a. Senior residents' perceived need of and preferences for "smart home" sensor technologies. *International Journal of Technology Assessment in Health Care* 24, 120-124.
- Demiris, G., Oliver, D.P., Dickey, G., Skubic, M., Rantz, M., 2008b. Findings from a participatory evaluation of a smart home application for older adults. *Technology and health care* 16, 111-118.
- Demiris, G., Rantz, M., Aud, A.M., Hussam, A.A., 2004. Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study. *Medical Informatics and the Internet in Medicine* 29, 87-94.
- Diethe, T.H., Mike.Kull, Meelis Nieto, Perello Miquel. Sokol, Kacper. Song, Hao.Tonkin, Emma L. Twomey, Niall. Flach, Peter., 2018. Releasing eHealth Analytics into the Wild: Lessons Learnt from the SPHERE Project, ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. Association for Computing Machinery (ACM), London, pp. 243-252.
- Georgiev, A., Schlögl, S., 2018. Smart Home Technology: An Exploration of End User Perceptions. *Smarter Lives Conference in Innsbruck, Austria*. .

Ghorayeb, A., 2007. ECOVIP: Espace de Communication Visiophonique pour personnes âgées – Conception, Réalisation et Évaluation Participative, Computer Sciences. University of Joseph Fourier, Grenoble, France, p. 212.

Ghorayeb, A., Rialle, V., Coutaz, J., Noury, N., 2006. Breaking through the walls of loneliness and isolation by means of videophony : A ubicomp orientation and a design process based on active participation of elderly people, ICADI, St. Petersburg, FL, USA, p. 33.

Giger, J.T., Pope, N.D., Vogt, H.B., Gutierrez, C., Newland, L.A., Lemke, J., Lawler, M.J., 2015. Remote patient monitoring acceptance trends among older adults residing in a frontier state. *Computers in Human Behavior* 44, 174-182.

Guest, G., Bunce, A., Johnson, L., 2006. How many interviews are enough? An experiment with data saturation and variability. *Field methods* 18, 59-82.

Hawley-Hague, H., Boulton, E., Hall, A., Pfeiffer, K., Todd, C., 2014. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: A systematic review. *Int J Med Inform* 83.

Herczeg, M., 2010. The smart, the intelligent and the wise: roles and values of interactive technologies, pp. 17-26.

Lee, L.N., Kim, M.J., 2019. A Critical Review of Smart Residential Environments for Older Adults With a Focus on Pleasurable Experience. *Frontiers in Psychology* 10.

Lie, M.L.S., Lindsay, S., Brittain, K., 2016. Technology and trust: older people's perspectives of a home monitoring system. 36, 1501-1525.

Malterud, K., Siersma, V.D., Guassora, A.D., 2016. Sample size in qualitative interview studies: guided by information power. *Qualitative health research* 26, 1753-1760.

Mann, W.C., Belchior, P., Tomita, M.R., J. Kemp, B., 2007. Older Adults' Perception and Use of PDAs, Home Automation System, and Home Health Monitoring System. *Topics in Geriatric Rehabilitation* 23, 35-46.

McNeill, A., Briggs, P., Pywell, J., Coventry, L., 2017. Functional privacy concerns of older adults about pervasive health-monitoring systems, pp. 96-102.

Mitzner, T.L., Boron, J.B., Fausset, C.B., Adams, A.E., Charness, N., Czaja, S.J., Dijkstra, K., Fisk, A.D., Rogers, W.A., Sharit, J., 2010. Older Adults Talk Technology: Technology Usage and Attitudes. *Comput Human Behav* 26, 1710-1721.

Morris, M.E., Adair, B., Ozanne, E., Kurowski, W., Miller, K.J., Pearce, A.J., Santamaria, N., Long, M., Ventura, C., Said, C.M., 2014. Smart technologies to enhance social connectedness in older people who live at home, pp. 142-152.

Ofcom, 2017. Adults' media use and attitudes.

Peek, S.T.M., Aarts, S., Wouters, E.J.M., 2015. Can Smart Home Technology Deliver on the Promise of Independent Living?, in: van Hoof, J., Demiris, G., Wouters, E.J.M. (Eds.), *Handbook of Smart Homes, Health Care and Well-Being*. Springer International Publishing, Cham, pp. 1-10.

Peek, S.T.M., Wouters, E.J.M., van Hoof, J., Luijkx, K.G., Boeije, H.R., Vrijhoef, H.J.M., 2014. Factors influencing acceptance of technology for aging in place: A systematic review. *Int J Med Inform* 83, 235-248.

Pigini, L., Bovi, G., Panzarino, C., Gower, V., Ferratini, M., Andreoni, G., Sassi, R., Rivolta, M.W., Ferrarin, M., 2017. Pilot test of a new personal health system integrating environmental and wearable sensors for telemonitoring and care of elderly people at home (SMARTA project). *Gerontology* 63, 281-286.

Pol, M., van Nes, F., van Hartingsveldt, M., Buurman, B., de Rooij, S., Kröse, B., 2016. Older People's Perspectives Regarding the Use of Sensor Monitoring in Their Home. *The Gerontologist* 56, 485-493.

Portet, F., Vacher, M., Golanski, C., Roux, C., Meillon, B., 2013. Design and evaluation of a smart home voice interface for the elderly: Acceptability and objection aspects. *Personal and Ubiquitous Computing* 17, 127-144.

Reeder, B., Demiris, G., Marek, K.D., 2013. Older adults' satisfaction with a medication dispensing device in home care. *Informatics for Health and Social Care* 38, 211-222.

Robineau, D., 2016. Ageing Britain: two-fifths of NHS budget is spent on over-65s, *The Guardian*, Uk.

Robinson, L., Brittain, K., Lindsay, S., Jackson, D., Olivier, P., 2009. Keeping In Touch Everyday (KITE) project: developing assistive technologies with people with dementia and their carers to promote independence. *International Psychogeriatrics* 21, 494.

Schatorjé, R., Markopoulos, P., 2015. Intra-Family Messaging with Family Circles, in: Neustaedter C, H.S., Sellen A. (Ed.), *Connecting Families*, Springer, pp. 57-74.

Seymour, J., Bellamy, G., Gott, M., Ahmedzai, S.H., Clark, D., 2002. Using focus groups to explore older people's attitudes to end of life care. *Ageing & Society* 22, 517-526.

Stilwell, P., Kerslake, A., 2004. What makes older people choose residential care? *Housing, Care and Support* 7, 4-8.

Tsertsidis, A., Kolkowska, E., Hedström, K., 2019. Factors influencing seniors' acceptance of technology for ageing in place in the post-implementation stage: A literature review. *Int J Med Inform* 129, 324-333.

Turjamaa, R., Pehkonen, A., Kangasniemi, M., 2019. How smart homes are used to support older people: An integrative review. *International Journal of Older People Nursing* 14.

- Van Berlo, A., 2011. Experiences with smart homes for older people. *A Friendly Rest Room: Developing Toilets of the Future for Disabled and Elderly People* 27, 19.
- van Hoof, J., Kort, H.S.M., Rutten, P.G.S., Duijnste, M.S.H., 2011. Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users. *Int J Med Inform* 80, 310-331.
- Vaportzis, E., Giatsi Clausen, M., Gow, A.J., 2017. Older adults perceptions of technology and barriers to interacting with tablet computers: a focus group study. *Frontiers in psychology* 8, 1687.
- Venkatesh, V., Thong, J.Y., Chan, F.K., Hu, P.J.H., Brown, S.A., 2011. Extending the two-stage information systems continuance model: Incorporating UTAUT predictors and the role of context. *Information Systems Journal* 21, 527-555.
- Wiles, J.L., Leibing, A., Guberman, N., Reeve, J., Allen, R.E.S., 2012. The Meaning of "Aging in Place" to Older People. *The Gerontologist* 52, 357-366.
- Wilkinson, S., 2004. Focus group research, in: Silverman, D. (Ed.), *Qualitative research: Theory, method, and practice*. SAGE Publications Ltd, Thousand Oaks, CA, pp. 177-199.
- Wilson, C., Hargreaves, T., Hauxwell-Baldwin, R., 2017. Benefits and risks of smart home technologies. *Energy Policy* 103, 72-83.
- Woolhead, G., Calnan, M., Dieppe, P., Tadd, W., 2004. Dignity in older age: what do older people in the United Kingdom think? *Age Ageing* 33, 165-170.
- Wu, Y.-H., Damné, S., Kerhervé, H., Ware, C., Rigaud, A.-S., 2015. Bridging the digital divide in older adults: a study from an initiative to inform older adults about new technologies. *Clinical Interventions in Aging* 10, 193-201.
- Yang, H., Lee, W., Lee, H., 2018. IoT smart home adoption: The importance of proper level automation. *Journal of Sensors* 2018.
- Zhu, N., Diethe, T., Camplani, M., Tao, L., Burrows, A., Twomey, N., Kaleshi, D., Mirmehdi, M., Flach, P., Craddock, I., 2015. Bridging e-Health and the Internet of Things: The SPHERE Project. *Intelligent Systems, IEEE* 30, 39-46.
- Ziefle, M., Rocker, C., Holzinger, A., 2011. Medical Technology in Smart Homes: Exploring the User's Perspective on Privacy, Intimacy and Trust, pp. 410-415.