

A Case Study of a Pilot Smart Home Monitoring System with Older Adults Living Alone in East Midlands

By Bertha MN Ochieng^{*}, Ismail Chaudhry[‡], Carol Chamley[°],
Dewy Nijhof[♦], Rebecca Ochieng[♦], Louise Rogerson[▲],
Richard Wong^{*} & Rishabh Prasad

The aim of this project was to examine older adults and their next-of-kins' experiences of using smart home technology. The technology unobtrusively monitors the older adult's physical functional ability to undertake their daily activities at home. Using a case study approach, the participants comprised three family units: three older adults with a history of long-term co-morbidities and who lived alone, along with their next-of-kin (n=4). The older adults were all female aged between 72- 82 years of age, while the four next-of-kin were all females aged between 40 and 55 years of age. Participants experiences of using the smart home technology was evaluated at three- and eight-months post-installation via in-depth one-to-one interviews with the older adults and their next-of-kin. The older adults described how the smart home sensors reduced their levels of anxiety because they were 'not feeling alone'. Likewise, their next-of-kin described how the sensors gave them an insight to their older relatives' activities of daily living, as well as the challenges they experienced. The findings highlighted the benefit of smart home technologies in terms of helping older adults and their next-of-kin monitor their daily activities, reduce social isolation, and adopt positive health and behavioural changes.

Keywords: older adults, home-sensors, functional ability, activities of daily living, intergenerational relationships

Introduction

Lifestyle or behavioural monitoring forms a subset within the wider and more general model of e-health and telecare (Brownswell et al. 2011, Peiris et al. 2018), reflecting an approach that is increasingly being considered by health and social care providers as having an enormous potential to maintain older adults in their own homes (Brownswell and Bradley 2003, COM 2009). For the older adults, living as independently as possible in their own home is an important aspect of

^{*}Professor of Integrated Health and Social Care, Faculty of Health & Life Sciences, De Montfort University, UK.

[‡]University Hospital Lewisham, UK.

[°]Research Assistant, Faculty of Health & Life Sciences, De Montfort University, UK.

[♦]Research Assistant, Faculty of Health & Life Sciences, De Montfort University, UK.

[♦]Research Assistant, Faculty of Health & Life Sciences, De Montfort University, UK.

[▲]Chief Operating Officer, Greenheys Business Centre, Manchester Science Park, UK.

^{*}Consultant Geriatric Medicine, University Hospitals of Leicester NHS Trust, UK.

Professor, GP Principal, Willows Health, UK.

maintaining their dignity and independence (Facchinetti et al. 2023). Furthermore, feelings of empowerment and functional capacity can generate a sense of self-worth, reducing social isolation and allowing them to feel connected to their family and to wider society. Whilst treatments and research into ageing will continue to support longevity, it has been suggested that by combining these innovations with diverse breakthroughs in artificial intelligence, digital technology can contribute to the quality of life of older adults as well as freeing up health and social care professionals and other resources that can potentially save the health and care sector £5 billion over the next decade (Napton 2016). Furthermore, the NHS Long Term Plan (NHS England 2019) sets out several ambitions for improvements over the next decade, including underpinning the importance of technology, and establishing the critical priorities that will support digital transformation and provide a step forward in the way the NHS cares for citizens (NHS England 2020a). The 2012-2020 eHealth Action Plan (EPHA 2017) outlines the vision for eHealth across Europe, recognising the added benefits of digital health in managing chronic diseases and co-morbidities. These predictions become even more important when taking the global demographic shift to an ageing population into account (Reeder et al. 2014).

The ratio of an ageing population has risen significantly in recent years, and as it is expected to continue to rise (Economics Online 2019), this comes with its own challenges. The progressive decline in physical and cognitive skills, the development of chronic diseases and co-morbidities, and the increasing incidence of Alzheimer's disease may interfere with the older adults' abilities and capacities to perform the basic activities of their daily living. Equally, multi-morbidity in the older adult increases the likelihood of hospital admission, the length of stay, and readmission rates, reduces the quality of life, and increases dependency and mortality (Mousa et al. 2018). Forecasts suggest that, between 2015 and 2035, multi-morbidity prevalence in older adults will increase, the proportion that have 4+ diseases almost doubling. Older adults living with combinations of frailty and multi-morbidities in the community have some of the highest levels of health and care needs in the population (Glynn et al. 2011, Gould et al. 2016, Peters et al. 2019). Related to this, the lack of direct continuous observation may mean that impending illness associated with inadequate social care support – such as anxiety (Gould et al. 2016) – will not be recognised until a relatively late stage. Adding to this issue is the sometimes relatively slow physiological response of a frail older person to illness; even a manifest temperature rise in response to an infection may be delayed in this group of individuals, who instead might respond through non-specific changes in function such as reduced activity levels, confusion, or reduced mobility (Leitjen et al. 2018). According to Payne et al. (2013), multi-morbidity is likely to result in unplanned frequent admissions to hospitals, plus the subsequent increase in the use of health care services. In their study, the researchers found that physical multi-morbidity was strongly associated with unplanned admission to hospital, including admissions that were potentially preventable. Thus, a key challenge for health and social care providers is to find new ways of enhancing the care of older adults in the community with improved outcomes. This has necessitated the integration of technology in the care of older adults to allow them

to live at home longer, independently, while delaying transition to acute or secondary care.

Methods

A service development was designed by a group of General Practitioner (GP) practices in the East Midlands, UK to introduce Howz sensors as mechanisms to identify and address the care needs of older adults living alone with long-term multi-morbidities. The Howz sensor is used successfully amongst healthy older adults in the UK (Rogerson et al. 2019), but not amongst older adults with multi-morbidity who live alone. The Howz kit – developed by Intelesant – is also available on the NHS app library (NHS England 2020b). Upon receiving consent, the home sensors are placed in participants' homes on everyday appliances such as electric kettles, toasters, bread makers, and doors they use daily. The app is then downloaded to the older adults' next of kin's (NoK) smartphone, and through this app the next of kin is able to receive information transmitted from the sensors about their relatives' routine physical activities (see Figure 1). After the installation of the smart home sensors, the activity recognition is performed, in which the detected activities are labelled. The daily routine of the participant is then analysed over the next seven days. Once their daily routine at home has been established, the sensors continue tracking their daily physical activities on an ongoing basis. During this period, if the baseline routine changes – such as the individual not switching on their kettle at the expected time or opening the bedroom door at unusual times during the night – the sensors transmit alerts to the app on their NoK mobile phone. When a change is detected, the NoK could then make an informal check of their ageing relative via phone, and intervene if necessary. In this study, the information was also relayed to the older adults' GP on a weekly basis with a summary of the participants physical activities (see Figure 2, an example of information sent to GP).

Figure 1. *Smart-Home Sensors and App*

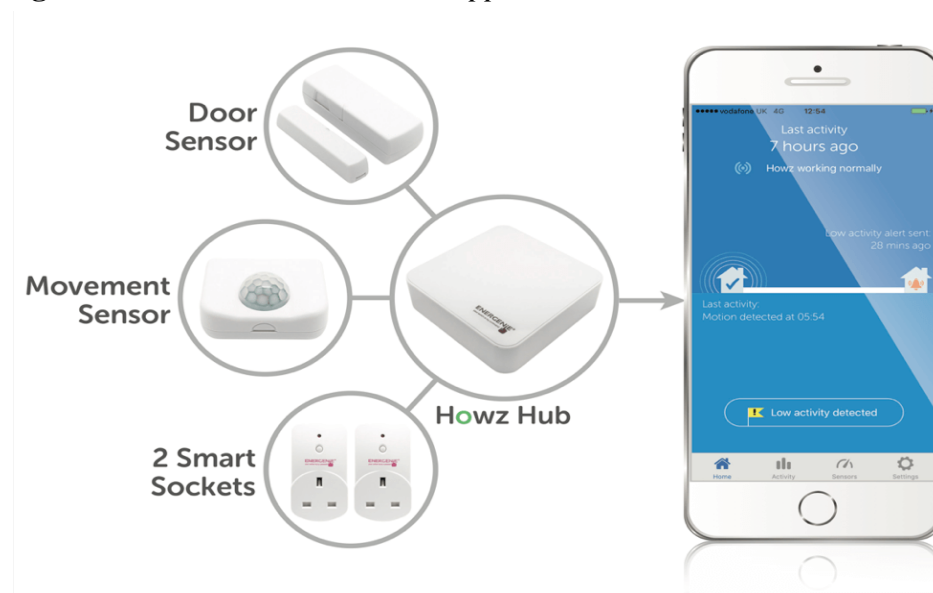
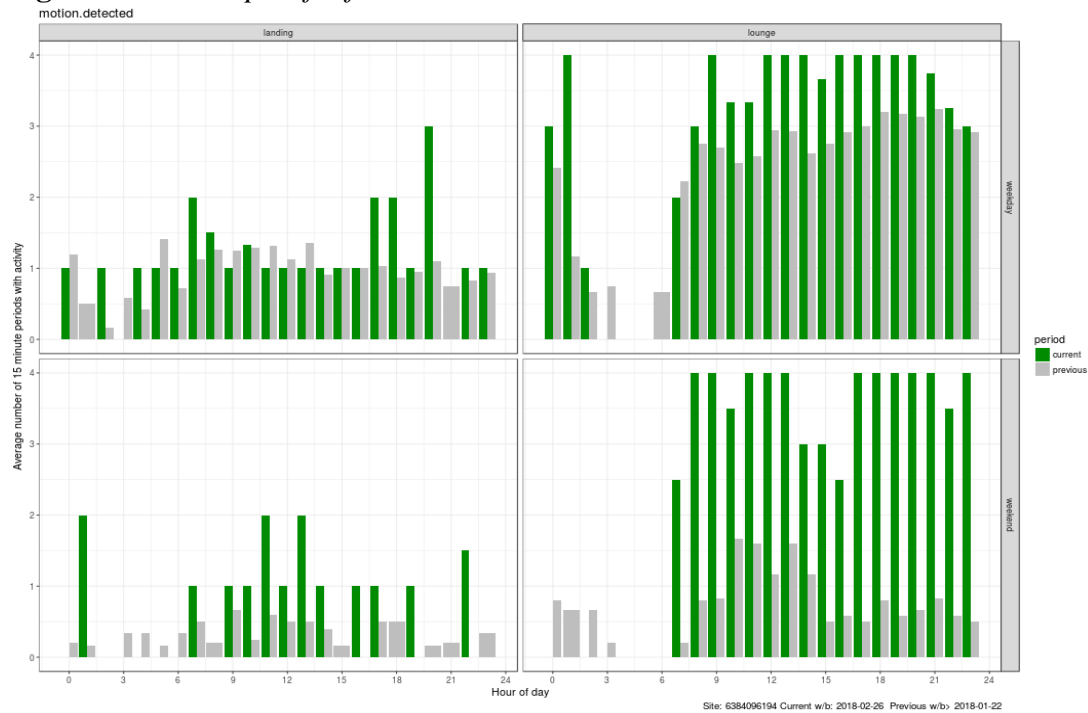


Figure 2. An Example of Information Sent to GP

Permission to conduct the service development evaluation was obtained from the Head of the NHS Services, according to guidance (Holmes et al. 2013, UK-PFHSCC 2017). All participants and NoK had previously consented to having the Howz sensors installed as part of the practice service development. The principles of purposive sampling were applied to identify a convenience sample of three family units, which comprised an older adult with multi-morbidities who lived alone and who was in contact with a carer/next of kin. Participants and their NoK were given participant information sheets detailing the service development evaluation, and were asked to give their consent before any data collection could commence.

Data collection included the baseline information to determine the older adults' perception of their wellbeing before the installation of the home sensors, as well as their demographic information. Following the installation of the smart home sensors, data from the older adults and their NoK was collected after one, three and eight months (December 2017- August 2018) post installation via one-to-one in-depth interviews that lasted from 60 to 90 minutes in the participants' homes. Two of the NoK were interviewed via the phone because they lived approximately 80 and 300 miles away from their older relatives. The aim of the evaluation was to assess the older adults' and NoK's acceptability and satisfaction of the software, as well as the benefits they saw to having the sensors. The interviews were recorded and transcribed accordingly. The case study approach allowed the researchers to focus on a single phenomenon within its real-life context (Yin 1999), make informed judgements about cause and effect in a particular case (Thomas and Myers 2015), and for participants to provide an insight into the complexity of their unique experiences as a family unit (Carolan et al. 2015).

Using an exploratory case study approach (Yin 2018) also allowed for a detailed in-depth evaluation of the participants and their NoK's experiences of having the home sensors. In this study, the narratives provided by participants offered extremely rich information in a complex setting. Table 1 summarises a profile of the three case studies.

Table 1. *Demographic Details of the Three Case Studies*

Demographic	Case study One	Case study Two	Case study Three
Gender of older adult	Female (<i>SM1</i>)	Female (<i>SM2</i>)	Female (<i>SM3</i>)
Age of older adult	77 years of age	72 years of age	82 years of age
Immediate family ties	Two daughters, one son, their partners and children	Two daughters, their partners and children	Three daughter, one son, their partners and children
Main carer	Daughter (<i>NoK-S</i>)	Daughter (<i>NoK-R</i>)	Daughter (<i>NoK-V</i>) Daughter in law (<i>NoK-W</i>)

Thematic analysis was applied to identify themes within the data, though several general themes had already been identified through ongoing reflection during the one-to-one in-depth interviews, which was used for the initial coding. The critical aspect of the analysis was to ensure that the voices of the older adults and carers were heard – therefore, before organising the findings into categories, the process included reading and rereading the texts to identify consistencies and differences. This was followed by a systematic process to identify components that were central to the aims of the evaluation. In analysing the findings from the three cases, we also applied a cross-case analysis approach (Yin 2018) to identify commonalities and differences across the three case studies, the results that emerged were broadly similar and, therefore, their findings are presented as a part of the whole. The interim results were also discussed with all the participants, both to ensure that the final categories were informed by the participants and to minimise the influence of the researchers' interpretations.

Results

Baseline Interviews: Before Installation of Home Sensors by Participants

Experience of Social Isolation, Loneliness, and Resilience

All three older adults reported being lonely, with varying degrees of social isolation. A number of issues came together that made social isolation and loneliness a challenge in older age, including bereavement of their partners which, at times, led to anxiety:

I do feel lonely sometimes, television is a big help but I do like to be in company... I like a good film, I watch most of the soaps... it helps 'cos the days are so long... I suppose most people are a bit nervous when they are on their own. I am when I go to bed at night (*SM1*).

I am a bit scared to go out to tell you the truth, because of falling down twice within a couple of minutes last time I went out (SM2).

It all depends, because my health, one day it could be fine and the next day not, therefore I don't really go out and my daughter she lives far (SM3).

It must be noted that, although all three older adults reported having contact with their adult children, according to them this contact was less than it used to be. Most of their children were reported to be living farther away with their own families; some of their NoK even lived nearly 300 miles away from the older adult relative, which also made the participants less likely to tell their NoKs about any emergencies or accidents.

I just say when I get off the phone, when do you want me to ring you again? I leave it in her court, because I don't want to be ringing her all the time (SM2).

All three older adults reported not immediately telling their NoK if they felt unwell, had a fall, or had chores they could no longer do because of their underlying medical condition, because they didn't want to be a burden or stand in the way of their family's lives.

I didn't let them [NoK] know till afterwards. I don't worry them unless I have to. No, I don't even tell them straight away that I'm poorly in bed. I let them know eventually and then my daughters will say we'll come over and I say there's no need, I'm fine (SM3).

In addition, all three reported being reluctant to visit their GPs unless they felt it was an emergency:

I won't go straight away [to the doctor], I always think you are being a nuisance when you go to the doctors... I always think when you are getting older they can't be bothered with you (SM1).

I mean, I need to see him [doctor] now but I just feel that I shouldn't be bothering him... I don't think they listen to you when you get older, they think you just come because you want to go out (SM2).

I went to see Dr... because he wanted to assess me. He gave me all these papers about being resuscitated if anything happens... I said I don't want to be resuscitated, what's the point, I'm in my 80s... (SM3).

Examining Home Sensors to Monitor Physical Activities of Older Adults Living Alone: Data Collected at Three and Eight Months

Thematic analysis revealed four themes from the three family units, suggesting that the placement of the sensors had a positive effect on the participants' lives.

Home Sensors and Association with Active Social Engagement

In all participating families, there was increased engagement between the NoK and their older adult relative, which was sustained during the data collection periods. Being able to keep track of certain routines allowed the NoK to pick up on changes, as well as prompting them to discuss with their older relatives their daily activities or non-activity, and unusual activity. Participants also reported that their NoK discussed with them the rich information provided by the sensors, which allowed more interactions and discussions about their physical health and issues that they may otherwise not have been aware of. The NoKs reported an increased awareness of their ageing parent's daily activities compared to before:

If there's anything wrong, even if she doesn't say, at least I can see what's what and we can discuss it (NoK-R).

She does sit down and watch a lot of telly, and then you'll see that she's been into the kitchen because she's gone and got her lunch or her breakfast or whatever, so... I don't worry as much, but I've spoken with her about moving about because I've realised how much she just sits at home alone, and I am now making more effort – and my brother too, and his family. We all try to reach out and talk to her more; she won't ask, you know (NoK-S).

If there's anything untoward I can call her and ask her: 'I noticed last night you opened your bedroom door five times at night, is everything OK, Mum?' and a few times after a discussion I've prompted her to see her GP, make sure she has her meals and just moves about. You know, she's now joined a local computer class! That's all good for her, you know (NoK-V).

Feelings of Security and Social Support

All older adults reported only being actively aware of the sensors directly after placement in their homes, getting used to them within days. All reported feeling more secure, and narrated how they felt if 'something were to happen', happy that their NoK would be alerted by the app. For example, if the older adult had not opened her bedroom door or switched the kettle on as per the routine that was reported on several occasions, this would prompt an alert and call from their NoK. This gave both the older adult and the NoK a feeling of safety and peace of mind, allowing each to feel more relaxed.

I know there are no cameras but it feels like I am being looked after and it makes me feel safe, I'm safeguarded, I don't feel as anxious. I have felt more relaxed knowing that someone will know if I am unwell... well, they will eventually know if there is a problem and I've not had to ring my GP or been to hospital since I've had the sensors (SM1).

You watch these adverts on the television about a stroke and I have often laid there and thought well I have got a phone at the side of me all the time – mobile phone. And everybody just says you let us know if there is a problem but if you have a stroke you probably can't get the phone to ring anybody. And that's one thing that used to play on my mind because I am at risk of a stroke because I can't take the

medication for my heart racing. But with this sensor, I know that somebody will know if I've not moved for a while and that makes me less anxious now (SM2).

Enhancing Family Engagement and Promotion of Healthy Physical Behaviour

The placement of the sensors, and the active engagement from those alerted by the sensors, allowed for a growing relationship in which the participant put their trust in their NoK to check on their activity regularly – and where the NoK got to know their ageing parent's daily routines. After the placement of the sensors, all participants reported some growth in the relationship with their adult children and the family network. This could be directly with the NoK, who is alerted by the app, or by having the alerted NoK keep other relatives up to date using the information from the app. This easy access to information regarding their ageing parent's daily activities allowed family members who do not live nearby to become more engaged socially with each other and to care for their ageing parents.

I mean if I didn't get out of bed and go to the toilet any night, then she would worry, because she knows I am a regular one for tripping off across the landing, and they talk amongst themselves, so even my grandchildren now ring me more often, you know (SM1).

I wouldn't draw my other daughter into anything anyway because it's not been easy with her, but she is on the computer so the other daughter tells her little bits about me and she has started ringing me too (SM1).

Well, I had not been eating well, but I didn't want to bother my daughter. Anyway, the weekend before she said to me, 'Do you want to come and stay here for a few days? You might feel a bit better then,' so I went over and stayed with my daughter and her family. It was lovely being there for a few days, you know, but I just wouldn't ask (SM2).

Well, we are in more contact, she is sort of keeping her eye on me (SM2).

The NoK reported that it was a great way for their ageing relative to maintain their independence, but still receive support where necessary. Moreover, for the NoK it allowed them to identify – in an unobtrusive manner – the areas in which their ageing relative may require support.

I don't think she's quite ready yet to give up her independence, if you know what I mean. She's quite happy to carry on, plodding along on her own. I mean, as long as someone is at the end of a phone, that's fine (NoK-R).

I now know when she's had a bad night because you can see the alert that the door to the bathroom has been opened several times at night, or she's not been to the bedroom, then I can sort of prompt her to go to the doctors and make an appointment if she needs to, whereas before I wouldn't have known that she was having bad nights unless she told me. For example, there was a time I was receiving alerts that the bedroom door was not being opened, and when I spoke with Mum, she wasn't using her bed and she was having problems getting to sleep. So, I got her to come here [...] and she slept better when she came here, because she wasn't on her own,

and it helped when she went back to her house, you know we were talking the other day with my sister that mum has not been to hospital since we've had the sensors (NoK-S).

Like I say, my sis-in-law [name redacted]'s got the app and I have. And she's monitoring it as well as myself, and if she's got a query then she'll call me and I'll say: 'No, don't worry, I've called Mum and she's okay.' and it's like a three-way-communication. And because my sister lives a bit of a way out, then we communicate to her as well. It's a valuable experience within the family (NoK-V).

All three older adults reported changes in their behaviour, which appeared to have a positive impact on their wellbeing – including the participant who had initially reported that she did not want to be resuscitated. At her three and 8-month interview, she reported feeling more positive about her wellbeing, largely because of the improved engagement with her adult children and grandchildren, which was facilitated by the routine dialogue regarding the alerts from the app. Similarly, another participant was prompted by their NoK to increase their fluid intake, following alerts that the kettle was being used only once a day and at times not at all for two or three days. The discussion between the NoK and the participant prompted an increase in their intake of hot drinks and water in order to stay hydrated. In addition, questions by the NoK about activity in the house motivated the participant to reflect on her health behaviours.

My daughter sent me a text message one weekend, so I rang her and she said I sent this text message because you are not drinking enough! She had looked on her phone and said you have not drank, you have only turned the kettle once the whole day the last few days. She then wanted to know how much fluid I was taking; since then I've been taking more. I'm on so many tablets and my mouth gets all dry, my daughter says my kidneys will go because I'm hardly having any fluids because it's the cold weather also, you see, so I've started drinking more (SM2).

The Benefits of Non-Wearable Unobtrusive Home Sensors

Participants who had wearable sensors, such as a pendant they'd obtained through the local authority, indicated that these relied on the individual remembering to wear the pendants all day long, and that they preferred the unobtrusive home sensors over the use of an alert pendant or bracelet for several reasons – including the fact that the link was with their relatives, while the pendant was linked to emergency health and social care providers as first responders.

Because I think things like that [the pendant] makes you feel that you are an invalid or... do you know what I mean? It's just like a badge of honour sort of thing of an invalid that you wear around your neck, and I'd rather my daughter rings me than having the social care to check on me. Whereas this [the sensor] nobody would see it, you know, it just makes me feel more independent. So, I keep the pendant for major issues (SM3).

Well, I think it's really useful because it lets me know what my mum is doing without seeming to be over her; it just lets us know that she's fine, really (NoK-R).

Although the information provided through the app is quite basic, it provided family members with more insight into the daily activities of their relatives. Quick and easy access to the app allowed family members to check on their relatives more often, and to incorporate this into their daily lives. Family members were able to deduct routines, time spent at home or outside, and time spent in certain rooms, as well as monitoring food and drink intake and sleeping times – all without seeming to be intrusive or meddling.

It's easier, rather than having to keep running around because you can't get through – because obviously you're relying on phone calls, whereas this alert shows me there's activity. So during the course of the day I can log on where there's WIFI anywhere and know that there's been activity during the day, whereas before if I couldn't get through then I'd be panicking because of her age... has she fallen? That's the advantage that you've got the app on your phone (NoK-W).

I log on every morning just to make sure she's up and about. I check her once in the afternoon and then in the evening. If I can see that she's gone out, then I check to make sure she's got back okay and then I check at bedtime just to see that she's trotted off to bed – really it's something that should have come out a number of years ago. I think it's very beneficial to the elderly (NoK-S).

It's just basically so I know whereabouts she is and what time she's got up and if she's had a bad night [...]. It gives me an idea on what's going on in her life. [...] It's very informative; it tells you quite a bit, really (NoK-R).

Discussion

The findings from the baseline interviews highlighted the challenges of social isolation amongst older adults who live alone, something that also undermined their wellbeing. Our participants reported that their adult children had their own families with their own lives, as well as being busy with their jobs, resulting in less time to engage with their ageing parents. Moreover, the opportunity to travel far becomes impaired when older adults have comorbidities – which was reported by our participants. Furthermore, feelings of social isolation were also largely attributed to experiences of bereavement due to the death of their husbands/partners and their preference to continue living in the same house and community, which has also been reported in other studies (Brittain et al. 2017, Clayton et al. 2022). The literature shows that social isolation forms a risk factor for both physical and mental health, with associations involving higher rates of morbidity and depression (Age UK 2021). A study looking into the different contributions of social disconnectedness and perceived social isolation or loneliness found that social disconnectedness is associated with worsening physical health (Brittain et al. 2017). The findings from the present case study also support previous work demonstrating that a change in the quality of relationships in older adults – such as having close family support and engagement – has a positive impact on their physical and mental wellbeing (Lam et al. 2023, Whitehead 2016).

In this present study, the home sensors appear to have facilitated engagement between the NoK and their ageing parents, which in turn was reported to decrease feelings of social disconnectedness, as well as appearing to have a positive impact on older adults' self-reported mental wellbeing. Moreover, the home sensors allowed the NoK to discuss with their parents their own routines and behaviour patterns while at home. There were several examples whereby the NoK's intervention resulted in their ageing parent adopting health-enhancing behaviours such as an increase in fluid intake, more physical activities, and better sleeping patterns.

Studies investigating monitoring technologies have demonstrated the benefits of home sensors in prolonging independent living for older adults (Facchinetti et al. 2023, Aggar et al. 2023). In the present case study, the NoKs' reported that the use of the Howz sensors allowed for the independence and privacy of their ageing parent while maintaining a family support system. Information obtained through the sensors allowed for a starting point from which they could converse about daily activities without being intrusive, as well as allowing for a dialogue about activities that were beneficial to the wellbeing of their ageing parent. In a study by Whitlatch and Feinberg (2003), they found that 30% of caregivers were unaware of the assistance needed by their relatives. In this study, the information from the sensors enabled the NoK to have an awareness of their ageing relatives' needs and to open up the possibility for dialogue. For family members that live farther away, it provided a sense of closeness and involvement in the lives of their ageing parents, while also allowing them to contribute to their care management. All NoKs reported learning something new about their ageing parent's daily activities, as well as forming a closeness through family dialogue that positively impacted the participants' wellbeing. According to participants and their NoK, the older adults had fewer visits to their GP compared to pre-installation, and no reported transition to acute or secondary care during the time of the study. All the family units informed us they would be continuing to use the monitors.

Inevitably, the potential impact of these technological developments for older people is huge, limited currently only by market development, costs, time, and human ingenuity. However, for technology to be accepted by older people and their careers, it has to be affordable and easy to use, it has to address the challenges around data sharing, it has to align with a clear ethical and legal framework, and it has to capture the trust of the individuals involved (CPA 2014, Auffray et al. 2016, Cole and Towse 2018). In our case study, the older adults did feel a reinforced sense of security and increased engagement with the wider family, without feeling that the system was intrusive or disruptive (Rogerson et al. 2019, Doyle et al. 2015). Lie et al. (2015) argues that the development of assistive technologies such as smart home monitoring systems is one solution for the older adults who do not describe themselves as old or frail enough to require personal care provision; it assists them in maintaining their identity, autonomy, and independence while still being supported by their family network. The smart home device used in this study collects timely data relating to the individual's functional ability, and for future studies it may be useful to integrate such findings with health and social

care records to inform better decision-making in the care of older adults in the community.

Implication and Conclusion

The evidence from this study highlights the positive impact technology could have on older people who live alone at home while maintaining positive engagement with their families. Technology may also improve the socialisation and wellbeing of vulnerable older adults who live alone. The technology could also enable the triangulation of data from health and care records which, in turn, could expedite rapid decision-making in the care delivery and timely interventions for older adults. However, the caveat remains that research needs to keep abreast with an ‘escalating creep of technological advances’, using a rapidly evolving and changing interface regarding the health and social care delivery landscape. Critically, due to the dependency on technology, which is often expensive and can be unfamiliar to many users, it may widen socioeconomic-related health disparities. While a critical limitation of this study is the focus on only three family units, the findings could be used to design a larger scale randomised controlled study that examines the use of smart home sensors in enhancing the wellbeing of older adults, as well as undertaking a social and economic evaluation and a cost-benefit analysis in the provision of health and social care.

References

- Age UK (2021) *Same as it ever was: ‘life during the pandemic was no different to normal . . . I’m always lonely*. Available at: <https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/consultation-responses-and-submissions/health--wellbeing/loneliness-and-covid-19---december-2021.pdf>. [Accessed 13 March 2023]
- Aggar C, Sorwar G, Seton C, Penman O, Ward A (2023) Smart home technology to support older people’s quality of life: a longitudinal pilot study. *International Journal of Older People Nursing* 18(1): e12489.
- Auffray C, Balling R, Barroso I, Bencze L, Benson M, Bergeron J, et al. (2016) Making sense of big data in health research: towards an EU action plan. *Genome Medicine* 8(1): 71.
- Brittain K, Kingston A, Davies K, Collerton J, Robinson L, Kirkwood T, Jagger C (2017) An investigation into the patterns of loneliness and loss in the oldest old–Newcastle 85 Study. *Ageing & Society* 37(1): 39–62.
- Browsell S, Bradley D (2003) *Assistive technology and telecare: forging solutions for independent living*. Bristol, UK: Bristol Policy Press.
- Browsell S, Bradley D, Blackburn S, Cardinaux F, Hawley M (2011) A systematic review of life style monitoring technologies. *Journal of Telemedicine and Telecare* 17(4): 185–189.
- Carolan CM, Forbat L, Smith A (2015) Developing the DESCARTE model. *Qualitative Health Research* 26(5): 626–639.

- Centre for Policy on Aging: Rapid Review – CPA (2014) *The potential impact of new technologies*. Available at: https://www.ageuk.org.uk/Documents/EN-GB/For-professionals/Research/CPA-The_potential_impact_of_new_technology.pdf?dtrk=true
- Clayton D, Clifford A, De Vries K, Kuuya H, Ochieng B (2022) My story: using a life story approach to build friendships between younger and older people to alleviate loneliness and social isolation. *Mental Health Review Journal* 28(2): 1361–9322.
- Commission of European Communities – COM (2009) *Dealing with the Impact of an Ageing Population in the EU (2009 Ageing Report)*. Available at: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0180:FIN:EN:PDF>.
- Cole A, Towse A (2018) *Legal barriers to better the better use of health data to deliver pharmaceutical innovation*. OHE Consulting Report, London: Office of Health Economics. Available at: <https://www.ohe.org/publications/legal-barriers-better-use-health-data-deliver-pharmaceutical-innovation>.
- Doyle J, Caprani N, Bond R (2015) Older adults attitudes to self-management of health and wellness through smart home data. In *International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, Istanbul, Turkey, 15(3), e3.
- Economics Online (2019) *The ageing population*. Available at: https://www.economicsonline.co.uk/Global_economics/The_ageing_population.html.
- European Public Health Alliance – EPHA (2017) *Digital solutions for health and disease management*. Available at: <https://epha.org/wp-content/uploads/2017/05/Digital-solutions-for-health-Discussion-Paper.pdf>.
- Facchinetti G, Petrucci G, Albanesi B, De Marinis MG, Piredda M (2023) Can smart technologies help older adults manage their chronic condition? A systematic literature review. *International Journal of Environmental Research and Public Health* 20(2): 1205.
- Glynn LG, Valderas JM, Healy P, Burke E, Newell J, Gillespie P, et al. (2011). The prevalence of multimorbidity in primary care and its effects on health care utilization and costs. *Family Practice* 28(5): 516–523.
- Gould EC, O’Hara R, Goldstein MK, Beaudreau SA (2016) Multimorbidity is associated with anxiety in older adults in the health and retirement study. *International Journal of Geriatric Psychiatry* 31(10): 1105–1115.
- Holmes T, Donoghue K, Sinfield P, Harrad F, Lester L (2013) *A guide to conducting evaluation*. Leicestershire: NIHR CLAHRC.
- Lam J, Broccatelli C, Baxter J (2023) Diversity of strong and weak ties and loneliness in older adults. *Journal of Aging Studies* 64(Mar): 101097.
- Leijten FRM, Hoedemakers M, Struckmann V, Kraus M, Cheraghi-Sohi S, Zemlényi A, et al. (2018) Defining good health and care from the perspective of persons with multimorbidity: results from a qualitative study of focus groups in eight European countries. *BMJ Open* 2018(8): e021072.
- Lie M, Lindsay S, Brittain K (2015) Technology and trust: older people’s perspectives of a home monitoring system. *Ageing & Society* 36(7): 1501–1525.
- Mousa A, Savva GM, Mitnitski A, Rockwood K, Jagger C, Brayne C, et al. (2018) Is frailty a stable predictor of mortality across time? Evidence from the cognitive function and ageing studies. *Age and Ageing* 47(5): 721–727.
- Napton S (2016) *NHS remote monitoring will allow dementia patients to stay at home*. The Telegraph.
- NHS England (2019, January 7) *The NHS long term plan*. Available at: <https://www.longtermplan.nhs.uk/publication/nhs-long-term-plan/>. [Accessed 20 June 2019]
- NHS England (2020a, July 1) *Digital transformation*. Available at: <https://www.england.nhs.uk/digitaltechnology/>. [Accessed 20 May 2019]

- NHS England (2020b) Available at: <https://www.nhs.uk/apps-library/howz/>. [Accessed 20 September 2020]
- Payne RA, Abel GA, Guthrie B, Mercer SW (2013) The effect of physical multimorbidity, mental health conditions and socioeconomic deprivation on unplanned admissions to hospital: a retrospective cohort study. *Canadian Medical Association Journal* 185(5): E221–E228.
- Peiris D, Miranda JJ, Mohr D (2018) Going beyond killer apps: building a better eHealth evidence base. *BMJ Glob Health* 3: 1–3.
- Peters M, Potter CM, Kelly L, Fitzpatrick R (2019) Self-efficacy and health-related quality of life: a cross-sectional study of primary care patients with multi-morbidity. *BMC Health and Quality of Life Outcomes* 17(1): 37.
- Reeder R, Chung J, Le Thompson H, Demiris G (2014) Assessing older adults' perceptions of sensor data and designing visual displays for ambient environments. *Methods of Information in Medicine* 53(3): 152–159.
- Rogerson LJ, Burr J, Tyson S (2019) The feasibility and acceptability of smart home technology using the Howz system for people with stroke disability and rehabilitation: assistive technology. *Disability and Rehabilitation. Assistive Technology* 15(2): 148–152.
- Thomas G, Myers K (2015) *The anatomy of the case study*. 1st Edition. California, US: SAGE Publications.
- UK policy framework for health and social care research – UK-PFHSCC (2017) Available at: https://www.hra.nhs.uk/media/documents/Final_Accessibility_uk-policy-framework-health-social-care-research_.pdf. [Accessed 5 December 2019]
- Whitehead BR (2016) Health behaviors in older adults: considering age, affect, and attitudes. *Health Psychology* 22(13): 1652–1657.
- Whitlatch CJ, Feinberg LF (2003) Planning for the future together in culturally diverse families: making everyday care decisions. *Alzheimer's Care Quarterly* 4(1): 50–61.
- Yin RK (1999) Enhancing the quality of case studies in health services research. *Health Services Research Journal* 34(5 Pt 2): 1209–1224.
- Yin RK (2018) *Case study research and applications: design and methods*. 6th Edition. California, US: SAGE Publications.