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Aging in Place Together: Journeys Towards Adoption and Acceptance of Smart Home Healthcare Technology

By

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Abstract

This thesis responds to the aging population crisis specifically within the UK, which sees the older adults increasing in proportion to other demographics. Consumer smart home technology on the market is diverse, from sensor systems, voice assistants, self-tracking devices, to smart watches and interconnected heat and lighting systems. However, previous research has identified that there are misalignments between older adults' needs, and the potential of digital technologies to support aging in the home; especially with others. Many smart home technologies designed to provide care are co-opted by residents of different generations for purposes other than care, e.g. play with children, or caregivers' own social and recreational activities. Yet it is of interest to investigate the shared care practises taking place when using smart home technology together. This thesis begins with the aim of identifying shared experiences and practises that take place in the home that support quality of life for older adults using home healthcare technologies. Drawing on a qualitative methodology through three technology deployment studies (stairlifts, voice assistants and sensor systems), this thesis provides several empirical contributions. Firstly, shared care practises, challenges and barriers to understanding smart home systems are understood. Diverse intents, needs and technology requirements from residents are shown here that enable aging in place together with bespoke human support mechanisms. Then, accounts of people's emotional journeys, felt and lived experiences of using home healthcare technology are provided. Accounts also show how the technology is avoided, not used, struggled with and misunderstood, as much as it positively supports care interactions. Lastly, unique care networks (the multi-resident home) are described through participants' shared experiences around their technology. These experiences go beyond self-care practises and identify how less obvious actors (visitors, technology suppliers and installers) become integral to delivering shared care in the home with smart home devices. This thesis proposes a range of outcomes including how emotionally supportive technology journeys must be tailored and nuanced to support multi-generational households, how older adults living together benefit from shared care activities through voice assistants and how labour can be reduced by continuous support of shared interactions for complex smart home health systems.

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PUBLICATIONS

Conference Papers

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3. Amid Ayobi, Ewan Soubutts, Rachel Eardley, Rachael Gooberman-Hill, Ian Craddock, Aisling Ann O'Kane. (2021). Mental Health Technology Needs of Knowledge Workers from Ethnic Minority Backgrounds in the UK. In Association for Computing Machinery (ACM) Proceedings of the 2022 ACM Conference on Human Factors in Computing Systems (CHI 2022).

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Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

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CHAPTER 1

INTRODUCTION

1.1 Introduction and motivation

The use of smart home technology is increasing at a formidable pace (Fredericks et al. 2018). The proliferation of devices such as Amazon's Alexa, smartphone sleep trackers, wireless motion sensors and digital weight scales have all typified conceptions of the 'smart home' as a space which brings together this technology for efficiency, comfort and ease of use for supporting people. In addition to this wearables (such as smart watches) and other touchable, bendable or stickable interfaces are being used with increasing prevalence in the home too (Hwang et al. 2012). All of these devices help people to look after themselves and connect with others in their homes for both social and technical activities, from self-care activities such as cooking, shopping or washing to supporting mobility e.g. walking and other shared social tasks such as playing games.

However, the smart home research domain also sees technology applied within a health and care context. For example, household residents may make use of an Amazon 'Alexa' device to schedule medication reminders or use sensors in the home to supervise the whereabouts of a person with Dementia (Burrows et al. 2018). However, HCI literature on the smart home has well documented how some groups of older adults (particularly those who were not introduced to digital technologies earlier in life), display hesitancy toward adopting new digital devices, even when they offer benefit (Steen et al. 2011). As such, smart home technology has seen limited uptake for older adults' wellbeing (in this thesis, wellbeing is defined as positive physical or mental health or the support of this through technology) (Thieme et al. 2012, Tongsiri et al. 2017).

This poses a unique problem for the current and future generations of the older adult demographic. In the UK, there is a need to support aging more directly through a greater provision

of healthcare resources for an older population. Before the COVID-19 pandemic at the start of 2020, the National Health Service (NHS) in the UK (where this thesis takes place) was already struggling to provide a suitable level of healthcare for the elderly and local UK councils struggled to meet patient care needs for home support. Since the pandemic, there have been radical calls for strengthening the UK's national health service to deal with this very current problem, as the demographic of the UK's older adult population increasingly grows. Solutions such as setting up a separate National Care Service to mirror the NHS (Grand 2002) has been proposed to tackle the scale of the crisis, however, this requires significant funding and economic security, during periods of increasing global uncertainty and the increased cost of living. As local councils also provide a great deal of support for low-income households, financial pressure has been placed on the provision of adequate social care to support everyone who needs this.

Instead, the NHS and care research organisations advocate for encouraging independence at home. Long-term social care into later life is outlined by the NHS as a significant challenge in their '2022/23 priorities and operational planning guidance' (NHS 2022). At the date of publication, this challenge is posed as solvable with a combination of service provision and encouraging independent technology use, should the increase in the world's older adult population were to remain steady. However, this is not the case. This report and many other national (UK, ONS) and international (WHO) predictions paint an alarming picture of the growth or a so-called 'silver tsunami' of the older adult population in the UK and worldwide over the next 10-20 years (Mitchell et al. 2014, ONS 2017). Another result of this shift towards an older population means a higher percentage of the population living with 'multi-morbidities' (CDC 2017); older adults with one or more chronic health condition. In turn, this places an even greater burden on health systems. If no action is taken, the cost of the crisis is estimated to be in the region of £2.5 billion per year up until 2040 (£45 billion in total until 2040) (GOV.UK 2020).

Therefore, there is a pressing need for alternatives within older adult care, outside of a clinical setting to support this increase in demand. More households are therefore seeking alternative living arrangements to accommodate informal care practises within the home; to reduce the cost of living, maintain a high quality of life for everyone in the home and to take care of older adult residents away from a clinical setting (Service 2014).

'Aging in place', originally termed by Davey et al. (2004) in their research on accommodation options for older people nearly 20 years ago), is one proposed household-centric approach which acts a means through which older adults are supported to live independently in their own homes. This is as opposed to transferring to a residential or managed care environment in later life. Instead older adults are supported through either informal caregivers such as family members or by using technology, to sustain their independence in their own homes (Light et al. 2015).

In recent years, there is an increasing trend towards shared aging in place arrangements, which stems not only from reduced financial costs on households (e.g. of not needing to pay for managed care) but also increases in rent for younger generations, which sees e.g. younger family members living with an older person to save money and provide care. As a key challenge for the older adult population is the provision of informal care in the home, inviting younger adult children, or live-in carers into their homes to care for them is one realistic solution Guzman-Castillo (2017), ONS (2017). It is also here, that this thesis' primary objective is placed; in order to understand how this informal caregiving is supported by and through the use of different types of technology (thus, aging in place *together*). Aging in place together has the potential to living arrangements across generations, each with individual needs but with the potential for each generation to support the other. These intergenerational home setups also apply in rental, co-housing communities (traveller sites) and communal building arrangements; beyond people who are related living together (Jenkins 2017, Lynch & Draper 2014, Caldeira et al. 2017).

There is an opportunity here to explore the intersection of older adults' independence at home, when they are supported by informal caregivers through the use of technology. We use 'care' in the context of this thesis, in line with Mol (2008)'s work, as the way in which actions are undertaken to support the physical, mental or emotional wellbeing of one individual by another. It is here, where this thesis builds on existing work in HCI and contributes understandings of: i) these different informal and formal caregiving roles, required to offer support to older adults (e.g. (Zallio & Casiddu 2016, Alemdar 2014), ii) the often overlooked work that is performed by these informal and formal caregivers that is dubbed 'invisible' or unseen work (Verdezoto et al. 2021, Procter et al. 2018) and often gendered work around technology and care (Mol 2008, Branham & Kane 2015, Bennett et al. 2018), iii) simple and non-digital technologies that have applicability to digital counterparts through the complex physical and emotional actions people perform with and through them, by way of, as Höök (2010) describes; 'transfer scenarios', iv) technologies that provide social presence to either aid in connectedness through and between residents as a means of supporting sociability or care e.g. the use of AI-based chatbots (Reicherts et al. 2022, Miner et al. 2020), v) how complex pieces of technology that work together Liu et al. (2016), Mennicken et al. (2015) as part of a system show how they can be appropriated for activities other than their intended purpose supporting care in the home and vi) how older adults' emotional concerns around frailty and deteriorating health should supported alongside the physical manifestations of shared care technologies. More concretely, this thesis investigates three different 'fidelities' (types of technologies; from low-tech, consumer-grade to mostly digital technology e.g. sensors) of smart home technology in the homes of older adults (including caregivers and recipients of care). This approach, that looks at non-digital as well as digital technology was chosen, based on the work of Höök (2010) discussed in greater detail in chapter two, that shows that there are transferable outcomes from studying non-digital human practises (such as horse riding), that can inform the design of digital technologies. This thesis also explores other key concepts that recur

throughout, including technology: i) acceptance (the ways in which people come to obtain, use and continue to use technology for their shared health and wellbeing), ii) adoption (how people go about choosing whether or not to use a specific technology), iii) appropriation (how people change technologies to suit their lifestyles in their own homes), and iv) abandonment (why people choose to stop using specific technologies in their own homes).

The research questions in the following section build on these major themes, which also stem directly from the review of relevant HCI literature in chapter two.

1.2 Research questions

Understanding the nature of the aging population challenge and its increasing prevalence is not only important for older adults but also researchers, clinicians studying aging (Wiles et al. 2011). Whilst attention is beginning to be paid to the ways in which people interact socially in the home, mediated through the use of mobile devices or smart home technologies, there is more to be done to understand how these technologies are used together, and for care (Pierce et al. 2020). Further, how these technologies can support people who are aging in place at home around others of different generations and ages is currently under-explored within both HCI and CSCW. As the objective of this thesis is to understand how people age in place together with others in their homes and which technologies will best support these co-living arrangements, the following research questions are proposed in order to scope this problem space:

1. RQ 1. What are the roles of the different members of the wider household in the adoption, acceptance, use and appropriation of technologies designed to support care?
2. RQ 2. How are commercial smart home technologies being appropriated for self-care and collaborative care practises?
3. RQ 3. How is self-care and collaborative care work impacted by the introduction of complex smart home technology to support healthcare at home?

This in turn, helps to articulate a wider, over-arching research question, for the entire thesis, of:

- TRQ 1. How are complex smart home technologies adopted, accepted and appropriated by shared households?

These research questions help to inform the empirical work in this thesis across each of its three studies. In Chapter Four, the first empirical study looks at the use of stairlifts in older adults' homes. In Chapter Five, the use of an off-the-shelf consumer smart home voice assistant (the Amazon Echo Show 5) is explored including how it is used in shared households. In Chapter

Six, an empirical study of a smart home health system (SHHS) is presented, which is also situated within shared households. In the closing chapters of this thesis, over-arching implications for the research and design of future smart home technologies are discussed. These include suggestions for research and design within multi-resident smart homes in the future as well as proposed limitations of this work for future HCI and CSCW researchers conducting investigations in the home that look at people's health and care as they are.

The following chapter covers related work within a literature review (Chapter Two), before presenting a methodology for this thesis' empirical work that is grounded in the outcomes of the presented literature (Chapter Three). The empirical chapters in Four, Five and Six then follow from this, before a general discussion, limitations and conclusion are presented for the thesis in Chapter Seven and Eight.

CHAPTER 2

BACKGROUND AND RELATED WORK

2.1 Introduction

This chapter reflects engagement with related work around the aging population challenge, smart homes, and health and care research within HCI and CSCW. The chapter begins by outlining key contributions in the aging population challenge area and moves into a discussion of technological contributions for the home within the field of Human-Computer Interaction for health and care. A selection of papers were engaged with and are reviewed here covering a period of time from 2005-2022 (17 years). This is also representative of when the largest body of smart home research within science and technology studies has taken place, according to the ACM Digital Library. The papers discussed predominantly in this section encompass a broad range of literature contributions across different streams of work, from more technically or clinically focussed papers, to user-centred, sociotechnical works and more recently, humanistic approaches to understanding the home, which draw on the arts and design epistemologies. We then discuss ways in which technology is used by people in our selected papers, the mismatches and barriers to use and lastly, opportunities for future research and development. These findings inform the direction of our three empirical studies and the over-arching empirical study methodology for this thesis that we describe in the next chapter. This chapter is structured firstly around an overview of the aging population in relation to smart homes and smart home research. This is followed by a categorisation of the four streams of work within smart home research, derived directly from the selection of our papers. Following this is a more specific overview of research topic areas e.g. customisation that is relevant to conducting smart home research independently before closing with a short summary of this chapter's review contribution.

2.1.1 Population changes - 2015-2025

As the world's population is becoming increasingly older, the number of people over the age of 60 is expected to double by 2050 and triple by 2100: an increase from 962 million to 3.2 billion globally (Nations 2017*b*). This shift represents one of the most significant social transformations of the twenty-first century (Nations 2017*a*). The increases in improved healthcare provision, better access to sanitation and amenities that support people's wellbeing all contribute to increased population lifespans and thus sees people living for longer into older age (Wiles et al. 2011). Health authorities have outlined how the change in aging populations will impact the delivery and effectiveness of health services on a global scale (ONS 2017).

Of particular note is the rate at which the trend towards an aging population is increasing significantly between the years of 2015 and 2025, in the UK. In particular, within the UK, the National Health Service (NHS) outlines the challenges associated with an aging population in their five year forward plan (2014-2019). The report explains how 75% of over 75's experience one or more long-term health condition (multimorbidities) as they age (Norman & McDonnell 2017, Service 2014). During this period, 25% more older people will be living with a disability: an additional 560,000 people requiring care per year (Guzman-Castillo 2017). This figure indicates that a dramatic shift in the makeup of the older adult demographic is already occurring and putting increased pressure on health services.

Now that we have identified the scale of the challenge presented by this increase in aging populations, it is necessary to understand the variety of solutions which have been proposed both within the fields of Human-Computer Interaction and Digital Health. Within this section contributions are identified which have been proposed to date, towards tackling the problems associated with an aging population.

2.1.2 Historical overview of smart homes

The earliest recognisable vision of the smart home comes from the era of home automation, or 'Domotics'. Domotics originated in the 1970's as a response to an energy crisis of the time and the need to reduce consumption worldwide, by about 30-40% (Márza & Dragan 2006). Domotics technologies of the time focused on a means of streamlining the home experience by making everyday utilities e.g. fold-away ironing boards, kettles which would turn themselves off once boiled, making them perceived as compact, efficient and easy to use (Bravo et al. 2006). This technology comprises the most recognisable vision of 'smart home' technology used today and informed the design of many later systems e.g. room temperature control units.

Works before this period did not fit the current definition of smart home technology: 'allow[ing] users to control and monitor their home through connected devices.' (Harper 2006*a*). Prior to this,

contributions sit more in line with the vision of 'Calm Computing', as identified by Mark Weiser. The calm computing vision advocates designing technology that exists in the user's 'periphery' - that is, computing that takes place without the user noticing, or with very little attention drawn from the user, in order to make it operate as required (Weiser & Brown 2001). Current Internet of Things (IoT)/Smart, Ubiquitous Computing (Ubicomp) and Mobile and Pervasive computing systems work contrary to this vision and instead, as Rogers discusses, are focused on and draw our attention to them, as opposed to receding into the background environment (Rogers 2006). Harper then built on the work of the Ubicomp and HCI communities here, looking further at social connectivity, networking and the interconnectedness of the environment of the home space (Harper 2006*b*)

It is also necessary to understand contributions from the health and care domain in the home where user centred approaches to the design of technology to support individuals here have been taken. Within the HCI literature, there is a strong convergence between healthcare and smart home living arrangements that has been studied in detail.

2.1.3 Towards 'Aging in Place Together'

The challenge of an aging population has been the focus of a range of technology research and interventions. 'Aging in place' is used within the CSCW, HCI and aging literature to describe older people who are encouraged to live independently in their homes, for as long as possible - without the need to relocate e.g. to retirement communities for additional support, however, there are also barriers to successfully achieving this (Lazar et al. 2017). Aging in place, as a way of living, therefore advocates autonomy in allowing older adults to age in their homes by themselves, thus reducing the burden on healthcare services, usually through the use of novel technologies (Caldeira et al. 2017). Bradford et al. (2018) proposes how the integration of both technology and services in the home is a pathway towards the development of smart home technology that supports aging. Other work by Lazar et al. (2015) deals with the implications of telecare solutions that support aging in place. Their findings show how the need for companionship, even through the medium of virtual assistants, is valued by older adults as a means of connecting with a real person - the "teleoperator" (a human being) on the other side of the virtual assistant. Chinner et al. (2018)'s work also looks beyond the impact of technology to support aging beyond the individual, by looking at the social impact within communities.

Evidence shows that these groups living 'around' older adults in the home also perform care duties and must adapt to individualised and dynamic housing situations, which make the challenges for aging in place with others, uniquely difficult (Kohli et al. 2014). This is of increasing concern as the traditional household setup in places such as the UK is moving away from homes being traditionally comprised of adults and their younger offspring and instead can

be made up of adult children, extended family and renters (Bengtson 2001), with an increase in multi-generational homes (ONS 2017). There have been recent moves towards looking at the shared use of technology in the home to overcome these challenges (Kraemer & Flechais 2018) and improve people's ability to conduct care routines together effectively in the home (Riche & Mackay 2010). Crawford et al. (2015) illustrates how users derive meaning and substantial use from another domestic visible technology; the weight scale, which requires: "collective, rather than individual participation" (p. 494) Crawford et al. (2015). Ogonowski et al. (2016) discusses how the shared experiences of fall detection systems had positive outcomes such as raising awareness about falls, which in turn encouraged the use of this type of preventative technology. These studies have identified how, for example, individual and group efficacy (the ability of groups of individuals e.g. caregivers to enact actions to perform care) affects the use and practises around shared technologies (such as Alexa devices) in the home (J Kraemer et al. 2019). Their findings show that these groups are fluid and extend well beyond the immediate household, to neighbours, guests and other clinical and non-clinical visitors (e.g. occupational therapists, social workers, to close family members, friends and neighbours). Other work has shown that technology use and freedom of use in the home is also determined by the role that each of these actors plays in the home e.g. parents restricting access to certain devices for their children (Geeng et al. 2019). This perspective provides a unique opportunity to explore the impact of technologies for care in households, considering the social structures that develop around the use of technology at home (Foong & Zhao 2016, Gutierrez & Ochoa 2017).

Beyond the primary user, it is of interest to study the holistic journey experienced by the range of stakeholders that will influence (and be influenced by) the introduction of a new healthcare technology that supports aging in place together. Therefore, there is benefit to an exploratory approach: capturing the process of adoption (beginning to use) and acceptance (becoming socially accepted in a space Carroll (2004) and accustomed to the the use) of an existing visible home health technology, which focuses on lived experience of a whole household, rather than the introduction of new technology being an end goal (Chen et al. 2017, Kon et al. 2017, Rashidi & Cook 2013)].

2.1.4 Health and care technology contributions within HCI research

Much of the existing HCI literature on health and care technology outside a clinical setting (that also includes a focus on care), has focused in particular, on self-care and self-management (the ability to regulate ones own health through the use of mobile technology such as blood glucose monitors and smart phones (O'Kane et al. 2016, Verdezoto & Grönvall 2016)). In particular, literature reviews such as Nunes et al. (2015)'s, identify the importance of self-managing chronic health conditions such as Type II Diabetes in the home, with family members. In their example, a family gamifies (turns an everyday activity into a game) the experience of taking blood glucose

readings for their children with Type 2 Diabetes by enabling them to compete with one another to achieve the highest or lowest blood glucose value (Nunes et al. 2015).

Ayobi et al. discuss the notion of self-management through self-tracking (e.g. through the use of simple tools such as journals, manual trackers) and how this self-care practise is easily embedded within our daily lives (Ayobi 2018). Particularly within the domain of 'personal informatics' (using tools to provide feedback on ones self e.g. on a chronic disease or fitness), tracking makes use of social, communal and technical elements, which converge to promote its continued usage in managing health conditions in home settings (Ayobi et al. 2016, Epstein et al. 2015, Choe et al. 2014).

In a related area of research, studies also focus on how health and care in peoples homes is supported using specialised healthcare systems (e.g. e-health, m-health (Liu et al. 2016) and smart home sensor systems). These studies mostly investigate the deployment of systems and medical devices as part of field studies. For example, Burrows and Gooberman-Hill et al. identify how the deployment of a smart, connected home sensor system (SPHERE), has been beneficial in delivering effective treatments to people in their homes Burrows et al. (2018). This whole systems approach (consisting of both the residents and technology using technology together collaboratively), extends the reach of healthcare at home beyond self-management through personal, mobile devices to personalised care plans and interventions, delivered effectively through the involvement of healthcare professionals via smart home technology. The use of this technology and the potential for its intersection with medial experts in the clinical domain, extends the smart home discourse beyond 'empowering the patient' (as with (Nunes et al. 2015)) and embeds principles of service design, that engage actors (patients, healthcare professionals), at different stages of life, with the ability to support people with e.g. disease progression and management remotely, while they remain living in their homes (Burrows et al. 2015).

HCI contributions from these studies show a progression from technology centered on individualised care, managed by a single person or small group, to a holistic, person-driven approach to caregiving, that makes use of many actors across the healthcare domain. A combined approach allows for the holistic management of diseases and administration of treatments which involve healthcare professionals, but which are driven by users (Burrows et al. 2015). The move towards smart home systems that support aging in place with others within this research shows a shift that is reflected in the nature of interdisciplinary research across HCI that takes place in the home. This shift builds on the work of Blandford et al. (2018) who discuss how it is important to adopt interdisciplinary methods when conducting health and care research within HCI (Blandford et al. 2018). Understanding that research within HCI adopts interdisciplinary approaches to health and care research in the home, allows for a starting point within this review, from which to examine different streams of research in the smart home domain, from more clinically-focussed

work through to emerging, humanistic approaches that transcend the need for technological interventions to assist with aging in place in the home.

2.1.5 Contemporary approaches to smart homes

A great deal of work has gone into the development of smart home technology research within HCI, CSCW, Ubicomp and beyond over the past three decades in particular. Despite more technical contributions of smart home technology e.g. (Chan et al. 2009, Jakobi et al. 2017, Jang & Bednarz 2018)), HCI and CSCW have taken a more socio-technical approach, instead focusing on the impact of smart home systems and individual smart home devices on users' everyday lives. Many recent studies have explored issues such as the privacy implications of using smart home devices in the shared space of the home (Kraemer et al. 2019), whereas others have looked at power relations around these devices and the impact of security when multiple residents are involved in sharing devices (Geeng et al. 2019). There has also, more recently been a turn to a more humanistic approach (focussing on the person, or technology owner, before considering the devices used) in smart home research, looking at, for example, the relationships between people dwelling in their home and the data they own, and how they access and interact with it (Desjardins et al. 2020). Futurism and speculative design has also become a popular space to understand the smart home through embodiment (physical and social presence centered around a technology or interaction) (Dourish 1999, Key et al. 2022) as well as embracing the nature of the unknown in the home through exploring human feelings towards the 'spookiness' of 'black boxes' of data within smart home technologies (Escarcha et al. 2022). However, it is care that has also become a locus for exploration within HCI and CSCW humanistic research on the smart home. Exploring care in the smart home has allowed for a greater understanding, particularly with older people of how technology can support everyday activities of daily living by those who are alone (Callejas & López-Cózar 2009), how care communities using smart technology come to understand it (Caldeira et al. 2017) and where care relationships are critically and closely reimagined for modern lives that include smart devices (Key & Browne 2021). It is here that we focus this study's contribution, with a consideration of care within wider households. The following section speaks further to understanding of shared care within HCI and CSCW research in the home.

2.1.6 Smart home technology and shared caregiving

Care is the focus of this thesis' work and it is necessary to explore previous work on caregiving for older adults. HCI and CSCW has conducted numerous studies with older adults to try and understand technology use patterns and how well these devices are accepted. Caregiving that takes place with others often describes a range of tasks (clinical and non-clinical) that are enacted in order to look after the older person's wellbeing. Studies such as Karlsen et al.'s describe how family caregivers often provide a range of support, from reminding older relatives to wear

their telecare pendants (Karlsen et al. 2019), to updating their calendars (Davidoff et al. 2010), organising Dossette box medication (Ploderer et al. 2017) and general assistance with activities of daily living (ADLs; daily routine activities such as washing and bathing) (England & Dyck 2011).

The collaborative use of smart home technology has made greater waves in both HCI and CSCW in recent years as studies address how quality of life in the home for an older person should not be dependent on simply the use of a single technology by a single older adult, but in fact requires a network of care actors in order to support its ongoing use and acceptance within the home. Zallio et al. makes the case for those living together to share technology that will benefit the longevity of an older adult at home (Zallio & Casiddu 2016). Others have developed conceptual frameworks for how families can modify and adapt IoT devices and everyday technology to better suit their homes (Williams et al. 2019), whilst some work has dealt with how individuals reason with and make sense of their smart home data to inform their own self-care activities (Kurze et al. 2020). Beyond the immediacy of the 'live-in' household structure, other studies have explored how neighbours, co-dwellers and 'live-out' visitors all interact with those living with smart home technology and how this either positively or negatively impacts the dynamics of households' social structures (Rajan et al. 2021, Dewsbury et al. 2003). For shared care, considering or 're-imagining' how the home can be structured considering the relationships between people and people, but also people and things; and how often IoT objects can possess a social quality that augments care, even if these smart devices are not social actors in themselves (Key & Browne 2021, Soubutts et al. 2021).

Voice assistants too, play a large role within both HCI and CSCW research on shared smart homes and deal with both individual and collaborative use of the devices. Beneteau et al. and Porcheron et al. have both explored the communal use of voice assistants as a means to support shared living, however this shared use often results in breakdowns in conversation when multiple actors try to interact with the same device at once (Beneteau et al. 2020, Porcheron et al. 2018). Voice assistants are also purchased by family members of those who are stroke survivors (Aidar et al. 2011), those with low vision (Duffy et al. 2021), and people living with e.g. Parkinsons (Storer et al. 2020). VAs have also provided opportunity for multimodal customisation in the home (Gollasch & Weber 2021), while studies by Pradhan et al. (Pradhan et al. 2019) and Sin et al. (Sin & Munteanu 2020) show how VA's can be effectively used by people with disabilities to provide greater control through speech and how to hold effective conversations between older adults and VA agents, respectively. Despite these advantages, there is also significant work still be done with VAs in the smart home, such as supporting code switching for different for non-traditional forms of spoken language (Harrington et al. 2022), and to support human-to-human intersubjective communication and sharing (Soubutts et al. 2022).

2.1.6.1 Assistive technology and collaborative care

Assistive technology (AT) describes a range of devices that are adaptive, rehabilitative or that support people's physical needs (Gilmour 2017). The term covers a broad range of technology from small and simplistic devices such as pendant alarms (which send alerts to emergency services and carers), to more complex machinery such as mobility scooters and stairlifts. Although there have been moves towards more digital assistive technologies in the UK, current AT devices are generally not considered 'smart' or available off-the-shelf, in the same way that a commercially available smart home technology might be, such as Amazon Echo (Trajkova 2020).

Research on the use of AT in health and care settings has been studied within the HCI community (e.g. Amiribesheli & Bouchachia (2018), Ayobi et al. (2020), Branham & Kane (2015)), however there are also examples from other disciplines that are relevant to the move towards technologies to support aging in place together. The work of Caldeira et al. (2017) highlights how many existing health and care technologies are developed to improve the QoL of a single older adult in their home, but they also identify how supervised and collaborative use is an essential part of older adults being able to sustain their own self-care. Similarly, Karlsen et al. (2019) study of telecare systems in the home, sets out the advantages of shared care in this space, where another family member supervises the use of technology with an older adult. Their findings also build upon Caldeira et al. (2017)'s work and lay out how other caregivers, supporting the use of assistive technology (telecare) systems are a necessary part of its continued use and adoption by older adults (Karlsen et al. 2019). These cross-disciplinary studies exemplify the benefits of conducting qualitative and mixed-methods research into the use of assistive technology.

Other studies have also dealt with the stigma that is associated with assistive and accessible technologies being "visible" in people's lives, which can lead to misuse and abandonment Profita (2016). Hearing aids, for instance, are often not adopted because of their association with frailty (O'Kane et al. 2016). Shinohara & Wobbrock (2011) discusses how blind and low-vision users take steps with others in their homes to make their devices accessible such as putting braille stickers onto microwave number pads, however, they can still feel stigma and shame. Whilst there are movements to tackle misconceptions around assistive technology (e.g. online bloggers Lazar et al. (2017)), there is still much work to be done on 'invisible' or unconscious ageism for people using assistive technology. These studies suggest that the visibility of assistive technology in shared environments such as the home and related feelings of stigma are important considerations for the adoption and acceptance of these technologies.

Nunes et al. (2015) evaluate the "complex contexts" that approaches to self-care often entail and in their review of self-management technologies in HCI. They highlight how the HCI lens on self-care in fact necessitates the involvement of others in care processes with the use of

assistive technology and as such, one must also discuss the other actors in proximity to an individual to fully understand their self-care practises. This approach highlights the importance of collaborative care, as an extension of self-care. Zallio & Casiddu (2016) further distinguishes the role that users play in the home, by delegating in-home care actors with roles such as 'primary resident' referring to the person in care, 'secondary resident' referring to other resident immediate family or friends, and also a 'tertiary' resident; referring to anyone not living in the home. However, Zallio et al.'s work does not account for the differences between the roles of temporary residents (who visit to provide care) or that of clinical and non-clinical providers who may have a care role within a household. It is here that Branham & Kane (2015) introduces the concept of negotiated access to care devices between multiple residents, and where Bennett et al. (2018) discusses "interdependence" to describe the relational aspects of shared access and use of assistive technology devices. Whilst the owners of assistive devices often assert themselves in using the device (independence), it is often interdependence between the owner, other actors, their devices and the environment (e.g. the home), where equal access can be best supported and AT users can be empowered (Bennett et al. 2018). Procter et al. (2018) builds on this work by addressing collaborative care from the perspective of the care provider. In their study, the challenges of operating an 'assisted living' service show how much additional or 'hidden work' (such as travel, setting up devices in peoples' homes, guiding first responders to a patient's house) is performed by care providers and informal caregivers, both inside and outside the home. These 'hidden' activities and influences are important to uncover in the context of ageing in place together with technology.

2.1.7 Caregiving in the non-stereotypical smart home

The notion of a 'non-stereotypical home' is explored most recently by (Desjardins et al. 2019), whose research explores the physical layouts of homes and considers how personalised devices and craft can be made useful for people who live in e.g. non-static locations such as house boats (Easthope 2014). At a more granular level , objects are similarly discussed as shaping the fabric of the home, and giving homes humanistic qualities e.g. warmth, comfort, colour (Key et al. 2022). Temporal aspects of the home are also considered a part of its physical makeup and affect caregiving e.g. self-care practises such as setting mealtimes (Chen et al. 2013, Garg & Sengupta 2020). The objects that older adults and their caregivers treasured are often most impactful on positive wellbeing as people aged together. Others too have looked at shared use of technology in collaborative settings such as care homes and how this has impacted the way ADLs are conducted together (Gruning & Lindley 2016).

Smart home research has also moved beyond looking at traditional family structures inside of homes (e.g. two parents and two children) and instead looked at diverse family dynamics e.g. inter-generational renters (Yuan & Yarosh 2019), co-habitors (Seymour et al. 2020) and

communities (e.g. culturally diverse and queer inhabitants (Retrum et al. 2016, Schulte et al. 2020)). Other research has also considered how care is delivered for people living with partners of people with cognitive impairments through use of conversational agents (Zubatiy et al. 2021), methods for caregivers of interacting with smart home devices, for those who are deaf (Mande et al. 2021) and even conversational agents that can comfort and support those in the home who have experienced racism (To et al. 2021). Work done within the home has also examined disease progression and prevention and how those in care and their caregivers reason with data and how it is then used within health communities (e.g. people with Parkinson's) (McNaney et al. 2022). In the dementia space too, work is being done to support the wellbeing of couples living with dementia using empathic, tangible objects for the home (Houben et al. 2022), However, others such as Harrington et al. make explicit how intervention-based research (using a novel technology to see if it supports an older person) is becoming more common in HCI research but is neglecting the wider impact of being well connected and supported by care networks, without which can negatively impact treatment and health outcomes (Harrington et al. 2022).

Lastly, it is often described how stigmatised health technologies are a large barrier to the adoption of new devices to help older people age in place successfully, which smart home technology does not always provide (Caldeira et al. 2022). These technologies (such as pendant alarms, wheeled walkers, stairlifts (Soubutts et al. 2021)), when used by an individual older adult, or even when suggested that they are used by a caregiver (Sixsmith et al. 2020), bring about resentment and abandonment and are not always replaceable by smart home alternatives. Therefore, as Light et al. suggest, for technology that is 'often ugly or stigmatising', it should be recognised that older people are not a homogenous group, but are individuals that do not all appreciate a specific style or taste in technology design (Light et al. 2014).

2.1.8 Understanding types of work and labour around care

It is also necessary to look at labour and the different types of work that come about in order to provide care. The types of labour we discuss here are interdisciplinary and extend beyond HCI/CSCW research into the health and care domain and clinical bodies of research too. It is also important to distinguish both labour and work here. Whereas care work describes physical or mental actions done in order to enact a positive goal in support of someone, care labour describes the effect of caregiving on individuals, groups (e.g. households) or wider society James (1992), Kaziunas et al. (2019) through the act of performing laborious or intensive work. There are several different types of work described in the health and care literature within HCI/CSCW and beyond.

The first, self-care work, is well-established within HCI/CSCW discourse (Nunes et al. 2015). Within many health communities, such as the Parkinson's community, ethnographic accounts of

self-care technologies have commonly been developed to understand self-care practises and how these intersect with the lives of others e.g. caregivers (Verdezoto et al. 2021). The counterpart to managing self-care at home has been the introduction of self-tracking technologies (e.g. using apps on smart phones, journaling etc.). Studies of self-tracking technologies have shown that they can be used to mindfully record and monitor disease and symptom progression e.g. for people living with multiple sclerosis (or MS; a degenerative neurological condition) Ayobi et al. (2020), as well as with older adults to positively impact their quality of life through encouraging physical activity (Vargemidis et al. 2020). Time-based work in the home is also discussed within a healthcare context. McCoy (2009) describes how people's internalised sense of time becomes quickly regulated to "clock time" (the 24-hour cycle), due to the need for strict adherence to medications, and that through reminders and prompts, this can help people by motivating this strict adherence. After a while, Huyard et al. describes how this time-based 'work' becomes internalised so that effort decreases and it becomes a routine (Huyard et al. 2019).

Boundary and articulation work fall into the social categories of work done in the home. Creating boundaries in the home can provide a physical separation from medicalised devices Strauss (n.d.) [p. 10] e.g. through hiding them in drawers to physically concealing them if they must remain attached to a person (O'Kane et al. 2015*a*). Aside from creating physical distance between a person and the intimate space of their home through establishing boundaries, articulation work is a predominantly social type of work that deals with the process of actualising caregiving tasks in the home (understanding what needs to be done to perform care and doing it), such as through an older person's informal carer setting up and providing medication for them on a daily basis (Timmermans & Freidin 2007).

Body work and restoration work are types of caregiving work discussed across HCI/CSCW and in the clinical literature. The former, body work, deals with the embodied nature of caregiving and how, whilst the embodied nature of care work mostly focusses on personal care (grooming, bathing etc.) and other ADLs, there is often a need for more personalised, embodied support that can involve physically demanding and technically challenging caregiving such as fitting and monitoring the use of oxygen tubes for a person or turning on and tuning in the television (England & Dyck 2011). Often, the emotional labour and closeness of performing such embodied work around the person being cared for, is noted to have strengthened the social status of the carer in the caree's home, such that rigid social boundaries are lessened and former strangers are often considered akin to close family members (Twigg et al. 2011).

Restoration work, whilst still dealing with the embodied nature of care, by contrast has a temporal nature and comes towards the latter stages of managing care. Kumar et al. describe such restorative work in the case of managing what happens when recovering from disease and how to reclaim parts of one's life that may have been lost (Kumar et al. 2019). However, this

type of restoration can also go beyond the immediate care network of the home to the immediate community, where e.g. frontline healthcare workers can help individual households or specific patients to restore the old social norms from pre-disease (Verdezoto et al. 2021).

This existing research shows how care takes place in the home as well as the types of work that are done in order to provide formal and informal care here. However, it is less clear what types of labour come about from doing work to use a smart home system for health and care and how this affects the existing work already being done in the home. Whilst deployment studies of smart homes have been performed before Amiribesheli & Bouchachia (2018), Burrows et al. (2015), our contribution here is contextualised within the self and shared care bodies of work within HCI. Previous studies have supplied frameworks Soro et al. (2017) or technical recommendations, whilst this paper falls more in-line with previous work done in the smart home around collaboration and modification of care-centric devices (Williams et al. 2020), the social support networks that underpin older adults' use of connected home devices (Light et al. 2015) and the collaborative and shared ownership of devices that help older adults care for one another (Gruning & Lindley 2016, Lazar et al. 2018, Pradhan et al. 2020). In summary, *this chapter contributes an understanding of different types of care work that are conducted with, in parallel, and despite the introduction of a smart home health system*, and how the addition of a SHHS impacts the wider household and not just the person being cared for there. All of the different types of work in our findings also occur inside of the home space, where smart home technology is present. In the following section, we describe how we went about conducting a study into these different forms of work around a novel smart home health system.

2.1.9 Smart home technology use and the COVID-19 pandemic

The pandemic provides a context through which to understand the unique circumstances in which technology is used (or used differently). Research has explored the mediums through which investigations into the home are conducted, for example, through studying technology-mediated support, where health and care is managed in isolation online, through remote consultations and patient diagnostics, as opposed to face-to-face contact (Lazar et al. 2018). These pandemic specific novel and shared approaches changed the way people engaged with healthcare, from doctor appointments to emergencies. Experiences of long-term health conditions in demographics such as isolated older adults were also shaped by engagement with technology and services during the pandemic (Donovan et al. 2017, Middleton et al. 2020, Xie et al. 2020).

The pandemic offered a unique lens to look at the in depth use (and shared use) of a multimodal VA to support health and care with older adults social distancing in their home. This is in line with previous studies of smart homes for health and care emphasise the need to avoid smart home technology design that simply follows trends in popular culture, in order to conduct in-

depth investigations into the impact of technology on people's everyday lives. Within the context of increased need and more time spent at home, the lived and shared experiences with this technology can be examined in detail during a time of social distancing.

2.1.10 Summary

This understanding of caregiving in different contexts, and the invisible and unseen work around supporting care, directly informs RQ1, which looks explicitly at how smart home technologies elicit specific care practises and how work is conducted to effectively support care, using different types of smart home technology too.

2.2 Identifying four streams of work in smart home research

Using streams of research as a framing for specific types of papers, allows for discussion of contributions which inform the overview within rest of this chapter, and helps to inform the research questions for the work in this thesis.

The four work streams approach, builds upon models such as (Wilson & Hargreaves 2017) and (Kozubaev & Disalvo 2019), which also propose different streams (functional, instrumental, socio-technical) for identifying contributions in the smart home literature. We also extend contributions from (Marikyan et al. 2019) and (Soro et al. 2017) which identify conflicting aspects of people's lived experiences in the home e.g. agency and information, security and the need for autonomy.

The streams of work were devised by categorising and sorting a randomised sample of papers between 2005 - 2022 and sorting them according to their most prominent methodological and empirical contributions. The culmination of this is four distinct streams of work that speak to aforementioned work in the smart home domain but also speak to the future of work within the smart home too. The streams of work are not prescriptive and are instead meant to be thematically representative of the work completed in this space in order to give an overview of the content for the purposes of illustrating key contributions.

Development stage was identified by cross-referencing the study publication date with the type of technology being discussed. Methodologies are the methodological approaches taken to exploring each technology within each study. Types of technologies are the different devices and equipment used and studied within this research. Thematic loci were decided upon based on the different types of actions and activities that took place within a study. Future themes are based upon authors' suggestions for future work, or as limitations of their own research. Focus are more generalised thematic strands of research informing each study. Aims were identified through researchers' descriptions of research aims for a particular study. Epistemology includes

the theories of knowledge underpinning both the research approach and methodology for each study. Approaches and objectives are the means by which each study contributes and draws from societal implications of the research. Data tracking methods refer to how individual studies proceeded to collect data and where relevant, track specific outcomes e.g. symptom progression. Common Language Keywords were selected words and phrases common to all papers which helped to provide specific search or indexing categories for each of the streams of research.

These work streams synthesise contributions from the selected papers in a way that does not conflict with e.g. HCI methodologies or other models of the smart home domain; instead adding to the picture of interdisciplinary work in this domain. Instead the contrasting elements of the smart home literature are seen as part of a complete picture, encapsulating the messiness and complexity of homes, that have often been recorded as part of studies. Below, are discussed four streams of work: *Techno-centric*, *Socio-technical*, *Humanistic* and *Clinically-informed*. Whilst conceptualisations of the smart home domain such as the socio-technical perspective have been discussed before elsewhere, the papers discussed here show interesting or ancillary viewpoints that provide new perspectives on how smart homes can support aging in place.

Figure 2.1 (below) details how the four streams interrelate with the literature that has been reviewed. Cross-cutting themes are identified which are common across streams (e.g. Methodologies). Each of these streams are discussed in greater detail in the rest of this section. Below, a brief overview of each of the four streams is presented.

Figure 2.1: Overview of four streams.

LENSES TOOL	CLINICALLY INFORMED	TECHNO CENTRIC	SOCIO TECHNICAL	HUMANISTIC
Development Stage	Early: Pre-smart homes e.g. domotics'.	Recent: Current developments of smart home technology e.g. through use of IoT/Machine Learning.	Contemporary development in HCI for smart home domain e.g. combining social care and technology.	Emerging developments in HCI for smart home health and care. Moving beyond traditional conceptions of 'home'.
Methodologies	Snowball Sampling Longitudinal Studies & RCTs	Deployment Studies Feasibility Studies	Action Research Interviews and Surveys Ethnographies Focus Groups and Workshops	Participatory Design & Co-Design Design Fiction Histories & Reviews
Types of technologies	Grab rails/toilet seats Pendant alarms Stair lifts Wheeled walkers	GPS trackers (insole) Fitness trackers M-health apps Home sensor systems Alarms Decision support systems	Home hubs Mobile devices/phones Email/web apps Sensor and health prediction algorithms	Community message boards Online forums `Common' houses Networked city infrastructure Fictional technology Non-technical
Thematic Loci	Independence and Autonomy Chronic Condition Management Care Delivery	Technology placement Adoption/engagement Decision making	Shared information/use Skill and knowledge improvement Activity-based collaboration Self-monitoring	Creativity and design Empowerment Community Problem solving
Future Themes	Sustainability of Care Algorithmically-Driven Drug-Development Ethics	AI capability System self-reconfiguration	New types of work Division of responsibility Promoting knowledge Users as designers	Design/research opportunities Community support Diversity Personal/social empowerment
Focus	Delivering health/care for the individual e,g, home modifications such as stair lifts	Deploying technologies to deliver care e.g. home sensor systems for health monitoring	Understanding self-management including families, caregivers, and clinicians in households and retirement centres	Exploring the needs of diverse user groups and centralised community practises and experiences
Aim	Informing clinical diagnoses and medical decision making to improve quality of life	Understanding health, optimising data collection and analysis, and informing clinical assessment	Supporting self-management, informal care, and patient provider collaborations	Fostering communities (diversity) and directing future directions of smart home research and design
Epistemology	Health studies and health psychology incl use of validated measures e.g. EQ-5D-5L	Health studies and systems engineering for health technology optimisation	Social theories and concepts of experiencing and living with chronic conditions	Critical theory and humanistic HCI Extending definition of home
Approaches & objectives	Service-driven approach to provide care as part of service infrastructures (e.g. NHS)	Technology to examine the feasibility and acceptability of smart home systems	Qualitative and participatory research to examine the lived experiences of self-care	Design methods and sharing community-specific knowledge for administering health and care
Data tracking methods	Health indicators for clinicians (clinical tracking. GP appointments) to administer care	Automated tracking of physical activities and primary disease indicators e.g. using Machine Learning	Semi-automated and collaborative tracking of self-care activities e.g. through paper bullet journalling for tracking health routines	Manual data collection e.g. email, hand written
Common Language Keywords	'assisted', 'Quality of Life (QoL)', 'multimorbidity', 'markers', 'tracker', 'intervention', 'mobile', 'cognitive', 'decision', 'clinical', 'biomedical', 'safety'	'In-home', 'clinical', 'wearable', 'device-based', 'algorithmically-driven', 'behaviour change', 'decision support', 'placement', 'signal', 'barrier', 'engage'	'service-driven', 'adoption', 'shared', 'caring', 'in-home', 'informal', 'patient', 'clinician', 'monitor', 'mis-use', 'non-use', 'active', 'passive', 'family', 'caregiver'	'design', 'create', 'adopt', 'use', 're-use', 'care community', 'neighbourhood', 'values', 'new', 'social', 'communal', 'queer', 'city', 'identity', 'share', 'personal', 'public'

2.2.1 The 'Clinically-informed' stream

The work discussed here focuses on interdisciplinary contributions within the HCI health and care domain, but also overlaps contributions from other fields such as medical informatics, personal e-health/m-health and the quantified self (the tracking of aspects of a person's physicality e.g. weight, BP etc).

These so-called "clinically-informed" studies make use of a range of methods including Randomised Control Trials (RCT's) and Longitudinal studies (over periods of years) to test the efficacy of specific health interventions. RCTs are a common method used within these studies. For example, the clinical review produced by Chinner et al. evaluates the feasibility of a range of smart home and 'domotics' (1950's - 1980's non-digital) technologies, which could be used within homes, to assist with dementia treatment (Chinner et al. 2018). Feasibility studies of specific technologies or so-called "living labs" and "smart environments" are typically longitudinal. Heine and Buhr's studies (Heine et al. 2016), exist as a clinical precursor to the more managed care environments emerging on the commercial market currently (e.g. Amazon's Managed Care home devices). The differentiation between the "LebensPhasenHaus" discussed by Heine and the emerging trend of care environments, is that the former is a regulated, monitored environment that is setup to observe people's health specifically by clinical professionals, whereas contemporary managed care environments are instead an informal assemblage of consumer smart home technologies that are networked together and can be monitored by informal caregivers in order to support, for example, an older adult's independence.

Chinner et al. also discuss how a wireless cognitive monitoring system has been deployed within homes to remotely assess cognitive states for dementia sufferers, to test whether it is possible to monitor such decline. The trial, involving 38 participants exemplifies the scale of such clinically-informed, lab-based studies. RCT's and feasibility studies provide a robust framework for trialling new medical innovations (Chinner et al. 2018). However, such trials are seen less-often within the HCI smart home domain, where predominantly socio-technical studies take place with much smaller groups of participants (around 10-14 in a study e.g. (Lee & Dey 2011, Callejas & López-Cózar 2009)). However, it is possible to adapt such feasibility studies for investigations that bridge health and care studies within HCI and the wider clinical field.

One study which bridges both the health and care literature inside and outside of HCI with a clinically-informed focus is a study by Fredericks et al. which introduces a cyber-physical system, built around a database and sensing system that detects decline in older adults through monitoring Activities of Daily Living (ADL's - e.g. washing, cleaning etc.) (Fredericks et al. 2018). Technology used within the clincially-informed lens draws from the HCI for smart homes domain, but applies medical methodologies, as described above to the literature, or in studies such as CAL (Fredericks et al. 2018).

Emergent themes within the clinical domain that are combining HCI and clinical approaches, come within the field of Behaviour Change. For example, a study by Caldeira et al. builds further upon the use of sensor systems to provide clinical outcomes (Caldeira et al. 2017). Instead, their system monitors behavioural and physiological cues in older adults and then provides recommendations to change an older adult's behaviour; aimed at preventing hospitalisations.

The novel use of a sensor system that provides a behaviour change support system, provides a future direction for studies we identify within the clinically informed lens. In this way, we recommend through this lens, the continued convergence of both clinical (digital health) practises and methodologies and previously applied HCI concepts e.g. behaviour change.

Considerations for future work within the clinically-informed lens are varied. Caldeira et al. (2017) proposes that the sustainability of effective care must continue to be considered in order to deliver high quality combined treatments through care services and smart home technology to support the health of residents. In a separate study, DanaKai Bradford (2016) goes on to highlight the importance of the ethical considerations of smart home interventions and how monitoring data is not valuable without human interpretation. A study by Chinner et al. (2018) also stresses how neglecting patterns in smart home data that indicates declining health, has lead to fatalities.

2.2.2 The 'Techno-Centric' stream

This stream focuses on studies designed around technology, as opposed to people (e.g. living labs (Heine et al. 2016)). Within techno-centric studies, works focus on how deployments and feasibility are assessed as part of these methodologies. An example of this is the Cognitive Assisted Living smart home system - CAL, which monitors interactions between doctors and patients and provides feedback in the form of contact data (Fredericks et al. 2018). This aims to facilitate better and more frequent interactions between doctors and patients (e.g. people living with Alzheimers) which can, in turn help to predict symptoms for doctors and monitor congitive decline. This notion of supporting clinical reasoning frames the majority of contributions within the techno-centric lens.

The technologies in these studies investigate the deployments of smart home sensor systems (such as SPHERE Burrows et al. (2018); a collection of sensors designed to track people's everyday activities)) and robot care assistants, as described by (Chinner et al. 2018). These systems may be fully automated; not requiring much user engagement beyond turning the sensors on or off and being set up to perform sole tasks by a specialist technical team, such as to track movement or blood pressure (Burrows et al. 2015)). These sensor systems can also utilise machine learning (ML) in order to identify patterns in human behaviour such as a lack of movement (possibly indicating a fall or a challenge for a person's activities e.g. not drinking enough water (Kurze et al. 2020). However, there are cautionary tales to the over-reliance of the user on sensor systems in a person's home such having a family member rely solely on a sensor's data to understand their loved one's wellbeing. This was seen with the case of "Mrs. Elle", discussed by DanaKai Bradford (2016), where an elderly woman falls victim to over-reliance on passive sensors monitoring and reporting on everything she does to the point that the system did not detect or report on her demise.

HCI contributions around the development of new smart home systems are also examined in current research, but are not discussed extensively; quite possibly due to the variability of directions, which the domain could take. Rather, smart home contributions within HCI discuss more the socio-technical outcomes from studies that were originally focussed on the development of a specific technology. This is the case for example with works such as (Rajan et al. 2021, Key et al. 2021, Zubatiy et al. 2021), which explore changing behaviour as a result of technology being introduced in the home, empowerment and power imbalances respectively.

The current 'state of the art' of smart home technologies, is seeing a move from individualised, single device or single unit systems, to smart environments e.g. 'smart care environments' as described by Amazon (Cancio et al. 2022). This move towards a more managed environment both in clinical and non-clinical settings, using smart home devices, in fact advocates the inclusion of additional actors into the management of these devices within the home. This is interestingly in contrast to foresight within the literature from even two years prior, which supposed that the next iteration of smart home technology development would see a turn inwards, e.g. to biomedical implanted devices within people's homes, that could be used to more accurately track a person's wellbeing by themselves over time (Marikyan et al. 2019).

This change from the prediction of biomedical implanted devices to the reality of popularised and integrated smart home systems can be attributed not only to the visual and aesthetic impact of implants but also the unobtrusiveness of having technology attached to your skin at all times, instead being more in-line with the calmer vision of Weiser (Weiser & Brown 2001). The intrusiveness of medical devices that are also attached to you at all times, as well as the need to conceal them is well documented with in the HCI literature too e.g. (O'Kane et al. 2015*b*).

The techno-centric work we have discussed in this stream focuses on approaches to developing systems, which are iterative and constantly improving, as with those discussed by (Rajan et al. 2021). However, it is also necessary to identify contributions which have factored in people to the design of digital health systems. For this, we identified socio-technical works that bridge human involvement into the design of new smart home technologies.

2.2.3 The 'Socio-Technical' stream

The contributions within the socio-technical work stream stem from methodologies which involve human engagement in some form, with the design of technology, for example; action research, interviews, focus groups and ethnography/autoethnographies. These qualitative methods frame the majority of research we discuss within this stream of work e.g. (Zallio & Casiddu 2016), (Callejas & López-Cózar 2009) and (Caldeira et al. 2017). Nevertheless, quantitative approaches

can and have been applied in this work area too, including use of validated questionnaires such as the Technology Acceptance Model (TAM) within HCI studies (Knowles & Hanson 2018).

The ways in which technology is used by people within these socio-technical studies is varied. As discussed previously, fitness trackers, and tools for clinicians such as dashboards to remotely track, monitor and later discuss disease progression with patients are utilised (Procter et al. 2018). These tools are used by e.g. clinicians and informal carers as a way of facilitating communication between the different stakeholders in home care. This introduces a social and collaborative dimension to these studies, where interactions are supported between multiple actors, using data. This contrasts studies identified from the techno-centric work stream, which focus predominantly on Machine-to-Machine (M2M) communication, with a person only checking on the person in care's data at a much later stage. Whereas with the aforementioned socio-technically focussed studies, user engagement happens between multiple actors throughout the technology use lifecycle (Evenson 2008).

In these socio-technical studies, communication between people, facilitated by technology is also better supported. Socio-technical studies facilitate a broad range of communication types through different technologies; from dashboards (Jakobi et al. 2017), to smartphones (Hill et al. 2017), smart watches (Pizza et al. 2016), voice assistants (Stigall et al. 2019) and even unconventional household appliances such as wi-fi enabled fridges (Gu & Wang 2009). It is here we also build upon Wilson and Kozubaev's definitions of socio-technical systems (Wilson & Hargreaves 2017) (Kozubaev & Disalvo 2019). These authors identify socio-technical systems as a co-evolving relationship between people (actors) and systems. By their definition, both social and technical systems will continue to evolve alongside one another, but never converge, instead interplaying between human actions and technological responses. The socio-technical dimension of smart homes is therefore complex, negotiated and delineated through agreement, disagreement and boundaries between people and the ways that they engage with their own technology and data in the home. The majority of recent smart home technology falls under this categorisation and as such, most of the socio-technical studies seen in the domain discuss the negotiation of people and technology in this space, in order for successful engagement between groups of people and their devices to take place.

Aging in place, in particular exists as a socio-technical approach to smart home living. As described, this practise "allows older adults to remain independent in their own homes, for longer" (Gruning & Lindley 2016) (pp. 02). The following section builds on this socio-technical work, focussing more specifically on the 'humanistic' approach to smart home technology and describes in greater detail, the facets of socio-technical systems, which characterise them and distinguish them from techno-centric, medical or humanistic systems.

2.2.4 The 'Humanistic' stream

The categorisation of a 'Humanistic' stream of work within HCI health and care research distinguishes studies which prioritises people's daily, lived experiences and their social activities over a focus on the intersection of social and technical activities in the home with technology. To make this distinction clearer, consider first McNaney et al's (socio-technical) study of people living with Parkinsons. They conducted a workshop for people living with Parkinson's to undertand their day to day uses of IoT technologies specifically and how decision-making and ownership can be improved for these technologies (McNaney et al. 2020).

In contrast, Muñoz and Brereton's study of families also conducts a series of workshops with both parents and younger children to try and explore ways to bridge inter-generational differences in these homes using activities (e.g. a game to see whether they agree or disagree about topics or not), which ultimately helps both older and younger generations see eye to eye. The aim of these workshops was not to derive a specific technology design, but to use the activity itself to identify whether opportunities existed in this social structure, where technology could intervene (Muñoz & Brereton 2019).

Whilst a technological presence remains in these papers, many interdisciplinary contribtions (which also sit outside the body of HCI literature), focus largely on interactions that take place solely between people. These 'Humanistic' interactions vary and may be creative (e.g. through the exploration of non-stereotypical homes, such as boats, flats and how to design objects for these spaces (Desjardins et al. 2019)), empowerment (e.g. how to foster and create communities through which different types of care can be delivered at home (Retrum et al. 2016)) or more intangible ideas about the home (e.g. Elliot and Neustaedter's examination of shared and negotiated possessions and examination of boundaries and 'information constellations' in the shared home space (Gruning & Lindley 2016)). In any of these cases, these so-called humanistic studies place an emphasis on re-humanising lived experiences in the home with technology, which can be inherently de-humanising, essentially removing of people's values when new technology is used (Gaver 2002, Haines et al. 2007).

The humanistic work stream is the most wide-reaching of these streams, which aims to capture elements of everyday life that do not always fit into 'traditional' care practises in the home (for instance, through the use of speculative design to improve people's experiences (Schulte et al. 2016)). The use of collaborative and speculative design methods also further differentiates the humanistic from the socio-technical, through qualities such as ownership, collaboration and trust, that focus on the posession of specific objects that evoke moods, thoughts and feelings; human emotions not traditionally discussed in the practise of care in the home (Gruning & Lindley 2016). Other factors, such as technology mis-use and non-use also characterise this lens through (often

negative) human qualities such as ‘exercising power’ and ‘expressing distrust’ within homes and managed care facilities (Knowles & Hanson 2018).

The methodologies that this stream deploys primarily include Participatory Design, Co-Design, Design Fictions and Speculative Design and Re-enactment. One study by Desjardins et al. explores co-design activities with household members to develop tangible items to live with in their diverse houses e.g. fishing hooks with sensors for detecting nearby people on house boats (Desjardins et al. 2019). However, these studies need not just be qualitative and Desjardins et al. conducts a later study exploring how voice assistant data from can be engaged with through performance, thereby turning a quantified artefact (voice chat logs) into something again tangible and ‘humanised’ (Desjardins et al. 2021). Marikyan et al. summarises how these methodological approaches bring to light diverse "attitudes, beliefs and norms" which "reveal new variables [to the] adopt[ion] of smart home technology." (Marikyan et al. 2019) (p. 151).

Communities also feature heavily in papers characterised by the Humanistic stream. The role that communities play in technology engagement is diverse and differs between each community that exists. Jenkins et al. describe how older ‘co-housing’ communities in the US typically hold three values as central to their engagement between each other and with technology: sharing, sustainability and diversity. Adhering to these principles has allowed co-housing communities to thrive and arrange their agreed upon living styles around centralised civic buildings (e.g. where technology may be stored) and ‘town halls’ where the ways in which technology will be used within the community, are communicated (e.g. an agreed-upon style for sending emails) (Jenkins 2017).

The last of these values; diversity, underpins work within the humanistic stream as a characteristic of the people involved in creating or living diverse lifestyles. The importance of human diversity in the home is stressed by many studies in HCI, which largely focus on how the negative experiences of these groups can be identified and supported. For example, Retrum et al. discusses older adult LGBT+ living communities in the US called Naturally Occurring Retirement Communities (NORCs) (Retrum et al. 2016). The people living in these self-sustaining communities adopt a lifestyle that is intentionally different to the ways in which counterpart non-LGBT+ elders conduct their Activities of Daily Living (ADL’s) at home e.g. through creating their own physical space - or ‘third place’. In turn, this impacts their adoption and use of technology to support this third place. Here they can conduct activities, such as online board games, which they see as differentiating their own communities from neighbouring ones. Retrum et al. argues that this provides the community with a physical separation from stigma within society at large, that they do not wish to risk arising from socialisation with non-LGBT+ community elders. In another study of technology mis-use and abuse by people using IoT devices in the smart home, Parkin et al. suggest that LGBT+ and ethnic minorities must be involved in design conversations around

this technology's mis-use to ensure its suitability and relevance to these communities (Parkin et al. 2019). The implications of this work are significant for technology design, and highlight participation from minority groups as a significant humanistic challenge to overcome for the design of human-centred systems.

2.2.5 Summary

In summary, these lenses present a means through which to identify specific types of work done with smart home technologies, across studies that focus on different outcomes (clinical, social, creative, personal etc.). However, there are many different types of social or care activity (and work), that go unmentioned in these studies. For example, it is unclear in Chinner et al. (2018)'s study, what happened after they finished providing 'cognitive support' to older adults with dementia using smart watches and how these people coped using them without further support. Also, in Karlsen et al. (2019)'s study, it is unclear how family caregivers found the process of 'continuous follow-up and adjustment' over longer periods of time. These human-centered questions around the use of such complex systems, inform our framing of RQ3, looking at how collections of devices, when used collaboratively ultimately inform their acceptance later.

2.3 How people use smart home technology

This section addresses how smart home technology is used from the literature discussed across these four streams of work, looking in greater detail about the practical applications of this technology, its uses, mis-uses, and the spatial and temporal dimensions in which both forms and modes of use and innovation with smart home technology occur. In particular, this section develops a reflective tool (the forms and modes of use diagram), that is used to understand how technology is socially and collaboratively constructed as well as used and how it can be socially appropriated too. Research which has touched on this is discussed, which leads into a broader synthesis of how this understanding informs a research direction for this thesis.

2.3.1 Customisation

Customisation describes the opportunity for people to tailor the technology they use according to their own preferences e.g. the user interface on a mobile device being set to 'dark mode' to prevent eye strain (Burrows et al. 2018). Within the context of smart home Internet of Things (IoT) technologies, customisation may also be a shared act e.g. a family choosing the style of voice of a virtual assistant that suits the household.

IoT technologies used in homes may potentially be used for both clinical and non-clinical purposes by different household members. For example, an Alexa device that provides medication reminders for a person in care can also provide music streaming for other members of the household. The studies from Bradford et al. (2018), Elliot et al. (2005), Desjardins et al. (2019) show how IoT technologies are used to support care in these contexts, and how they should be customisable by multiple residents if a household consists of more than one member beyond the person in care.

Gruning and Lindley (2016) highlight the differences in customisation practises around technology in single and shared ownership households. In this work, they define the notions of 'primary ownership' and 'joint ownership' - between a single person or multiple people living in a household. In single/primary-ownership scenarios, people customised their possessions less, and there was less of a need to place them apart from 'shared items' such as communal TV sets (Gruning & Lindley 2016). This is furthered by the work of Mynatt et al. (2001) who explores the social presence of digital family portraits, looking at how devices can be appropriated and customised together, rather than just being speculated about or appreciated as explored in Gruning and Lindley's work. In cases of co-ownership between more than one person in the household, items were heavily customised e.g. placing 'coloured labels' onto books in a shared bookshelf, or in the case of 'digital possessions', customisation took place through the use of locked or open repositories of information, left available for household members.

Customisation therefore highlights two important aspects of how people use technology in the home. Firstly, that customisation is frequent in homes with more than one resident and secondly, that there is a distinction between the ways that digital and non-digital posessions are customised, where for the former; leaving the device in one particular state e.g. unlocked, acts as a way of inviting other residents to use the device or to appropriate it further (Gruning & Lindley 2016). In the smart home domain, this type of customisation is also touched upon in studies such as Marikyan et al.'s use of a 'tailored interface companion robot' (Marikyan et al. 2019) accessible to people native to and not native to the household (e.g. the owner, versus a carer). However, the extent of customisation in smart homes could be explored further, identifying the roles of others who customise in the home, besides solely the owner of an object or piece of technology. These 'messy' Hägglund et al. (2010) types of interactions between different residents could facilitate different types of customisation, which are valuable for designing for different types of smart home technology.

The 'physical' and 'digital' types of customisation that Gruning & Lindley (2016) describe, indicate broader and more nuanced forms of use for different types of objects and technologies. We go on to identify these different forms of use (situations) below that are described elsewhere in the literature and then contrast these against modes of use (between actors, locations etc.),

which have emerged within our search of the literature. Both the forms of use and modes of use below involve the engagement of both people and technology - and also the convergence of both people and technology, to enable new ways of interacting with and appropriating this technology in the smart home, for a variety of uses.

2.3.2 Forms of use

'Forms of use' of smart home technology are discussed within our selected literature - that is; the various situations in which this technology is used (within various studies) by actors involved in caregiving within the home. This section derives five distinct types of use - expected use, creative use and appropriation, mis-use, over-use and non-use - arising from the analysis of the selected papers, which are discussed further, below. A short summary is then provided of the forms of use that are identified, before highlighting how this may contrast with the modes of use described after.

2.3.2.1 Expected and Unexpected use

Expected use covers people using technology in its expected manner; that is, without any form of unconventional appropriation. However, there are situations arising in the selected literature where technology use that is described as being as intended, is in fact not, due to unintended factors such as time spent using devices by elderly residents. For example, Caldeira et al. describe the use of technology within Continuing Care Retirement Communities (CCRC's) (Caldeira et al. 2017). In this environment, elderly residents were prompted to monitor and self-track their wellbeing over time using mobile devices. The use of these devices fluctuated and influenced later abandonment and lack of self-tracking, in cases where residents were 'over-observed' by care staff. As has often been detailed in the aging in place literature, older adults value their independence greatly (Marikyan et al. 2019, Lazar et al. 2017, Bradford et al. 2018, Light et al. 2015). In this instance, the interventions of the care community staff in monitoring the residents to ensure they are self-tracking created additional difficulties for the older residents which may have seen standard use otherwise. Whilst the technology was operating and was used as expected, the influence of the external factors here (e.g. time with the devices, presence of others) on the older residents, held negative consequences for expected use.

2.3.2.2 Creative use

The creative use of technology by older adults occurs prominently in the selected literature. Dourish et al. (2003) defines creative appropriation as "the process through which people adopt and adapt technologies, fitting them into their working [or living] practises." (Dourish 2003) [p. 472]. Within the literature reviewed, creative use of smart home technology is typically described as the intentional deviation of the use of technologies from their intended purpose e.g. through

DIY 'hardware hacking' (Callejas & López-Cózar 2009), or through customisation or appropriation for specific purposes, suited to a person's lifestyle. This is different from the aforementioned unexpected use, as this stems instead from unintended, external factors which affect traditional usage patterns, whereas creative use is intentional. In many instances, the literature describes the use of wearables such as emergency alarm pendants by older residents as being 'modified' from their intended purpose by residents. For example, in Soro et al.'s study, wearable pendants are 'hidden' or 'placed low down' in the home, usually to show "that the device is cumbersome, intrusive, and, in some degree, demeaning." (Soro et al. 2017) [p. 7]. This notion that the expected use of care technology is to varying extents 'demeaning', is prevalent in discussions of this technology. The stigma associated with its use, especially when others are present (e.g. (Caldeira et al. 2017)), frames much of the motivation for older adults' creative appropriation of their technology, in order to make it look less clumsy, stigmatising or burdensome for them. These implications are discussed further within the section on stigma and its implications across both older and younger generations who cohabit, in the design of smart home technology systems.

2.3.2.3 Subversive Use and Non-use

There are many instances within the aging in place and smart home literature, where technology is mis-used by one or more people or altogether abandoned. Within this selected literature, mis-use entails the appropriation of technology to such an extent that it may be deemed unsafe. This is again different from customisation and creative use, which describes modifying technology within its existing operating parameters. Subversive use within the domain of care technologies is described by Bradford et al. whereby people in care at home have circumvented the use of e.g. 'smart thermometers' by manually entering their temperature readings (avoidance) either when the device has malfunctioned or they have disagreed with the indicated reading (negation) (Bradford et al. 2018). For example, within the smart home domain, the act of concealing has been achieved by placing cloths or drapes over sensors in the household (Bradford et al. 2018). Of particular interest is the notion of concealing described by Astell et al. whereby residents would express concerns about visitors to their home "about technologies that were visible to others." (Astell et al. 2019). Again, this study identifies the importance of perceptions that people in care have about their home, when it is seen by visitors or wider family to the home. In this sense, the care is extending beyond the bounded space of a single home and leaving impressions upon guests and wider family.

Non-use within the smart home domain is typically characterised by two additional components: trust and redundancy. Trust in a system appears essential to the initial uptake and usage of a specific piece of technology. As Procter et al. describe, successful use of some systems must be

made up of a "bricolage" of trust by all stakeholders in a ‘care network’ (family, friends, clinicians, guests, to the home) (Procter et al. 2018) [p. 11:4]. In this sense, non-use may arise when a person in care is first introduced to a technology, if it is not fully endorsed by all of the stakeholders in that person’s care network. Secondarily, non-use of smart home technology may come about towards the end of the period of expected use for a piece of technology, if it appears redundant to the person being cared for. As described by Geeng and Rosener, parents of children would often stop using specific pieces of technology e.g. baby cameras when their children transitioned into a different life stage, as they felt this intruded on their privacy (Geeng et al. 2019). It is therefore apparent that central to the non-use of smart home technology are issues of trust, redundancy and privacy, emerging at the start and end of the ‘usage journeys’ of specific pieces of technology (Brown & Venkatesh 2005).

Beyond these usage instances, negative consequences of device use in the home can also come about through over-using technology.

2.3.2.4 Over-use

In contrast to the mis-use and creative use we have described, there are also inherently negative aspects of smart home technology use that come about through using devices too much. Technology over-use can be described by situations that arise where the excessive use of a single piece of technology, can lead to negative health consequences, as a result of exhibiting certain attitudes or behaviours. This can take place either by the person in care or their caregivers. An example of this is discussed by Tori et al. (2022) where they describe the concepts of ‘gamification’, whereby the story-driven and progression-based features of games are leveraged for the design of technological systems and ‘serious games’ whereby technology (such as smart watches) is used for non-entertainment purposes e.g. health tracking. Repercussions of using ‘serious games’ scenarios in health contexts are exemplified here whereby parents may end up encouraging their children (with Type II diabetes), to compete for the lowest blood-glucose level. In the context of older adults, such serious games may also appear reductive or humiliating for those with multi-moribities. For example, turning complex health conditions into simple visualisations within a system (such as a smiling face, if a person is in good health), can come across as patronising to older adults, who give concern and importance to their health conditions (Consolvo et al. 2004).

2.3.2.5 Summary

This section has explored different facets of interaction between people and smart home technology. In Customisation the individual and shared practises around modifying homes were identified, and happens often in shared settings. The Forms of use section identified how expected and unexpected use often influence adoption and technology retention behaviours such as abandonment. Creative use showed how devices in the home can be repurposed or 'hacked' in order to perform a more specific of specialised function for residents. Lastly, the negatives of use and mismanagement of smart devices were also identified with 'subversive use and non-use'. These different forms of use all showed how, within existing literature, smart home technology can be appropriated or rejected by a household dependent on its social makeup, aesthetic desires and care needs. Contrasting the forms of use described above, 'modes of use' for smart home technology are further described in the next section.

2.3.3 Modes of use

In this section we describe the modes of use for smart home technology. The 'modes of use' described in this section complement and extend the 'forms of use' discussed previously. Whereas the forms of use we described, showed the extents to which technology is used by different actors in the caregiving process, at different levels, we differentiate modes of use through the context-specific situations in which such technology may be used. To exemplify this, we provide three modes of use - collaborative use, temporally distributed use and location-specific use. Studies are identified which make use of these various modes, and contributions of these works are summarised at the close of this section.

2.3.3.1 Temporally-distributed use

Through examining the ways in which technology is used within smart home studies, we have identified that temporally-distributed use of technology is typically either event-based, or ongoing.

Soro et al. (2017) characterise event-based usage as "the need for older adults to configure and reconfigure their worlds [over time]" (Soro et al. 2017) [p. 6]. By attributing attitudes, values or emotions towards objects or pieces of technology they may own, older adults assign meaning to objects, not only for themselves, but for others in their home. For example, in Soro et al's study, as one of the precursors to the design of the 'messaging kettle', feelings and meanings towards objects such as mugs and pots were gathered, to help identify what attitudes were typically present towards these items (Soro et al. 2017). Other temporally-focussed activities in the smart home come about as Kurze et al. describe, where 'sensemaking' of personal smart home sensor data does not happen all at once, but over time, as understanding of the data and how to use it, evolves between residents (Kurze et al. 2020). This is reflected elsewhere e.g.

in personal informatics research within HCI where the act of, for example, inputting fitness data into wearables or smartphones, increases people's abilities to track and monitor their own wellbeing as time passes (Nunes et al. 2015).

Ongoing usage describes events that happen in continuous succession throughout a person's life: routines. Routine-driven care is also common in the smart home literature. Soro and Brereton identify how a group of older women used objects to facilitate their daily routines e.g. placing telephones at the top and bottom of the stairs for convenience and, with decreases in capacity, in light of falls (Brereton et al. 2015). Ongoing use of routines is also applicable to the division of responsibilities in the home. As Karlsen et al. describe, there is no clear definition for the 'roles' of family caregivers, therefore information must be distributed and stored across devices over time and updated regularly (or in paper-based formats) around the home, based on the unique and nuanced household routines and interactions that take place there. This can help to facilitate care routines and to delegate tasks and register routines as completed (e.g. ADL's; electronic shopping lists) once tasks are completed (Karlsen et al. 2019).

2.3.3.2 Location-based use

Location-based use of smart home technology forms the last of our categories of 'modes of use'. We describe this mode of use as being dependent upon the location within a home, where use of technology for a care or ADL-related activity takes place. Elliot et al. describe the concept of 'information constellations' existing within a variety of homes (Elliot et al. 2005). These 'constellations' describe how areas within the home tend to be grouped according to the information stored there. For example, shopping lists would typically be stuck to surfaces in the kitchen. These findings also apply to interactions between households with technology. In the same way that a household may have a 'to-do' list posted on the kitchen fridge with tasks for everyone in the home to complete, people also gather round televisions for shared experience (Elliot et al. 2005), collaboratively use Amazon Alexas for shared communication (Soro et al. 2017) and share health readings between individuals as a form of 'exer-gaming' (Nunes et al. 2015).

Smart home technology, unlike other devices (e.g. TV's or pendant alarms), are not typically destined for use in any once specific location in a home, due to the diversity of home structures that exist (Desjardins et al. 2015). As a consequence, both positive and negative aspects of usability arise. As Elliot et al. continues, "knowing the [personal] value of locations" (Elliot et al. 2005) [p. 16] in the home, attributes objects and technologies with that same importance. For example, a family heirloom placed above a fireplace, may signify its importance to that household. In contrast, smart speakers such as Amazon's Alexa are not afforded any additional value, whether they are placed above a living room fireplace or in a bedroom. Therefore, integration of more complex smart home devices into the household (e.g. IoT sensor systems) may come as more

of a challenge for use. As Elliot suggests, providing flexibility and adaptability to be able to fit into specific locations in the home without becoming incongruous, is a challenge for smart home devices (and IoT devices more generally). A range of solutions towards achieving integration in the home are suggested; including novel human-centered solutions such as projection systems which display messages in appropriate locations throughout the home. Nevertheless, these type of solutions remain costly for the average household and are largely research-driven or state of the art pieces of technology, above consumer-grade affordability. Design of smart home object s could also be improved by allowing older residents more flexibility to customise and adapt their own posessions, making off-the-shelf technology seem less impersonal. The ability to tailor smart home technology to individualised settings could be offered to help support both formal and informal caregiving through familiarisation and reassurance.

2.3.4 Applying forms and modes of use as a tool

Above, the specific forms and modes of use that can be used to understand the application of various smart home technologies are discussed, along with key research approaches and contributions, which are used to motivate this thesis' research and to outline the key in studies in across the most relevant chosen literature.

It is possible to see how, for example, technologies exist that align across both categories of use (forms and modes) (Fig 2.2). The Amazon Alexa is a popular smart speaker which typically performs in its expected manner of use in a single location within the home. In contrast, telecare pendants used by older adults in care facilities are a collaborative technology between the person in care and their carers. They may however, be mis-used, moved around and used by multiple owners over time or as Caldeira et al. describe, hidden or moved elsewhere in the care home (Caldeira et al. 2017). Within the context of this thesis, forms and modes of use help to illustrate how the technologies discussed in the smart home health and care domain, fit within the range of human perception, ability and lived context for using different devices in the home, which is often opposite to the mobile-centred, person and handheld ubiquitous mobile devices that most people own (Dourish 2004, Weiser & Brown 2001, Desjardins et al. 2019).

2.3.4.1 Collaborative use

Collaborative use of smart home technology is commonly discussed in the context of informal caregivers in the home, with technology sharing taking place between individuals and also with a community-wide coordination of resources for collaborative activities. Informal caregivers often take on different roles within the 'care network', of a person in care (Procter et al. 2018, Zallio & Casiddu 2016). Informal caregivers are commonly identified as the adult children of older

parents who wish to either live-in with, or visit their elder relative in order to provide hands-on care for them as a person's physical or cognitive capabilities become hindered by age Karlsen et al. (2019). As described by Karlsen et al., family caregivers provide a range of support with technology use; from reminding older parents to wear their telecare pendants, updating their calendars and medicine reminder information, reducing 'task-specific' burdens of Activities of Daily Living (ADL's; e.g. washing, cleaning) and providing emotional and social support to combat loneliness in the home (Karlsen et al. 2019). In this sense, informal caregivers are collaborators within the care process, where they are able to contribute, extend and support the existing care provided to older adults through formal care services and by adapting and learning to use of many different types of smart home technology available to them to support the older adult they are caring for.

Other forms of collaborative use within the literature include technology sharing and community coordination. Technology sharing is exemplified frequently within the smart home literature as a means of collaboration. Gruning et al. (2015) discuss 'Placing in age' in the context of a study which looks in detail at the lives of a group of older women living in a retirement community, where collaboratively designed objects by the group aided them with recall of past memories in their lives and which were stored around their homes in the community. When designing the objects for each home, residents were able to intervene and provide their own recollection of a place or an event should the memory of another resident be deteriorating; which would inform the design of their friend's object (Gruning & Lindley 2015). Beyond this, knowledge was also shared amongst the group and the act of teaching the group how to crochet their objects was enacted in a distributed manner amongst the care home residents.

Community coordination also exists within the smart home literature in regard to collaborative use of the technology. Jenkins et al. describe the practise of 'cohousing' whereby diverse groups of people choose to live together who share values and resources (Jenkins 2017). These small communities draw together like-minded individuals with shared values into 'cohousing settlements' which advocate the collaborative use of resources, space and technology. Of particular interest is the use of a 'common house' - a single dwelling, typically at the centre of a co-housing community which is accessible by everyone in the area. In these spaces, technology is available to everyone in the community. This arrangement provides a unique perspective on the ways in which boundaries of public and private spaces are set, common to most smart home literature that focuses on single, privately owned dwellings. Much of the smart home literature also portrays devices as being set up for access by one user e.g. (Callejas & López-Cózar 2009, Burdick & Kwon 2016, Kozubaev & Disalvo 2019). Whereas within the centralised 'common house', TV's, computers and even smart fridges are set up for everyone within the community (Jenkins 2017). As Jenkins et al. suggest, this provides an alternative vision of use for the future of domestic IoT. However, we propose that there are also greater implications of this use of IoT for diverse communities, who are disparately

	Expected Use	Creative Use	Mis-Use	Over-Use	Non-Use
Collaborative Use	Amazon Alexa	Use of keys on string for multiple residents (Marikyan et al.)	Telecare pendants being hidden around care homes (Caldeira et al.)	Serious games e.g. competing for lower blood glucose scores (Nunes et al.)	Care home residents removing sensors from their rooms (Caldeira et al.)
Temporally-Distributed Use	Fitness trackers (Nunes et al.)	Home 'history' books (Desjardins et al.)	Medication book reminders being ignored (Procter et al.)	(As above)	Cognitive decline impacting non-use of smart watches (Soro et al.)
Location-Specific Use	Nest home environment systems	Info 'windows' (Desjardins et al.)	Post-adjusting beds in CCRC's (Caldeira et al.)	Movement data readings being taken to often on smart monitoring systems (Burrows et al.)	Pulse oximeters hidden in private rooms when guests visit the home (Knowles et al.)

Table 2.1: Form-mode use tool: Table identifying how our proposed forms and modes of use can be applied to categorise specific technologies and uses of technology in the literature. Some technology activities, e.g. serious games described by Nunes et al. can fit into both collaborative and temporally-distributed use.

located across different communities. Leveraging community smart home technology, could also serve to draw together minority communities for example, to reduce isolation for individuals and improve the cohesiveness of minority groups that live together. The implications of smart home technology for minority communities are discussed in greater detail in the following section. Whilst communities demonstrate collaborative use, we can also look to the temporal dimension of the use of smart home technology in informal and formal caregiving settings.

2.3.5 Summary

The identification of different ways that smart home technology is used frames the discussion of specific barriers to use in this section. The tool above demonstrates how use is both social and distributed in different home environments and how some technologies (e.g. Alexa, fitness trackers and the pulse oximeter study) afford specific social actions resulting from their social presence. This in itself, is of interest to investigate further and forms the basis of RQ2, looking to understand how social activities can be conducted collaboratively in the home through the use of

commercial smart home technologies too.

The previous section identified the need to engage more with the needs of residents besides the person in care. As the home is complex socio-technical and humanistic space, there must be greater consideration placed on the collaboration and interaction between the person in care and other people living in the home so that technology can be cooperatively designed for the needs of informal caregivers as well as older adults in care. Nevertheless, there are currently a great deal of barriers identified within the smart home literature, that prevent such an easy convergence.

2.4 Mis-matches and barriers to use

In this section, we identify mis-matches and barriers to the use of smart home technology. Trust, Identity, Privacy and Security (TIPS), safety, stigma, knowledge deprivation and the medicalisation of the home are introduced as barriers to the use of domestic technologies. Whilst the smart home literature is abundant with challenges that are dependent on the different applications of technology, within the different literature reviewed, the aforementioned challenges are the ones which are most prominently discussed and appear most frequently throughout all works. Limitations to these studies are also addressed, which are identified in order to inform research study planning in this thesis.

2.4.1 Trust, Identity, Privacy and Security (TIPS)

This section deals with common issues of Trust, Identity, Privacy and Security. It is beyond the scope of this literature review to provide a complete account of these four areas within the smart home domain, so discussed in this section are contributions relevant to this thesis' aims and objectives.

The most commonly discussed barrier to the use of smart home technology is the ability for people to trust the technology they use, protect their privacy from unwanted presences (J Kraemer et al. 2019), secure the information they own (Cho 2019) and preserve their sense of identity in their home (Davidoff et al. 2006). At the highest level, Marikyan et al. and Lindley et al. discuss how these TIPS challenges are framed by a need for reassurance, comfort and a sense of safety and care being provided across all homes (Marikyan et al. 2019, Lindley et al. 2009).

2.4.1.1 Trust

Trust is framed within the smart home literature in different ways. Callejas et al. discuss a dialogue-driven smart home interface system, which would allow the elderly to communicate

with their technology 'more directly' (Callejas & López-Cózar 2009). When surveying elderly respondents, older adult participants expressed a distrust in the system if it failed on them (if it did not perform the task correctly, or they lost their information). Participants in this study also indicated they would not use the system again if it failed on them in such a way. This indicates that older adults' trust in technology is fragile and more easily lost than younger peoples' trust.

Responses such as this are similar across other studies which identify trust in system usage. Karlsen et al. and Marikyan et al. both identified how older adults are skeptical of the benefits that smart home technology will bring to their lives, when they are faced with managing multi-moribidities (Karlsen et al. 2019, Marikyan et al. 2019). Their studies also reinforced the evidence that older adults will stop using smart home and telecare systems they cannot trust the system to meet their needs.

Trust is also discussed in the literature beyond the older adult in care. Jaschinski and Allouch's study highlights how informal caregivers also place trust in systems which are designed to support their older relatives (Jaschinski & Ben Allouch 2018). Participants in this study indicated that they felt comforted when the telecare system notified them that their elder parents had a fall in their home. In this sense, they placed trust in the system to perform its expected use. In other cases, if the system did not perform in the expected way, this lead to a lack of interest in households adopting new devices and lower acceptability of existing home care systems (Callejas & López-Cózar 2009).

Trust in smart home technology has been shown to be fostered between different devices and older adults through the device being able to provide reliable, predictable actions that help people to conduct everyday, mundane household duties such as washing, cleaning or cooking (Knowles & Hanson 2018). In contrast, a study of technology use in residential care settings showed that older adults who lived with non-wearable sensors (e.g. wall-mounted devices that detect motion, falls), reported greater trust in this technology when they could interact with other residents to discuss the technology. These shared conversations helped to foster greater trust in the devices through dispelling negative self-perceptions (Caldeira et al. 2017). The shared and communally discussed use of technology in different living spaces has fostered greater adoption of smart home technology, increasing independence and supporting aging in place (Knowles & Hanson 2018).

For older adults, much aging in place literature focuses on technology that supports connecting them with friends, family and caregivers (either formal or informal) (Kon et al. 2017, Lazar et al. 2017, Odom et al. 2010, Schorch et al. 2016). However, older adults report issues with adoption and ultimately, trust in smart home technologies, if they feel that the use of technology is not reciprocated by others around them (Astell et al. 2019). Caldeira et al. (2017) builds on this, reporting how negative perceptions arise for older adults in care settings when a new technology

is thrust upon them, as opposed to trust being built incrementally, through sustained use (Soro et al. 2017). In addition, research on multi-generational households show that adult children, spouses and other live-in or live-out residents can impact misuse, non-use and adoption of health and care technology (Astell et al. 2019, Kon et al. 2017, Lazar et al. 2017). As a result, it is of benefit then to consider how factors such as trust in voice assistants and other devices, develops at an individual level (e.g. for a person who is isolated), in order to gain a situated understanding of the wider, more complex process of adoption and acceptance of VA technology for health and care that is influenced by others.

Geeng and Rosener further this discussion to the involvement of trust in people living outside of their home, who may visit the home frequently. Their participants discuss how a smart home entry monitoring system allowed them to place greater trust in who they allowed into their home, as they did not trust handing out physical keys to people outside of their immediate family (Geeng et al. 2019).

Knowles et al. also describes varying levels of trust in older adults sharing health information with clinicians (Knowles & Hanson 2018). For example, participants in this study indicated high levels of distrust in sharing health information with clinicians as they were convinced that it would be passed onto government organisations and sold onto insurance companies.

All of these descriptions fit varying definitions of trust within the smart home domain. This evidence primarily indicates that trust in smart home technology and health and care data that these devices collect, varies between people. It is harder therefore, to ascertain a general sense of trust in a specific technology across the home as different residents may invest different levels of trust in technology. Distrust in systems by older adults is a serious consideration for designers of smart home technology. This apparent within managed health and care environments where patients' trust is low and as a result, from not wanting to share their health status, this becomes safety-critical to people's wellbeing (Scrivener et al. 2021) and to feeling personally supported (Larrea et al. 2022). Trust is therefore a challenge to overcome for smart home technology design so that all resident stakeholders can be engaged with care through smart home technology and feel comfortable placing trust in these systems.

2.4.1.2 Identity

Identity is characterised in the smart home health and care literature as the self-perception of older adults towards and their ability to maintain a sense of self as they age. Independence and autonomy largely frame discussions of identity in this literature (e.g. (Astell et al. 2019, Gram-Hanssen & Darby 2018)). Independence refers to the ability of older adults to live separately from the interference of other people in their lifestyles. Autonomy on the other hand, is exemplified by

Soro et al. as older adults holding the ability to conduct their lives by themselves and perform, for example, activities of daily living (ADL's) (e.g. washing, cleaning), by themselves (Soro et al. 2017).

The identity construction of older adults is therefore quite complex and is characterised in different ways within the smart home literature. What is common between discussions of older adults' identity is a renegotiation of roles between the older adult and the people they may reside with (who may also be younger than them), as they age, as exemplified by (Muñoz & Brereton 2019). This renegotiation of roles encompasses the duties they engage with on a daily basis, e.g. washing bathing, as well as wider responsibilities for the home e.g. caregiving for younger children. This impacts the older adult's identity as, when tasks are delegated away from them to others, it is necessary for them to assume new roles and re-frame their identities to adapt to change.

As a result of giving physically demanding household tasks such washing and cleaning over to younger residents in the home, power imbalances may come into play. As Gomez et al. discusses, new arrangements are necessary to accommodate 'increasing fragility' in older adults and relinquishing a sense of agency may cause tension, resentment or at worst conflict between residents, who are now burdened with increased care responsibilities and household duties (Gómez 2015). Therefore, as a result of older adults' re-framing their identity, the adult children and informal caregivers living in the home may also have to reevaluate their identities and roles in this shared home.

Lastly, older adults' identity is often discussed differently when they are asked to describe themselves compared to others outside of the home. Some studies show participants holding the view that technologies that had been designed for older people, were not for them but instead were for a generation of people more old and infirm than they were (Astell et al. 2019, Bradford et al. 2018). Such self-perceptions are important for designers of smart home technology to understand and engage with during the design process. Designing technology for stereotypical visions of 'the old' can be reductive and lead to abandonment if this technology does not align with older adults' values and self-perceptions (Lazar et al. 2018). Therefore, it is necessary to consider designing technologies for people of all ages, but which also facilitate the mental and physical changes older adults' experience as they age.

2.4.1.3 Privacy

Discussions around privacy are one of the most commonly discussed topics within the smart home literature. Privacy is usually discussed in regard to how privacy is set up, maintained or lacking in particular technologies. Soro et al. discuss how privacy is typically talked about

between household residents as a matter of "confidentiality" whereby users are either able or unable to set their own boundaries for aspects of their lives that they wish to share or keep private from other residents (Soro et al. 2017) [p. 5]. Technology use therefore complicates the division of privacy within a home.

As Marikyan et al. discuss, privacy is also another important factor affecting technology adoption and the acceptability of smart home technology (Marikyan et al. 2019). Many systems that make use of features of automation, may inadvertently breach the privacy of users in a home, for instance, setting medication reminders on a voice assistant like Alexa, for an older adult in care, can be overheard by other residents. Senstive information, such as medication type and frequency, can therefore also be overheard by other residents or even visitors to the home, compromising the privacy of the person in care.

Surveillance and video monitoring are also privacy concerns unique to smart homes. Smart home sensor systems such as SPHERE Burrows et al. (2018) deploy sensors which track movement and the 'silhouettes' of people in the household to preserve privacy. Whilst this data is anonymised, studies have also highlighted the issue of unintentional surveillance, whereby this information can be on display through visualisations in public spaces (e.g. the living room), instead of private spaces (e.g. the bedroom) (Kon et al. 2017, Kozubaev & Disalvo 2019).

Issues of privacy in smart homes therefore raise unique concerns about the use of the technology in these spaces as well as who this is monitored by. Considerations for the design of smart homes must therefore who holds access to this data (both intentionally and unintentionally), so that the information stored across devices can be administered effectively and privately.

2.4.1.4 Security

Security of the information that is generated within the home is controlled in different ways within different studies. Security encompasses the ways in which data can be protected on devices (e.g. encryption of passwords).

In a study by Knowles et al. participants discuss their online banking security, admitting that whilst they acknowledge that their data may be secure, some claimed for example, "I'm risky"; indicating that they do not trust themselves to keep their data secure and therefore may be unreliable in ensuring their own security (Knowles & Hanson 2018) [p. 21:11]. The reasons that older adults may be more at risk of decreased personal security is suggested to come from, as Knowles et al. describes, a lack of 'conceptual understanding' around the basic principles of securing technological systems, through which vulnerabilities can be exploited (Knowles & Hanson 2018).

In Karlsen et al.'s study however, the importance of family caregivers is again highlighted as younger generations often step in to provide extra safety and security for their older parents' online accounts (Karlsen et al. 2019). Older adults with cognitive decline also relied heavily on their younger adult children to remember passwords and perform software installation or setup of telecare devices in their homes. When nurses were not available to intervene in this, informal caregivers were required to learn how the technology worked and to set this up themselves, to secure these systems from interference - either from other members of the household or from fraudsters.

Enforcing security for older adults in smart homes is therefore identified as a primary TIPS challenge and barrier to use. As informal caregvers such as adult children are the only other people available to secure technology for older parents, it falls on these individuals to figure out systems and understand how they are used (Schorch et al. 2016, Ruggiano et al. 2021). Opportunities arise here for better means of familiarising these lay caregivers with processes for securing and administering care technologies. Smart home designers could therefore provide greater resources, training and support either through care services, or independently in supporting informal caregivers to help protect older relatives technology.

2.4.1.5 Limitations of TIPS studies

The TIPS-focussed studies identified here also include some limitations. For example, Karlsen et al.'s hermeneutic study, which identified the experiences of 10 older adults' with histories of substance abuse, trialled the use of smart home technologies, to collect accounts of their experience with this technology (Karlsen et al. 2019). Whilst this provided insights into their concerns with security, it would be of interest to understand security concerns from different groups' perspectives to see if there are similarities and differences or shared experiences. Similarly, Muñoz et al.'s study showed position exchanges on points of view between younger and older adults (Muñoz & Brereton 2019). Interviews in this study mostly focused on the 'positions' of younger adults, whereas a closer comparison between these interviews and the positions of older adults' shared differences in technology perception between younger and older generations which could have been more closely reported on.

2.4.2 Social presence and sociability with smart home voice assistants

To understand social presence in this section and the next, it is useful to look at this with a technology that is widely accepted to convey a social presence within the smart home: that of

voice assistants.

The HCI literature describes the phenomenon of "social presence" broadly. Pereira et al., for example, define it as "the sense of being with another [human being]" (Pereira et al. 2014) [p. 1450]. Others define the phenomenon in greater detail, stating that it is the human-like qualities of a technology that embody social presence within a specific device (Kontogiorgos et al. 2020, Winkler et al. 2020). Efforts to provide these embodied human characteristics that enable greater social presence reportedly range from giving devices artificial limbs (i.e. robots) Kontogiorgos et al. (2020) to replicating the human face (Wang et al. 2019) and voice (Winkler et al. 2020).

Interestingly, work in the CSCW domain, focusing on group-based perceptions of social presence in different technology settings (outside of VAs), has revealed that a stronger sense of social presence is perceived dependent on the degrees to which the agent becomes involved in a group's activities (Lee & Nass 2003, Pereira et al. 2014). Specifically, in a study by Shamekhi et al. (2018) of shared use of voice assistants, participants detailed a number of factors that influenced the strength of the 'presence' of the technology, such as the amount of time spent in that setting with the device, the number of successful interactions, and the ways in which the device could interact with participants (modality e.g. screen, voice, arms, legs etc.).

However, the factor that most strongly influenced 'presence' of a technology was when the device was assigned a human name (Shamekhi et al. 2018). It is here that this study's own research begins to intersect the existing work on social presence found in voice assistants. The understanding of social presence by Shamekhi et al. (2018), also directly informs our understanding and research approach; acknowledging that shared perception of social presence is the sense that other intelligent beings co-exist and interact with people, even if those beings are non-humans. The lived and shared experiences of the 'presence' of a multi-modal voice assistant can be examined in detail during a time when almost all health, care and wellbeing needs are being experienced and actioned at home by older households. Therefore, understanding the impact of social presence can lead to an understanding of the boundaries between the social presence imbued by e.g. voice assistants, and the social presence innate to human-human communication. This can help digital health and care designers to build more appropriate conduits for social engagement rather than technology driven social presence.

We build on work that has shown how health and wellbeing studies have shown the need to evaluate different healthcare interventions at different points in time Peek et al. (2014) e.g. pre- and post-installation, for the research and design of novel technologies Ayobi et al. (2016), where health and wellbeing interventions are well documented (Bjering et al. 2014). A deeper understanding can be gained from studying VAs before and after installation, balancing between looking at users Kon et al. (2017) and at the technology (Rashidi & Cook 2013).

2.4.3 Impact of social presence on voice assistant technology

Voice assistants (VAs) are devices which allow their users to converse, ask questions, and obtain information simply by speaking to the device (Pradhan et al. 2019). Often a trigger word is used to wake the device and begin a conversation. VAs are not confined to the mobile device landscape (e.g. Siri on iPhones) and can also be integrated as standalone, fixed devices that are a part of people's homes. The current commercial leader is the Amazon Echo Gao et al. (2018); an Alexa-enabled smart device that has been the source of academic attention as a socio-technical component of households (e.g. (Pradhan et al. 2018)).

Research shows that voice assistants have been used extensively as shared (communal) devices within the home. Porcheron et al. (2018) discusses challenges of VA use within multi-person households, in situations such as when conversational breakdowns occur. In these situations, a multi-person family might try to engage in conversation with the device at the same time. As voice assistants only respond to one person at a time, this can cause interpersonal tensions as well as difficulty operating the device if it is receiving conflicting commands (Porcheron et al. 2018). As the device can also only respond to one command at a time, many conversational interactions are missed and as such, fully multi-person interactions with the device cannot occur. A study by Fuentes et al. (2019) suggests moving away from 'scripted' interactions, with a single person speaking to the device at once and instead, developing the technology to support open-ended conversations with multiple actors. Other findings by Beneteau et al. (2019), Garg & Sengupta (2020) demonstrate how this lack of support for multi-person conversations has implications for family interactions, for instance where parents and their children are trying to use a voice assistant for different purposes (e.g. parents running errands, shopping and children wishing to play games on the device) causing tension (Beneteau et al. 2019).

However, VAs show much potential for health and care support for shared devices, including the shared use of voice assistants that facilitate care, for example amongst families with mixed visual ability Storer et al. (2020), stroke survivors Aidar et al. (2011) compensating for physical and cognitive impairments, and people living with Parkinson's Duffy et al. (2021). Similarly, recent studies discuss how VAs provided an opportunity to better engage with marginalised groups (people who may be at an inherent disadvantage within society due to a physical or mental disability), who may otherwise struggle to use non-voice based technology (Seetharaman et al. 2020).

Beyond this, studies have also shown the negative sides of using VAs for positively-intentioned health and wellbeing support, where they have been over-relied upon (e.g. by adults of all ages

to tailor and personalise content in different multimedia formats Liu et al. (2021), Trajkova (2020), Singh et al. (2020)), caused nuisance to other adults or arguments, when many household members talk over one another to ask the device a question (Richards 2019). Similarly, Liu et al. discuss how some VAs, whilst well intentioned for supporting shared caregiving can in fact, increase the cognitive load on already burdened informal family caregivers (Liu et al. 2021). Despite these everyday uses, they have also been used for the care of people with Parkinson's, to help understand complex symptoms and disease progression (Trajkova 2020).

These studies show how VAs can support individual and shared health and wellbeing situations in people's homes, but there is also the ability for these devices to be mis-used and there are trade-offs when considering decisions that need to be made between serious and non-serious use (e.g. between using the device for leisure or practicality, having simple conversations or trying to ask more complex queries of the device). As a result, tensions can arise between one person and the device or between multiple people within the same home and a VA, due to the lack of functionality for supporting more complex, voice-based interactions. It is of interest within our study to investigate whether these or similar tensions will arise in our research context of social isolation and how the Echo Show will impact the burden of caregiving in the home space.

2.4.4 Safety

Beyond this, safety is also a concern for smart home healthcare technologies. Safety can be defined as the use of technology by older adults in the home without inflicting physical or psychological harm on themselves or others. It is possible to view safety within the home as an extension of both TIPS and customisation discussed above, too. Both of these areas require the safe use of technology in combination with the other elements discussed. For example, whilst an older adult may be able to self-track their health initially, this may become harder or impossible going into older adulthood (Astell et al. 2019). Cognitive decline can also lead to unsafe use of technology, which even ongoing monitoring from informal caregivers can struggle to prevent (Caldeira et al. 2017). Safety also applies within the context of customisation. Soro et al. identify issues of safety when customising smart home devices . Some modifications to existing technology may be so 'radical' that the original purpose of the device is compromised and it becomes unsafe (Soro et al. 2017). Whilst these technical aspects of safety exist for the use of devices by older adults, there are also social consequences of safety to consider in the home too.

2.4.5 Stigma

Building on the social safety of older adults, stigma arises in different forms within the literature. Stigma is sometimes discussed with regard to stereotyping older adults within the design of

technology. For example, Soro et al. describe stereotypical assumptions made by IoT researchers and designers in that the lifestyles of older people are commonly viewed as those in constant need of care and attention - assumptions that do not assume older adults' strong sense of identity or autonomy in their homes (Soro et al. 2017).

As discussed previously, older adults strive for "every ounce of" independence they can maintain (Caldeira et al. 2017) [p. 7]. In studies such as Karlsen et al.'s, this has been associated with a need for older adults to simply 'appear' like they are not getting older and thus, do not require additional assistance (Karlsen et al. 2019). In this sense, they are able to preserve their outward-facing identities, sense of youth and to a certain extent, dignity in the presence of guests and non-family members. However, the need for independence also arises as a result of stigma that older adults can experience. This can result in the partner and the older adult in care refusing to make use of local care services for fear of discrimination from care providers and also stigmatisation from the wider community.

In both of these contexts, there are broad opportunities for smart home technology to intervene in reducing stigma. As Light et al. describe, using empathy and the acknowledgement of other experiences in the design of new systems and tools that can be used in the home helps to reduce sidelining of marginalised groups and can facilitate lively engagement with both systems and other people (Light et al. 2014). There are also opportunities for care providers outside the home (e.g. the NHS) to better engage in reducing the stigma around aging, as Gomez et al. suggest, by removing the stigma of "subtle ageism that inform[s] policy and practise" both inside and outside of technology design (Gómez 2015) [p. 9]. Removing stigma around aging and helping to reinforce positive identities, could therefore help to reduce barriers between individuals, communities and enable older adults and their caregivers to better engage with their health through healthcare institutions and the technology provided for them.

2.4.6 Using knowledge

Tying together the aforementioned barriers is the theme of knowledge deprivation. Common to almost every paper reviewed are barriers for people in care, informal caregivers and whole communities centred around how to access knowledge for using technology and services.

2.4.6.1 Knowledge sharing methods

To be able to discuss how knowledge deprivation is occurring within these groups, it is necessary to discuss how knowledge is currently being shared. As previously discussed in relation to security in the home, knowledge sharing at an interpersonal level for older adults comes about through interactions with informal caregivers (usually family members (Karlsen et al. 2019)). Geeng and Rosener take this one step further, with participants in their studies advocating using smart

home technologies to reinforce the knowledge of their own caregivers, about how to use their own devices, in order to learn how to share equitably with one another in their homes (Geeng et al. 2019). Knowledge is also shared between people a household may be with familiar with, but who live outside of their home. For example, older adults and their families often converse with GPs, clinicians or other healthcare specialists such as telecare centre directors and helplines over the phone. Forming relationships with these individuals either in-person or remotely (over the phone, or through videoconferencing Seuren et al. (2020*b*)), provides households the ability to share knowledge and utilise the remote experience of others in order to care for one another and to set expectations around the use of digital services for the people who need them (Procter et al. 2018).

Knowledge sharing also takes place at an inter-generational level. Robertson et al. describe current 'new' generations of older adults (baby boomers now going into older age), who are making use of technology they used at working age (Robertson et al. 2013). Participants in this study emphasise the emergence of a new generation of digitally literate older adults, who are able to engage at a high level with mobile devices and services. The knowledge of how to use technology, gained earlier in their lives, now provides them with greater ability to age in place with smart home technologies, independently. Light, Leong and Robertson's study emphasises a different means of inter-generational knowledge sharing. This study highlights the importance of bridging the divide between older and younger generations. The notion of the "old people ghetto" is discussed where in parts of Australia, younger generations actively avoided certain neighbourhoods in cities like Brisbane (Light et al. 2015) [p. 7]. However, by introducing council-led initiatives such as mixed-interest focus groups that discuss local policies (e.g. where new houses should be built), the inter-generational divide has been lessened, and younger and older communities have come together to engage in important topics, relevant, or even intimate to them. A similar means of engagement is suggested for home technology design whereby relationships between younger and older people in the same household can be fostered through activities of common interest (Schulte et al. 2020). By engaging people across generations in this manner, the aging gap can be reduced and in turn, better engagement and care fostered between people of different ages.

Community knowledge sharing is exemplified again most prominently within minority communities e.g. the LGBT+ community. As Nunes et al. describes, participants within studies in this community have engaged in knowledge sharing online for example, through HIV/AIDS-related health forums (Nunes et al. 2015). In these forums, patients shared self-management solutions with other patients, including scenarios for appropriating and customising their own technology, as discussed previously (Nunes et al. 2015). Sharing and learning are also facilitated online in relation to communities health. Procter et al. describe the importance of organisational learning taking place in a community-focussed manner. Sharing knowledge about systems and processes within an organisation, at scale, can rapidly up-skill workers in, for example, telecare call centres

(Procter et al. 2018). These forms of community knowledge sharing not only provide greater access to resources, but also offer social support for those engaging with sharing this knowledge. Exchanging information across communities and between individuals in this manner, is beneficial for all members of a household to provide engagement and support for their shared health and care, no matter whether it is sourced through an unfamiliar resource (online) or a familiar one (family member, friend, relative).

Nevertheless, whilst the literature proposes these methods as a means of supporting the sharing of knowledge, there are apparent gaps and opportunities for ways in which knowledge could be better shared across the home. As a result, it is necessary to identify sources of knowledge deprivation and how this could be improved.

2.4.6.2 Knowledge deprivation evidence and limitations

Knowledge deprivation is defined as a lack of information for a person or group, leading to uninformed decisions being made about health and lifestyle. Social exclusion and isolation also commonly prevent older adults from engaging with local communities, health organisations or even relatives to gain knowledge about managing their condition. Lynch et al. and Soro et al. both highlight the importance of removing isolating social boundaries to reduce knowledge deprivation from a lack of access to local communities where individuals are marginalised, simply through having less access to shared knowledge that could support their health, than their neighbours. In their report of telecare knowledge sharing within ethnic minority communities in Birmingham, UK, it is discussed how 'information poverty' is a key challenge for older adults in the area (Lynch & Draper 2014). Because of this, minority groups are often left without easily accessible information that is relevant to them, which can have long-term health impacts for these older adults in their future aging (Lynch & Draper 2014, Soro et al. 2017).

Another challenge coming as a result of knowledge deprivation holds implications for future generations of older adults and for the research questions identified in the next section. Willingness to embrace new technology is heavily impacted by peoples' ability to access knowledge. Lynch again highlights this issue within the BAME community and stresses the importance of information about new technologies for care and aging in place, being made available not just online, but also offline in publically accessible spaces (Lynch & Draper 2014). The willingness of all stakeholders involved in care inside and outside of the home, to engage in embracing and learning about new technologies is foregrounded in studies by Procter et al. (2018), Nunes et al. (2015), Bjering et al. (2014), Bradford et al. (2018), Knowles & Hanson (2018). Common across these studies is that whilst multiple actors in the home engage with technology to varying degrees, there is, as Procter et al. describe, a "lack of motivation and capacity to invest time" in engaging with new forms of technology, that extends from a lack of shared support with new

health and care systems, that could inevitably prove more acceptable and also improve the quality of life of older adults.

It is therefore important to identify that whilst these studies do highlight the issue of engaging with new smart home technology, this is not the primary focus of these studies. For example, in Procter et al.'s study, the lay carer participants (N=5 informal caregivers), could have also been interviewed to discuss their broader opinions on the acceptability of care technologies, beyond specific telecare systems. Similarly, Knowles et al.'s study, consisted of N= 3 participants from telecare provider organisations, interviewed across three focus groups. Whilst these questions more directly addressed acceptability of these systems, the study could have probed more deeply as to what members of each organisation perceived as barriers to knowledge from their clients, that stopped them engaging at a higher level with their services.

2.4.7 Summary

This review covers a wide breadth of HCI and adjacent literatuere on the smart home and healthcare in general. In particular, we draw the following conclusions from our review that articulate the key gaps in the literature and help to inform the research questions presented in chapter 1. Namely, these are:

- **Clinical and non-digital technology.** Sections 2.1.6 - 2.2.1 discuss different types of technologies that have been used to support care in a non-digital way, such as more manual devices e.g. pendant alarms. Further, the work conducted around these technologies and the resulting labour, poses questions around what work is *not* being captured within e.g. clinically-focussed studies, that may address labour in the home, but not acknowledge its full extent. RQ1 builds on this understanding and poses an avenue for future investigation to examine work that is often not seen or acknowledged in the home.
- **Social Presence for Care.** The discussion of social presence around voice assistants in sections 2.4.2 and 2.4.3 discuss the collaborative and social integration of such technologies into the home. Yet a further question arises around this, considering how technologies that hold social presence are collabloratively accepted in the home when providing care in the primary aim.
- Further, the discussion of Trust, Identity, Privacy, Security (TIPS) and Safety in sections 2.4.1 and 2.4.4 further identified a gap around how smart home technologies can be collaboratively used to support residents, particularly to care for one another. RQ2 therefore stems from both this and the previous research point in order to explore the social construction of care in the home in greater detail here.

- **Exploring Complex Devices Being Shared Collaboratively.** Sections 2.1.5 - 2.1.7 and our exploration of the socio-technical and humanistic lenses, as well as the types of use all discuss complex digital technologies that are deployed in ordr to support (mostly) individual older adults and their care at home. Yet RQ3 is posed, developing from this understanding in order to explore how social understanding of complex smart home technologies is constructed and is framed in order to be broad enough to examine this through different lenses of interaction from different types of residents within the home.

This section has also identified how the four barriers to use may impede the ability of older adults in care, their caregivers and communities to use smart home technology. Recommendations for improving the accessibility of this technology range from facilitating trust and emphasising the need for adequate security within smart home systems, to better supporting diverse needs of cohabiting residents with different life experiences and in different physical home structures. Community-level barriers such as stigma may impact the ability of minority older adult communities to be aware of and engage with technology that could improve or sustain their health. The limitations to these studies, both in methodology and content, are taken forward to help inform the research questions of this thesis. Lastly, the impact of knowledge deprivation between different people in the household, different generations and different communities was highlighted. Providing access to adequate knowledge about technology and services is framed within the smart home literature as a significant and contemporary challenge.

2.4.8 Limitations of review and implications

Whilst this literature search and review has been conducted rigorously, it is necessary to discuss the limitations of performing this search and the categorisation of distinct streams of work too. This review is primarily a 'scoping review' (choosing and identifying relevant data from a specific set of chosen literature, with subjective relevance to the thesis author Munn et al. (2018)). This review scoped a range of papers between 2005 - 2022 within the smart home domain that focused on health, care and aging. These were primarily chosen from the ACM Digital Library, but also from interdisciplinary sources cited by works here too. The process of cross-analysis identified through the creation of the streams of work has provided insight into the ways in which technology is used (forms and modes) as well as ancillary issues such as TIPS, acquiring and sharing knowledge and providing safety when using healthcare technology.

Whilst this chapter has aimed to be rigorous and concise in collating and presenting this smart home research, there are other ways in which this research could have been presented including, e.g. conducting a grounded theory literature review which selectively eliminates and analyses a data corpus based on thematic keywords to produce a set of papers to evaluate. As Munn et al.

describe, systematic reviews also provide evidence (in this case, prior research) in a way that is reliable and meaningful to end users (Munn et al. 2018). This review contributes a categorisation of the existing literature through the assortment of the four work streams. Again, this review's rigor could be improved by inductively identifying and sorting the literature, coding (as discussed by Corbin and Strauss (Strauss & Corbin 1997)) e.g. open, axial and selective codes to generate a narrative for such a review, although an open presentation and assortment of prior research was preferred in order to provide a snapshot of the diversity of research on the smart home. The selective approach taken to this review has helped to identify key contributions within the selected research timeframe and to articulate these in a way that can help to suggest a specific methodological approach to conducting the empirical studies for this thesis.

Based upon this and upon the research questions identified in Chapter One, this thesis will take a qualitative methodological approach, which will be detailed further in Chapter Three. In line with concurrent research within HCI and CSCW, this thesis positions itself within the socio-technical and humanistic work streams identified in this chapter. It will conduct e.g. semi-structured interviews and contextual enquiry to help articulate insightful data that can tackle the aging population crisis within the context of the shared home.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides a methodological outline that underpins all of the empirical studies in this thesis and a description of how this aligns with other similar methodological contributions within the fields of Human-Computer Interaction (HCI), Computer Supported Cooperative Work (CSCW) and health and care. The contribution of this chapter is an overview of a qualitative approach which ties in to the methodological grounding of the first empirical study beginning in Chapter Four.

3.2 Positionality statement

As a researcher, it is important to acknowledge my own positioning and experiences when conducting research with a health community (older adults). As the author is a white, male, working-aged adult, the author acknowledges differences in physical age, life experience and opportunity between himself and many of the participants involved in the research within this thesis. As the empirical work that forms this thesis is also conducted with older people, many of whom are living with chronic health conditions, the author acknowledges that it is not always possible to relate to disclosures around such conditions, particularly when the author's lived experiences are different to this.

Related to this, it is also necessary to describe how the authors' own lived experiences affect the process of conducting data analysis. As described in further detail in the accompanying sections, the chosen data analysis method for these empirical chapters is the reflexive thematic analysis process, as outlined by Braun and Clarke (Braun & Clarke 2021). As the thematic

process also took place not only between the author of this thesis, but 1-2 others from the same institution, there is also an interplay of different lived experiences affecting the analysis and ultimately, conclusions made about the data based on our own experiences. Whilst having multiple research engage in co-analysis of a qualitative data set in this fashion, can reduce biases in the presentation of the data (e.g. 1 author favouring a more interesting piece of data), there is also a risk that multiple data coders can draw interpretations of the data corpus in too many different directions, for example.

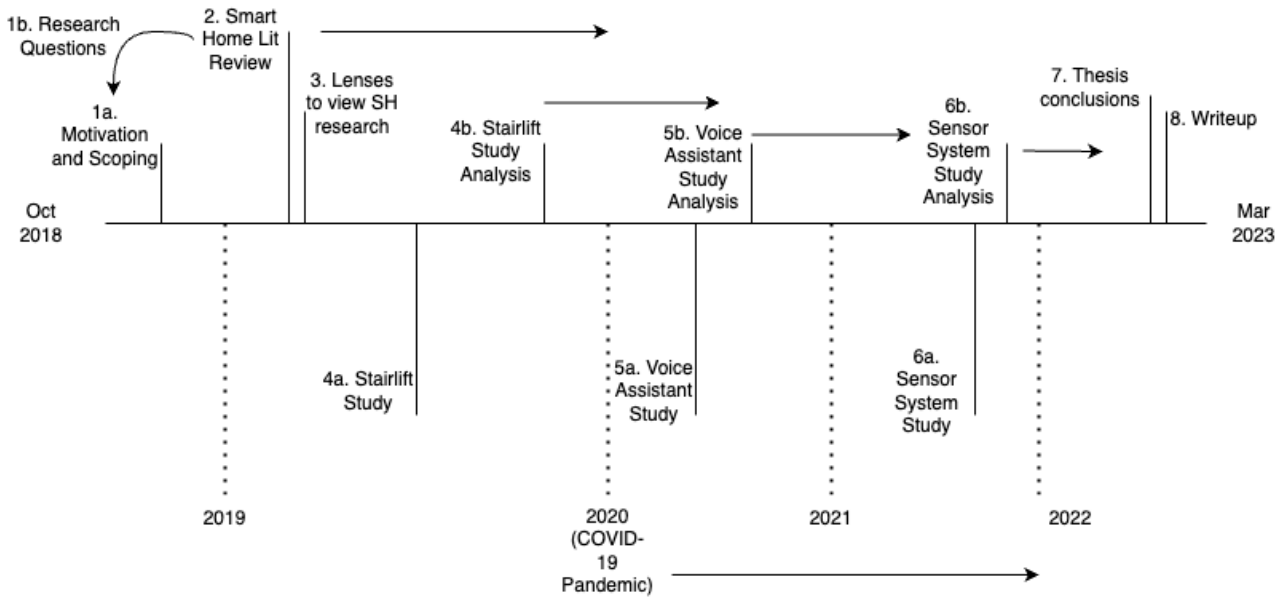
The author feels as though an even balance was struck between the researchers when the data co-analysis took place across the three studies and ultimately, the author determined the overall narrative of and trajectory when describing the data in each of the following chapters.

The author also acknowledges the value in having the same researchers share their experiences and help to shape not just the analysis but the early design of these studies (based on their own experiences conducting qualitative, empirical health research) and also assist in the practicalities of conducting these studies too (e.g. attending interviews in-person or online as a backup interviewer too).

3.3 Thesis timeline

An overview of the timeline for this thesis is provided below, including key dates for specific chapters and empirical studies completed.

Figure 3.1: Overview of the thesis' key contributions and relevant dates.



3.4 Empirical and epistemological approaches

This section deals with the theoretical and epistemological underpinning's of this thesis' work that drives the latter empirical chapters and approaches to qualitative research and also selects an appropriate epistemological viewpoint (Hogue 2011).

3.4.1 Research paradigm and epistemological foundations

In order to answer the research questions posed in Chapter 1, this thesis draws on an explorative qualitative research approach. More specifically, this research approach is informed by a constructivist view to understanding human engagement with technology for the purposes of exploring degrees of wellbeing and personal health in the home (Osborne 1996). Constructivism itself advocates the idea that acquiring knowledge (in the case of this thesis, through doing research) is subjective and dependent upon the researcher's own interpretation of the data. In contrast, a positivist approach to research sees researchers approaching a problem with the expectation that there is an objective 'truth' or solution-focussed outcome to investigating a research question or area, and typically, that this outcome can be quantified (Caldwell 2015).

Within HCI, both positivist and constructivst approaches to research are conducted commonly, yet constructivist qualitative studies can also draw on other methods within the same work, including design ethnographies, diary studies, contextual enquiries and co-design groups e.g. (Duarte & Baranauskas 2016). Whilst this thesis only makes use of semi-structured interviewing within the empirical research chapters (and contextual enquiry within study 1) and does not engage in design HCI research practises Fallman (2003, 2007, 2008), it does draw on the theoretical underpinnings of these other approaches and as such the interviewing process is informed by a range of qualitative methods. This allows for an in-depth understanding of people's motivations to use technologies individually and together (Blandford et al. 2016). Moreover, in-depth interviewing helps to draw out individual differences and nuanced characteristics of households as places that can affect how technology is used, discussed and presented to researchers at very localised points in time (Guest et al. 2013). Understanding that people's presentation of themselves and their use of technology may change over time is one motivation for adopting a constructivist approach to this research.

3.5 Ethics

This section considers the responsible practises that underpin the research in this thesis as well as the ethical guidelines that this work aligns with. This section also discusses the impact of each of the three studies as pieces of research that inform the work of local partners and stakeholders who have supported the research to take place.

3.5.1 Responsible innovation and reflexivity in older adults research practise

Careful consideration was given to the best ways in which to engage older people and their families and/or carers in this research. The people recruited to each study held variable and fast changing health conditions that fluctuated during the research. As such, it was necessary when applying our qualitative methods, that consideration was given to each person's ability to complete a study and as such, participants were able to skip interview questions, whole interviews or withdraw from the study completely at any time. UK research councils and researchers recommend a phase of "anticipation" before "act"-ing in person-based research (Research & EPSRC 2022, Stilgoe et al. 2020). Within these case studies, the anticipatory phase before research came from planning how best to engage with participants through local organisations and community experts who had prior experience in and pre-established trust with specific communities (e.g. Bristol City Council (Study 1), Knowle West Media Centre and Bristol Nilaari Society (Studies 2, 3)). During the 'Act' phase, when research was taking place, it was the researcher's responsibility (along with any co-investigators supporting this research), to demonstrate flexibility, reflexivity and understanding to adjust to the participants' needs and accommodate these throughout the duration of the studies. It was also necessary as researcher to reflect on interview experiences, their affect on the researcher personally as well as what had been learned. As a result, the outcomes and empirical findings in Chapters Four through Six are a collection of insights into households' experiences, lives and activities that the supervisory team of this thesis agreed were most suitable to discuss and to agree to showcase before publishing the details of people's lives (albeit pseudonymised), in any form.

During study 1 for example, there were specific instances where two participants sadly passed during the course of the research. It was essential therefore to respect the wishes of their family at that time. In each case, the family were asked what they wished to do with the data from the time that their loved one had participated in the research and whilst one household wished for the contribution of the person to be preserved through the research, another equally wished for it to be removed, which was subsequently done. Again, due to the sensitive nature of discussions in this research, the participants in these studies were also given copies of submitted versions of research papers to comment on and feed back to the researchers.

Equally, the sensitive and challenging nature of hearing about and processing other participants' experiences meant that it was necessary to engage with vicarious trauma that was experienced as a result of doing the research and to mitigate this where possible so that it did not affect how the research was conducted in future e.g. dealing with participants passing away by speaking with a university counsellor. As such, the researcher performed reflexive activities when engaging with other people's lived or traumatic experiences through journalling, sharing with colleagues, 1-1 individual counselling sessions at the university and speaking to other members

of the PhD supervisory team about their own experiences of health and care research and the challenges they have faced too.

3.6 Empirical contributions

This thesis provides empirical contributions that seek to answer how people can age in place together using different types of technology for their health and care. It also seeks to answer to what degree this technology is acceptable in shared household settings (RQ 1, 3). The outcomes of the research conducted in this thesis are primarily drawn from the qualitative accounts provided throughout the three empirical chapters. However, it also provides interrelated contributions that focus on how emotional journeys impact the use of technology and how learning and effort stemming from adverse household labour to use the technologies affects their acceptance.

Chapter Seven, General Discussion deals with the outcomes of this thesis in greater detail before providing a General Conclusion on these topics in Chapter Eight. Chapters Four, Five and Six provide the in-depth qualitative insights using the methods outlined in this chapter to explore the use of three different types of technologies (stairlifts, voice assistants and IoT systems) in detail, where empirical findings are discussed that are central to the narrative of this thesis and help to explore answers to the aging population problem in full.

3.7 Justification and methodological approaches

This thesis employs a qualitative methodology throughout the empirical studies whilst also drawing from methods found commonly within studies of smart homes e.g. contextual inquiry (Holtzblatt 2001), to enhance discussion. This is also common to research approaches within HCI and CSCW (e.g. (Mitchell et al. 2015, Van Turnhout et al. 2014)). Having reviewed health and care research within the HCI and CSCW domain in the previous chapter and empirical research within other fields outside of these around health, care and aging, one commonality is the varied use of qualitative methods in order to explore a problem. In order to understand the broad problem space of an aging population and to answer the aforementioned research questions requires a broad investigation. On the one hand, methods such as interviews, focus groups and workshops will help to gather an understanding of people's experiences with different types of technology in the home. On the other, design-focussed methods Cross (1982)such as research through design (Zimmerman & Forlizzi 2011, Findeli et al. 2008) or co-design (Steen et al. 2011) can help to creatively explore the problem space and create new solutions driven by people's needs (Dourish 2003), although this thesis focuses on understanding people's experiences. This interdisciplinary and methodologically diverse approach to research on older people's health and wellbeing in the home is described by Blandford et al. (2018) as a way of gaining a holistic view of people's health over time.

The empirical studies in this thesis are not clinical trials of technologies or medicines. However, many of the same methodological approaches are chosen within specific studies e.g. running pilot interviews and planning technology deployments; as discussed in the first study overview in Chapter 4. The inclusion of interviews with non-household members e.g. professionals such as clinicians (occupational therapists), within our first study is a further example of an approach taken across HCI studies in health and care in the home (Carnemolla 2018). Whilst this methodological approach therefore draws on interdisciplinary research methods, in contrast to other clinical studies (e.g. (Heine et al. 2016), the studies in this thesis are not procedural or conducted as a Randomised Control Trial (RCT), but instead seek to inform future research or design contributions for HCI and CSCW researchers in the health and care domain through the systematic development of research, by paving the way for future investigations here (Blandford et al. 2018).

The nature of this thesis' research questions identify a problem of shared quality of life for an aging population, which largely sits within the remit of health and care research in the home. Again, the approach to solving this problem also draws on the interdisciplinary literature examined in Chapter One and Two and as such, this also frames the ethical approach taken to involving participants. The next section examines in further detail the qualitative methods chosen across each empirical study and the rationale for choosing these.

3.8 Technology selection criteria

The technology chosen to study for the empirical work within this thesis was chosen in order to represent the broadest possible range of devices that could be used to support shared health and care within a smart home.

The stairlift was chosen as there is a well-known adoption journey for this technology that could be studied as part of a route to care supported by a range of stakeholders including GPs, councils, occupational therapists and private companies. Other digital technologies by contrast also do not have care pathways to adoption like the stairlift which made for a unique avenue of investigation for this case study(Williams et al. 2020). For the second study, it was decided that a technology should be chosen to contrast the stairlift and provide a point of juxtaposition for a follow up study. As such, voice assistants were selected as these are commercial, lightweight and generally regarded as having off-the-shelf setup processes and affordability (Sin & Munteanu 2020). For the sensor system study, a point of contrast from the other two technologies seemed suitable, and the smart home sensor system was selected, as it is both a digital technology, but which has a lengthy setup process (like the stairlift), but which is also commercially available, and is supported in

some capacity by technical workers (Burrows et al. 2015). This again seemed a suitable contrast to, and also means of complementing the previous two studies' chosen technology.

3.9 Empirical approaches

This section covers the qualitative empirical approaches taken to the thesis in general and then provides a chapter by chapter breakdown of the research approach taken to conducting each study here.

3.9.1 Qualitative interview procedure

In order to answer RQ1 ("How do established or appropriated home care technologies support older adults to age in place at home with others?"), qualitative methods are used to gather evidence of the ways in which smart home technology is used in the home. Contextual, semi-structured, qualitative interviews are used across all three studies in this thesis, which provide "in-depth [...] grounding" (Dourish & Bell 2011) during in-person research and are used as a tool to investigate experiential, personal, social and phenomenological experiences in the home. Semi-structured interviews were chosen over e.g. structured interviews for this thesis as they allow for probing into conversational topics in greater depth but at the same time provide direction and focus for the conversation which unstructured interviews do not (Mueller & Segal 2014).

The interviews across all studies in this thesis are also temporally-distributed over 3 months of use. This decision allows for capturing snapshots of experience with technology as participants gain more familiarity with both the research process itself and the technology they are living with. Rubino et al. describe the benefits of pre-installation interviews in their own study, which captured lived experiences of a home sensor system before it was fully integrated into the home (Carlos Rubino de Oliveira et al. 2015). Kaufman and Dourish also encourage "exit interviews" that can capture significant changes in the experience of technology, when placed significantly after (in a period of months after) a new technology is first introduced in shared homes (RQ3; " How does the use of this technology and its integration within the home affect the primary user of the technology and the wider household?") (Marcu et al. 2010). Three distinct temporal stages were decided on for interviews to be conducted: i) pre-installation interviews, before the household received a piece of technology and where the researchers can probe experiences of the household setup, other devices, social relationships and care support; ii) the post-installation or "out of box" interview, where the new technology has recently been installed in the home (with the interview being conducted up to 1 week later). To probe the households' reactions to the new technology, their initial thoughts as to how it affects their home and any changes in social dynamics; iii) the 3-month post interview being the exit interview, where a significant time has passed between the arrival of the new technology and its integration into the social

fabric of the home. An interview-based interval of a 3 month period has also been supported in previous HCI studies where a 1 month follow up has been too short a time to measure impact and where a 6 months follow up moves the research into the realm of a longitudinal study (Lan et al. 2018, You et al. 2015, Barnason et al. 2006). Topic guides for these interviews were created in order to adhere to the open-endedness of semi-structured interviews and to support a two-way discussion. Doing so reduces power imbalances of researchers over their participants and allows for a more conversation-like engagement with participants (Furniss et al. 2014). Many of the participants recruited for the studies in this thesis had prolonged underlying health conditions, where discretion, tact, empathy and even thanatosensivity (Massimi & Charise 2009) on the part of the interviewer were all necessary to discuss their lived experiences and to accurately portray their lives through these qualitative accounts (Blandford et al. 2016).

3.9.1.1 Empirical chapter 4: stairlift study procedure

Members of households (residents) who were expecting a stairlift installation were recruited. Residents are defined as those living inside a dwelling (household), or those who live outside and visit the household frequently e.g. an adult child. Residents over 18 years of age were recruited in the city of Bristol in the south west of the UK through Bristol City Council; a city based local government authority who fund care services for people who are older or vulnerable, including home adaptations and assistive technology devices. The city council also work with and fund local assistive technology providers so that vulnerable and older people can receive the technology they need, cost-free. The council's own team of Occupational Therapists identified lower income people eligible for city council-funded stairlifts who would be suitable to be involved in the interview study and gave them the recruitment advertisement. Many of the people the OT team worked with were clinically extremely vulnerable or near their end of life, and as such, the OTs did not deem suitable for recruitment or interview. This consideration initially limited the scope of our recruitment, so the research team branched out participant recruitment through advertisements in local libraries, engaging with two local charities, through the occupational therapist's contacts working within the community, and through word of mouth. Five households were initially recruited, with four households completing the study, due to a member of household five passing away. Socio-economic status of our participants was not collected as part of our demographic questionnaire, however the authors provide an identification of whether each property was urban or rural and the living conditions of each of our participants within the notes column, in the table below. All members of the household who were eligible and willing to take part in the study were informed about the study and provided informed consent, if they were willing to take part.

Each household was asked to take part in three in-depth, semi-structured contextual in-home or phone (post COVID-19) interviews before installation, shortly after installation (up to one week) and three months after installation. Interviews included questions on technology experience,

("How easy do you find it to use your household devices e.g. fridge/kettle?"), the design and aesthetics of the stairlift ("What are your thoughts regarding the look and feel of your stairlift?"), and the experiences of the other people in the home ("How do you feel about other people using your stairlift?"). For in-home interviews, two authors visited each of the four households recruited for the study to conduct these interviews in situ, however the first author led the interview. Phone interviews were conducted by the first author.

All interviews were audio recorded and transcribed verbatim. All interviews lasted between 1 and 2 hours. 11 hours and 44 minutes of audio was captured from households and an additional 4 hours and 16 minutes from service providers (16 hours in total recorded and transcribed verbatim). Photos of any assistive technology in people's homes (including the stairlift) were taken during the first and second interviews. Informed consent was gained as per institutional IRB ethical approval. Participants were reimbursed £10 in shopping vouchers per hour for their time, per interview. All participants were sent a finalised version of the findings in this paper with their pseudonymised names. Participants then gave approval for the publication of their contributions to this study having read our account.

A complete participant demographics table is provided within Chapter 4. A selection of service providers outside the household were engaged in this study. The role of these service providers added complementary insights to that of households. They provided a critical perspective on the installation process, the benefits of which have been highlighted in CSCW literature previously through providing more depth to a topic area (van Hoof et al. 2011) and by providing additional validation to directly captured data sets (Karlsen et al. 2019). Five city council Occupational Therapists (OTs) involved in mobility assessments in Bristol participated in a one hour focus group. Two experienced stairlift installers from commercial companies in the UK participated in one-hour phone interviews, and two assistive technology customer service representatives (reps) participated together in a one-hour contextual interview at a local mobility assessment centre in Bristol. Questions to these service providers were developed in line with those used in households, however we also asked the OTs about their role as health professionals and the assessments they carry out, the installers about the installation process, and the reps about how they discuss assistive technology with customers. Including the service providers' accounts into the corpus for our data analysis allowed us to contrast the qualitative accounts provided by each household and supplement them, particularly about the early parts of the stairlift journey before adoption. All were audio recorded, some with photos taken, and transcribed verbatim.

Informed consent was gained and service providers were reimbursed for their time with shopping vouchers for £10 per hour. All participants were sent a finalised version of the findings in this paper with their participant ID. Participants then gave approval for the publication of their contributions to this study.

3.9.1.2 Empirical chapter 5: voice assistant study procedure

11 households were recruited that had either an older adult, aged 65+ or a vulnerable person of working age and above, aged 50+. Up to three additional adult (18+) members of the household could also be involved in the study (the maximum number that the researchers could financially reimburse for their time), and included people such as live-in carers and live-out adult children who provided care remotely. Some residents who lived in a household but did not take part in the study (e.g. those under 18) were discussed anecdotally.

Participants first expressed interest through seeing one of our online advertisements, contacting our partner charity organisation (Knowle West Media Centre), or through viewing our recruitment brochure. Interested participants contacted the research team via email or telephone contact information, provided in the recruitment materials. Once decided that they would like to take part in the study, participants were provided online informed consent documentation (participant information sheet, consent form and demographic questionnaire) to read through and complete, before the study could begin. A complete participant demographics table is provided within Chapter 5.

It is important to note that we wished to capture shared isolation experiences and not those of individuals, to study the collective use of Echo Show in a shared isolation context. Therefore, the households with the greatest number of residents were selected to provide greatest insight into the lived and shared experiences of the Echo Show. All participants were reimbursed £10 in shopping vouchers for each hour of interview time they completed, including extended household members (live-out), as well as the household being compensated with Echo Show device at the end of the study.

Not all residents were able to take part in all interviews due to either health or time commitments, and these are labelled in the findings as: "PRE" (pre-installation of Echo Show), "POST" (up to 2 weeks after installation of Echo Show) and "EX" for Exit (at 3 months after the installation of the Echo Show in households) interviews.

To prepare participants to take part in the study, we provided YouTube videos which would brief participants on how the study would run. Semi-structured interviews allowed for in-depth conversations which took place between the researcher and each participant over the telephone or videoconferencing (e.g. Skype/Zoom), to cater for participants' differing levels of digital literacy and comfort with technology, and to make use of the ubiquity of telephone connections in our study's demographic. Participants were interviewed sometimes individually and sometimes

together, depending on that household's preference at the time of the interview and lasted from 13 minutes – 60 minutes. Interviews were recorded and transcribed verbatim after each interview took place.

The intent with the three stage interview structure was to capture longitudinal experiences of the use and changes in shared practises with the Echo Show over a longer duration of the lockdown than just weeks at a time. Whilst this structure did not inform our later thematic analysis, we acknowledge that the pre-install interviews allowed us to gather unique snapshot of households' technology experiences right at the start of the first COVID-19 pandemic lockdown, that contrasted the latter accounts. These pre-install interviews allowed us to examine the household context before the technology was deployed, focusing on each household's lifestyle and their expectations for the Echo Show device (e.g. "Can you tell me about a typical day in your home?", "How useful do you expect the Echo Show device to be?"). After this interview, participants were mailed an Echo Show device for use in the study. Post-install interviews up to three weeks after the device arrived provided us with an understanding about the initial reactions to the Echo Show devices, how they had learned how to use it, given minimal instruction and their expectations during the "out-of-box" experience (Carlos Rubino de Oliveira et al. 2015) (e.g. "What were your initial reactions to the device?" and "Have you used the device to support your health or wellbeing yet?"). Exit interviews with participants were captured after 2-3 months of use of the technology. During exit interviews, participants were asked questions regarding their use of the device over a longer timeframe, whether any adjustments had been made to the way they used the Echo Show as well as their expectations for living with the device in the coming year (e.g. "Has your use of the device been as expected?", "Has anything changed about the way you are using the device?", "What are you mostly using the device for now?").

3.9.1.3 Empirical chapter 6: sensor system study procedure

Five households were recruited with at least one older adult (aged 60+) who could be designated as the 'owner' (the person for whom the system was setup) of the Smart Home Health System (SHHS). Up to three additional adults (aged 18+) who were also affiliated with the extended household were eligible too, in order to capture shared experiences of the use of the system (e.g. live-in carers, or live-out relatives who would visit the household). Anyone under 18 who lived in the household was discussed anecdotally.

The study was advertised to prospective participants via Bristol city council and was advertised through an online recruitment website. Prospective participants were encouraged to email or telephone the researchers if they wished to take part, they were given an information sheet

about the study, asked if they had any questions and were asked to provide informed consent for themselves and any other residents interested in taking part in the study. Informed consent was offered to participants who expressed an initial interest in the study. Each participant was reimbursed by way of £10 in shopping vouchers per 1 hour of interview time.

We conducted 15 semi-structured interviews across all 5 households, totalling 13 hours 46 minutes, with interviews lasting up to 1 hour per session. A complete participant demographics table is provided within Chapter 6. Interviews took place over the telephone (landline) and over videoconferencing software (Zoom). Both these contact methods were offered to participants on a preferential basis, to cater for the range of digital literacy and comfort with technology across the cohort. The semi-structured interview style allowed for detailed conversations to take place around the use of households' technology, their health and wellbeing and the SHHS.

All residents took part in all interviews for this study. Interview quotations are labelled below as: "PRE" (installation of the SHHS), "POST" (installation; up to 2 weeks after install) and "EX' (for exit interviews up to 3 months after the installation of the SHHS). Structuring the interviews in this manner allowed for a longitudinal view of the use, work and lived experiences around the SHHS. The temporal structure of these interviews was not used as a basis for our later thematic analysis, though we acknowledge that the pre-install phase provided unique insight into households' technology experiences before being exposed to a largely 'never-before-seen' system (the SHHS). Questions during the pre-install phase focussed on the contextual home setting and technology use patterns (e.g. "Can you describe a typical day in your home?", "Who do you use your kitchen iPad with?"). In between the pre- and post-install interviews, participants in each household were scheduled a call with a user experience researcher from the research group that provided the system. During this call, they chose the sensors they wished to have in their home for the system as well as providing information for delivery of the system to their homes. Following this, the post-install phase probed the "out-of-box" (relatively new; up to 3 weeks of use) experiences of using the SHHS once they had received it. Questions were asked around initial user experiences (e.g. "What do you feel about the device in your home?", "How do you feel the SHHS is supporting your health or wellbeing?"). The Exit interviews covered experiences with the system between 2-3 months of use. For these interviews, participants were asked how the system had integrated into their home life, routines and daily activities together, including (e.g. "What has changed in your lives as a result of having the SHHS?", "What impact has using the system had on your wellbeing?").

The SHHS in this study was created by a research group who are interested in developing technology solutions to help older adults live independently. The authors contacted the SHHS research group to express interest in running a qualitative study of their smart home system to identify its efficacy and acceptance within the context of shared use for older adults' households.

The SHHS research group provided five systems to be sent out to each household that was recruited.

The system was comprised of a range of sensors and a voice assistant that collected data from each sensor, sending it to a cloud to be stored. Data collected from each sensor was available to view online on a 'dashboard' that could show information about each sensor to the user. The range of sensors on offer to participants for this study included: IoT devices such as smart weight scales, door opening sensors and wearables, and a voice assistant (pseudonymised name: "HealthHelper").

The full range of sensors provided, included: 1) a ***smart mug*** (used by (H-A, B, D, E), ***motion sensors*** (used by H-A - E), a ***smart watch*** (used by H-A, B, C, E), a ***smart plug*** (used by H-A - E), ***weight scales*** (used by H-D), a ***pulse oximeter*** (used by H-B), and an ***IR Thermometer*** (used by H-C). The online dashboard, "HealthHelper" voice assistant and phone app were also provided and used intermittently by all households.

The households received their system in between the pre-install and post-install interviews, after they had spoken to the user experience researcher from the SHHS research group. Once the sensors were selected, they were described to each participant over the telephone and then boxed and shipped to each household to unpack and use by themselves. A small booklet with setup instructions was provided within the box, though the households were told that they could phone the SHHS research group to ask for additional help with their system setup at any time. The following section describes how the sensors chosen by each household were used and experienced across the three consecutive interviews that took place with all participants. The accounts reflect a range of experiences with the system and how it was used and not used, as well as the work entailed for setting up the SHHS in a shared household setting.

It emerged during the course of this research that damage had occurred to participants' homes as a result of using the SHHS (discussed in detail in section 4) and the household was reimbursed to help them repair the damage.

3.9.2 Qualitative data analysis

This thesis draws on reflexive thematic analysis (RTA), newly discussed by Braun & Clarke (2014) as a means of analysing the qualitative data garnered from interviews and focus groups. Whilst each individual empirical chapter provides its own unique description of the methodological approach to analysing that specific data set, each study in this thesis makes use of RTA. This

approach provides flexibility and an inductive open-endedness to the analysis process. The "reflexive" element to RTA, introduced by Braun and Clarke in their 2021 update to the thematic analysis process allows the researcher to draw on "experiential [...] and [...] critical framings of language, data and meaning" from a data set. This is beneficial for this thesis' research, which seeks to understand the contextual, nuanced and messy lived experiences of older adults' lives with smart home technology (Braun & Clarke 2021).

The general process of conducting the RTAs across all three studies involved transcribing spoken audio, captured from interviews and writing this into text documents. The text documents were then imported into a qualitative data analysis programme (in this case, QSR International 'NVivo'). Following this, the transcripts were searched, in order to identify words, phrases or parts of speech that could be identified as important or relevant to answering RQ's 1 - 3 (described above). Once identified, the selected passages were 'coded', and gathered accordingly (e.g. a code of 'Trauma' may contain passages that describe unpleasant emotions involving either technology, people, or both). Codes are then reviewed and iterated upon, with some being merged (e.g. 'Trauma' and 'Worry', may form a higher-level code, such as 'Psychological harms'). At this point, codes within this thesis' studies were typically iterated upon with another researcher at the same institution and discussed, revised and changes, before being finalised. Higher-level themes were then developed, based on these revised codes, which describe more broadly the key contributions of the work and, within the coding software, are visually represented as a heirarchy of 'nodes'. In all three studies, codes were visualised using a mind map tool (Lucidspark's 'SimpleMind'), to graphically represent the linkages between these codes ans the accompanying passages that they are derived from. These final themes then formed the basis for the description of each study's findings section and any subsequent discussion sections. A more specific process of the coding and analysis work done, is provided within the methodology sections of each study chapter.

3.9.2.1 Empirical chapter 4: stairlift study analysis

Interviews were transcribed using NVivo software by the first author and an inductive thematic analysis was performed. Co-analysis took place between all supporting researchers (Wong 2008), however, the first author consolidated codes before the themes of the paper were agreed upon again by all authors. Codes were developed as interviews were completed within individual households. The experiences of participants were then compared across households which allowed for developing an in-depth understanding of the lived experiences of the stairlift in a household. In households where only one participant was interviewed (the stairlift owner), anecdotal accounts of other household members' experiences with technology and the stairlift were included (e.g. from household members who were under 18 years of age), to examine the accounts of people who

would not have been captured otherwise e.g. as a result of being under the age of 18. Once the individual experiences of each participant had been identified, similarities and differences were then compared between households and consolidated among the rest of the research team. At this stage, trends were developed from themes which were linked (e.g. decision making, and within it, coercion). These trends were iteratively compared and contrasted between the authors and against existing theoretical models in health and care research, leading to a higher level framing, relating to household actors' emotional journeys of the stairlift's adoption and acceptance.

The inductive thematic analysis method was chosen over, for example, an Interpretive Phenomenological Analysis (Elsden et al. 2017) due to the need to understand the stairlift experience from all of the stakeholders involved in the installation of stairlifts and not solely individuals or individual households. Adopting thematic analysis therefore, allowed us to examine themes which are common to and inclusive of the experiences of all households and individuals, which in turn, allowed us to more easily derive transferrable research and design implications for smart home healthcare technology.

3.9.2.2 Empirical chapter 5: voice assistant study analysis

Data analysis took place between all co-researchers and was led by the thesis author. NVivo (qualitative data analysis software) was used to organise codes and to perform an inductive thematic analysis on the interview transcripts. Pre, post and exit interviews were inductively analysed to develop codes that could be iterated upon and developed further into themes, following an inductive thematic analysis methodology (Clarke & Braun 2017). Authors developed low-level codes that reflected the data from our interview transcripts. Initial codes were then discussed and higher-level codes were synthesised that reflected cross-cutting themes between interviews. The experiences of each member of each household was considered, which reflected the experiential use of the Echo Show devices. Similarities and differences between participants' experiences in each household were reviewed in order to develop trends (e.g. the need for residents to keep up daily exercise and physical activity and the difficulty of this, during the pandemic) and our final, higher-level themes were finalised, which focussed on all aspects of health, care and wellbeing in the home, as these have been discussed together in the adjacent literature that we have reviewed. The over-arching theme of 'facilitation' was developed which informed our understanding of the Echo Show's social presence, which we discuss below.

3.9.2.3 Empirical chapter 6: sensor system study analysis

The data analysis process was inductive and iterative. Interview audio was transcribed and written up to be analysed using NVivo (qualitative analysis software), and SimpleMind (a mind-mapping tool). An inductive, reflexive thematic analysis was performed on the entire data set (Clarke & Braun 2017). In the first coding iteration (by the first author), codes were developed

in order to be more "artfully interpretive" (Finlay 2021) of general occurrences or trends in the data set (e.g. the need for participants to learn in different ways, that spanned different types of work using the SHHS). The second and third iteration of codes leaned towards being more scientifically descriptive and developed these initial trends into themes. The authors aimed to make this an interpretative process to directly distinguish specific codes and themes and to develop them coherently as part of this work (Braun & Clarke 2014), to avoid common problems in the thematic analysis process. This second and third iteration also involved the research team reviewing codes along with the first author. The use of the mind-mapping tool helped to visually group codes within the data set until it could be agreed upon that the chosen cross-cutting themes (derived from the second and third round of coding codes) were more clearly representative of the over-arching narrative and important nuances of the interview data set. An over-arching framing of "Labour" was decided upon for the research, which helped to set a direction for how to arrange and describe the interview data in the findings section that follows.

This concludes the introductory chapters to this thesis. The following chapters (Four through Six) showcase the entirety of the empirical work for this thesis, followed by a General Discussion and Conclusion (in Chapters Seven and Eight).

CHAPTER 4

LOW-TECH HOME MODIFICATIONS STUDY

4.1 Preface

This chapter outlines the approach to the thesis' first empirical study; investigating how a low-tech home modification (stair lift) impacts upon the Quality of Life (QoL) of all residents within a household. Drawing on RQ1 ("What are the roles of the different members of the wider household in the adoption, acceptance, use and appropriation of technologies designed to support care?"), and RQ3 ("How is self-care and collaborative care work impacted by the introduction of complex smart home technology to support healthcare at home?") from Chapter One following our literature review, this first study will investigate how engagement with existing low-tech home modifications will impact the acceptability of future smart home technology. The idea of 'transfer scenarios' - whereby a non-digital experience or artefact informs a digital outcome, as proposed by (Höök 2010) is used to underpin this work and contextualise the latter outcomes within the smart home domain. This chapter also looks at the impact of this for health and care research as well as the impact of technology on the quality of life for everyone living in a shared household; not solely the care receiver.

As discussed in the methodological approach to this thesis in Chapter Three; there is a need to conduct in-depth contextual research in order to evaluate the impact of smart home technology on the households of older people. In keeping with the aim of this work; studies of home modifications have identified that they can positively impact older adults' Quality of Life (QoL) (Tanner et al. 2008). However, there are a number of limitations to previous work: they typically only evaluate short-term benefits (Tanner et al. 2008, Heywood & Turner 2007, Tongsiri et al. 2017); they tend to focus on the impact on the primary care user, rather than the whole household; and they only provide economic evidence not contextualised evidence for the efficacy of home modifications that

can impact national policy or guide the local use of limited resources to support independent living.

In partnership with Bristol City Council, the stairlift study investigates the impact of this technology on the quality of life of households of older people living with either formal or informal caregivers. This chapter uses the collective 'we' to reflect multiple authors collaborating on this research, where the author of this thesis is the ran the study and analysis for the paper and this chapter.

4.2 Introduction

The World Health Organisation (WHO) suggest the approach to tackling the aging population crisis begins at home (Tongsiri et al. 2018). Their approach underlies the principles of 'aging in place': the "ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level" (p. 1) (Schneider & Malin Eiband 2018). Therefore, the majority of technological interventions to support older adults to date, have been deployed in the home e.g. pendant alarms and other Low-Tech Home Modifications (LTHMs) such as stairlifts (Elsden et al. 2016). Previous studies of LTHMs show how they can improve older adults' quality of life (Bennett et al. 2018). Yet there are a number of drawbacks to this previous work; namely, that they focus on the primary owner/user of the technology and not the wider household. Since 1997, there has been a 93% increase in the number of cohabiting families in the UK (increasing from 1.5 million to 2.9 million as of 2017), with multi-resident, inter-generational families now the largest growing household group (J Kraemer et al. 2019). Therefore, important evidence of how the addition of home health technologies impact the greater household is missing: how do we age in place together, amongst multiple residents, with the assistance of health and care technology?

Our qualitative approach in this study, starts with this gap in understanding the complex sociotechnical nature of a household (which we define as containing people either living inside or regularly visiting a dwelling), who are engaging with or involved in health and care technology adoption, acceptance and use. We look at the impact of a substantial and intrusive LTHM, a stairlift installation, through engagements with numerous stakeholders who are privy to the journey from adoption to acceptance: primary users, other residents, occupational therapists, care technology providers and stairlift installers. We combine focus groups and semi-structured interviews to produce an aggregate picture of the lived experience of the stairlift for the primary user and also more broadly, across the whole household (Chen 2010). We document the emotional journey that the household goes through from adoption to acceptance, providing insights into the importance of engaging entire households in the design and process of installation of intrusive home health and care technologies. We also address the implications for future smart home

technologies that are impacted by the whole household's shared socio-technical dynamics, which all of our households presented. Consequently, this study extends previous research on home healthcare technologies in the following ways by:

- Providing an empirical account that advances the simplistic view of stairlift installations from the perspective of the primary user, to account for the complexities of the entire multi-resident home;
- Illustrating people's pragmatic and emotional journeys of the stairlift through: decision making, conflict and trauma, and catharsis and independence; and,
- Presenting transferrable research and design implications for smart home healthcare technology: 1) highlighting the roles of the multi-resident home in the context of the stairlift and providing transferrable design recommendations for different contexts; 2) suggesting support for these households to cope with adverse experiences; and 3) to cater for the highly diverse and unique nature of health and care technology installations in homes.

4.3 Ethics approval and participant demographics

This study took place with a mix of residents across four different households (table 4.1). Outside of the household, we engaged with occupational therapists, assessment centre workers and stairlift installers (table 4.2); all of whom oversee the different technical stages of the stairlift installation process (from referral, to assessment and eventually installation). This study was approved by the University of Bristol Faculty of Engineering ethics committee (ref 2019-5420-5367).

4.4 Findings

Our analysis illustrates the emotional journey households went through in the process of adoption and acceptance of a stairlift. The process in which this journey takes place was articulated in different ways by the service providers involved in this research, often in a simple linear model beginning with a request being made to the city council and ending with a stairlift installation (see Figure 4.1).

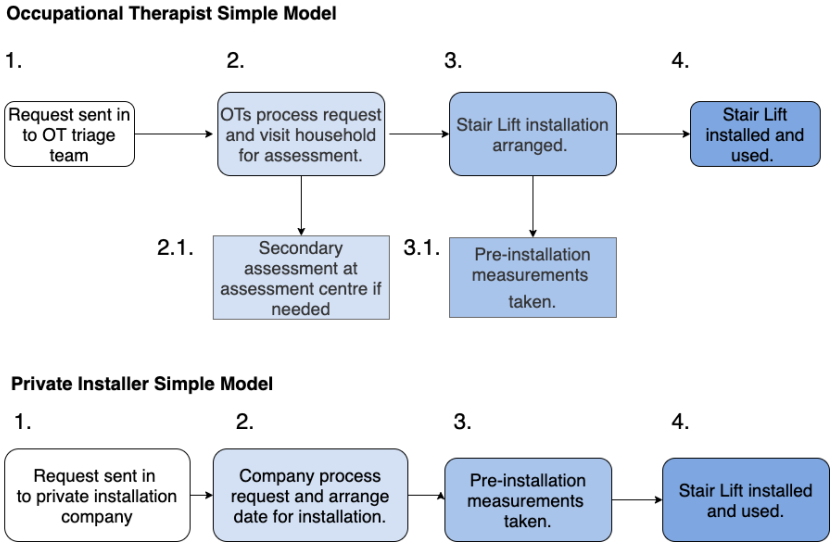
Table 4.1: Demographic data and participant information for households recruited during the study.

Household number/ID	Name	Age	Gender	Role	Install Type	Notes
H-A	Abbie	71	F	Stairlift Owner	Privately Funded (rural property)	Abbie lived with a chronic pulmonary condition, where only 35% of her heart was functional. She could not go upstairs more than once a day for bed and required assistance from her husband, Andrew, who not only supported her mobility inside and outside of the home, but also supervised and maintained the stairlift.
	Andrew	71	M	Spouse		
H-B	Brenda	58	F	Stairlift Owner	City Council Funded (urban property)	Brenda had thyroid cancer and recently had a highly invasive operation to her spine that left her severely mobility impaired and prone to falling down the stairs. She is assisted by her husband, Bradley who also supports her mobility inside and outside the home.
	Bradley	55	M	Spouse		
H-C	Claudia	54	F	Stairlift Owner	City Council Funded (urban, council owned property)	Claudia has been hospitalised numerous times from a chronic lung condition and countless falls. Shortly before our first visit, she was released from hospital again and was expecting a return for further surgery. She is assisted by an extensive family network and a live-in granddaughter who helped her up the stairs to prevent her falling, prior to installation of the stairlift.
H-D	Doris	63	F	Stairlift Owner	City Council Funded (urban property)	Doris has sciatica and lymphedema in both her legs. She is supported by her daughter who increased the frequency of her visits to her mother after a serious fall, shortly before our first visit.

Table 4.2: Demographic data and participant information for service providers recruited during the study.

Role	Participant ID	Recruitment Method	Engagement Method
Occupational Therapist	OT1	Email/telephone	Focus group at council offices
	OT2		
	OT3		
	OT4		
	OT5		
Stairlift Installer	IS1	Telephone	Interview at institution office
	IS2	Email/telephone	Telephone interview
Assessment Centre Workers	AC1	OT contacts/email	Interview at Assessment Centre
	AC2		

Figure 4.1: The simplified Stairlift installation models for occupational therapists and private installers, developed from interviews with OTs, Installers and ACWs.



However, we uncovered ways in which these linear journeys are quickly complicated by the socio-technical interactions between the wider household and the stairlift. This supposedly simple process towards getting and using a stairlift is impacted by the individual experiences of the residents and the household dynamics. This leads to a journey through decision making, conflict and trauma, and catharsis and independence towards the adoption and acceptance of this visible domestic assistive technology that is experienced by all residents in the multi-resident home. We discuss how these actors are each affected by the stages of this emotional journey.

4.4.1 Decision making

4.4.1.1 Stairlift decision making in the home

Decision making constitutes the first 'stage' of the stairlift installation process where households go through a process of discussion, argumentation, conflict and resolution between all residents as to how to reconfigure both the physical space of their home and what lifestyle compromises they will make in order to accommodate a large piece of intrusive, assistive technology. As a result, the difficulty in making these decisions varied between households.

In H-A and H-B, residents were faced with a decision: to install the technology or to move to different accommodation. There was mutual agreement between both residents in H-A that *"[...] it's the right decision. No upheaval.*" (Abbie). In H-B, there was considerable tension that developed between residents deciding whether or not to get the stairlift. Early in the decision-making process for H-B and after speaking to an OT about Brenda's health, Bradley made a decision on her behalf to investigate how to get a stairlift installed. At this stage, Bradley's daughter and granddaughters decided to arrange a mobility assessment from an OT, who came to their home. Brenda ignored the OT when he arrived: *"... she was very rude [...] she wouldn't speak to him and just kept watching TV [...] but he was completely lovely [and] took it completely in his stride."* (Bradley).

In H-C and H-D, extended family and friends who visited these households frequently took a central role in helping to make decisions about getting the stairlift installed. As such, Claudia's decision-making around the stairlift was impacted by the variety of different family members who frequently visited her. Whilst she had minor home health modifications installed into her home before (e.g. grab rails), the decision to get the stairlift appeared a step too far to her, despite the insistence from her regular visitors: *"my granddaughter said 'oh nan, don't you think it's time...' [...] but I didn't want to [...] I've always been the carer of the family I suppose... I didn't want to give in."* (Claudia). Similarly, in H-D, Doris also had a number frequent visitors to her home including extended family and friends, and as her mobility declined, Doris' daughter had started increasing her visits from once every other day to almost twice per day. On our first visit, Doris' number of falls had recently increased and as a result, like Claudia, she was becoming hospitalised more often. At this time, her daughter and a friend both happened to make a suggestion to her: *"[they] just came in one day, saw the mess [after a fall and said], '[Doris], you've gotta put in for one.' [...] A few days later, my daughter said: 'mum, I'm doing it.'"* (Doris). At this stage, Doris resented the decision: *"I didn't want one [...] [they're] horrible, ugly things. But, y'know, needs must."* (Doris). As with Claudia and Brenda, Doris began the installation journey feeling resistant to the technology, but also feeling despair at her health situation. Whilst much of the initial decision-making process experienced by residents was informed by a physical need, arising from

their underlying health conditions, other emotional considerations affected these decisions and were reported across each household.

In H-A, the decision to get the stairlift extended beyond Abbie's physical health. Andrew managed to persuade Abbie early in her decision-making process that moving out of their current home wouldn't be beneficial: *"The alternative was moving into a bungalow [and] for the cost of the stairlift [...] with the [property acquisition tax] on top, it wasn't worth it."* (Andrew). To this, Abbie retorted: *"He made the decision more than me! [laughter] [...] [Andrew] phoned [local stairlift company] for me. To tell you the truth, I was a bit reluctant."*. However, it was not just her spouse who influenced her to remain in place in her home and to go ahead and get the stairlift: *"My daughter was bullying me into it, [. . .] even my granddaughter who's only 3 had a go at me about it [laughter]. She had been primed, I must admit. 'Tell grandma she needs one!'"* (Abbie). This account exemplifies how it is not just the stairlift owner making the decision about getting the stairlift for their own health. The wider household have suggested to, argued with and (sometimes with the help of grandchildren) coerced the stairlift owner into considering their feelings as well. Abbie's account describes explicit coercion (*"bullying"*) which impacted her decision to get the stairlift. In H-B, H-C and H-D, however, the influence of other residents is more nuanced: *"my daughters really wanted me to get it. [I'd] had a fall once and they couldn't get a hold of me, so they bought me a new mobile. That was before they told me to get the lift!"* (Brenda).

Figure 4.2: Abbie (H-A) making use of the stairlift in her home.

Participants recounted stories from close friends or relatives who had a stairlift in their homes, and in some cases residents actively sought out stairlift owners to source information and experiences to alleviate their own unease about the technology. In H-A, Abbie described how her mother had a stairlift, with Andrew later confirming (or perhaps reassuring Abbie): *"it's an old rickety thing [..] ours [will be] much better"* (Andrew). Both Claudia and Doris also describe

how they reached out to their sister and mother respectively, to gather more info: *"I've used my sister's before now... it was quite slow. But I didn't have any problems on it. I knew what to expect."* (Claudia). Brenda describes a situation where she sought out friends to find out more about the stairlift and to help guide her decision on it: *"I was feeling very unsure about it so [I spoke to] our neighbours... they were very interested that I was getting one put in. They had one put in. So I asked them [what it's like] and they went 'ooh, it's so good [Brenda], it'll be a big help.'"* (Brenda).

At the same time as these high anxiety levels were reported, participants described reaching out to friends or relatives for their opinions based on experience (either lived or anecdotal), but they did not describe looking for written clinical or diagnostic information. The self-reporting of high anxiety levels at the start of this shared stairlift journey, supports the accounts of "unsure" participants seeking out advice, stories or information from trusted (rather than official i.e. government health) sources, as an important step for our participants towards tackling this anxiety and moving forward with their installation journeys.

4.4.1.2 Clinical Decision Making in the Home

Conversation with the OTs began by informing us that stairlifts are designed and tailored to a person's dimensions and their home environment (e.g. height, weight of a person, space on the staircase, which all informs the type of stair lift (stand up, kneeling) that is provided and where it sits in the home. This is contrasted interestingly, with accounts from our Assessment Centre Workers (ACWs), who describe how the ability for stair lift owners to personalise their stairlifts (e.g. change the colour, fabric etc.) is in fact "limited" (ACW1) to only basic choices on colour (e.g. cream, black). Decisions relating to stairlift installations paid for by the local city council often take place outside of the home. Clinical assessments of a person's mobility and health, to determine whether they should have a stairlift installed or not by OTs can take place over many months. However, during the focus group with the OT team, they described how they form strong relationships with households as part of their roles through numerous home visits. As OT2 pointed out: *"It's a holistic assessment... [we] speak to family members, carers, especially if that person isn't able to [...] communicate very well."* (OT2). OT1 added: "*Often, these people are not in the best of health."* (OT1). This account emphasised how important it is to not only get to know and assess the person who the stairlift will be designed for, but also to complete a holistic, interpersonal assessment of the whole household and each individual's needs to ensure that the right equipment can be put in place for the right person and health condition, aiming for acceptance of the technology by other residents as well.

The OTs expand on how it is often necessary for them to speak to other members of the household during an assessment, if the stairlift owner is, for example cognitively impaired: "*we look at all sorts of options first [...] who's supporting them, who's affected [...] [I was] working*

in the children's team.. so we had children with severe autism. So we had to look at putting a stairlift in that was going to meet the mum's needs [for her home], and her child's as well." (OT3). When the user of the stairlift is not able to give voice to this decision, the OT must then weigh the benefits of the stairlift for an entire household, in order to carefully make a decision that balances all of the residents' needs. The OTs described how, often, it is the fears of the other residents (as seen with OT4) that lead to the decision-making around the stairlift taking place: *"... families want to jump to this [getting a stairlift], because they're scared, because they're not living there. They're afraid - they're afraid they're gonna get a phone call that person's falling - and.. [...] if we'd put a stairlift in, that wouldn't have happened."* (OT5). However, the OTs role also requires them to dissuade people from choosing a stairlift: *"They see it on the TV and they think 'Yeah, that's what I need.' Or I've had [another case where] the son was like 'well if she needs a stairlift, we're going to buy one. We'll do it ourselves. We don't need you.' [...] They were quite rude actually. But [...] they're scared [...]"* (OT2). In this case, the OT described how families often ignore their clinical decisions and dismiss the wishes of the person with mobility needs, to get the stairlift, even if that is not the most clinically suitable option. This supports findings from H-A and H-B, where family members used coercion (H-A) and intervened on behalf of the person requiring care (H-B) in order to ensure the stairlift would be put in.

4.4.2 Conflict, trauma and risk

4.4.2.1 Conflict outside of the home

Following the decision-making stage that takes place between residents within the home, our participants discussed a stage of struggle that sometimes takes place outside of the home in local assistive technology showrooms. At the facility called the "Assessment Centre" (Figure 3) (OT3), city council-funded households are referred for an appointment to test their mobility and cognitive ability, if this information cannot be gleaned from a home visit by the OT. This site was where conflict and trauma was experienced most by our participants.

H-B was visited by an OT in their home and also attended their local assessment centre. Brenda describes how initially: *"It was difficult in the beginning, but I've grown to like him [OT]."* (Brenda). As a result of this, Brenda eventually conceded: *"I said I'd go [to the assessment centre]... but, only if [my husband] went with me."* (Brenda). Despite this initial agreement to attend the appointment at the centre, conflict was apparent almost as soon as they arrived: *"When I first got there.. I did say 'I don't think I need one. I'm quite alright to walk at this stage' ..and I went to leave"* (Brenda). Her husband disagreed because despite her recent spinal operation and her frequent falls, which impact him: *"She likes to fall.. in the night. She'll get up and sometimes I'll hear a loud.. crash. [...] Only the day before this [appointment] you fell again, didn't you?"* (Bradley). However, the OT spoke further with Brenda and convinced her to stay for the rest of her appointment: *"...he kind of knew that I wasn't happy being there [and having a stairlift]."* (Brenda).

Brenda and Bradley then argued over the need for getting the stairlift in the assessment centre with the OT present: *"She told me 'I don't need it, I can do without it.' But I said back to her.. 'just try'"* (Bradley). Brenda proceeded to walk up a small set of stairs which were built into the centre for their clients to use during assessments. After failing twice, the OT came over to her and said: *"'Okay, I've seen enough [...] I can't force you to get one but you do need one' [...] at that stage, [Brenda] was in tears. And I knew that that meant she had surrendered to the idea. And there are advantages to being married for nearly 30 years. [laughter]."* (Bradley). Sometimes, the OTs made recommendations for additional modifications at the assessment centre (at no extra financial cost), but which would further support the stairlift owner's mobility elsewhere in the home. Doris also reported how the OT suggested to her that she must consider getting an accessible bathroom installed, to further support her in the upstairs of her home, beyond the stairlift: *"... Yeah I cried. Because it was such a shock. I thought 'oh we're only having a stairlift' [...] but then [...] I didn't want to lose any more space in my home."* (Doris).

The experience that H-B describes is echoed by the Assessment Centre Workers (ACW1, ACW2). The ACWs describe their role as: *"...not here to sort of pressure sell them. We're not here to say 'this is what you must have'. It's just to give them advice. [...] We have an in-house OT, as well as [OT from the local council]. [...] It's all about... giving them the information they need."* (ACW1). However, in some situations, despite solely acting as information providers, the ACWs are drawn into a household conflict: *"You can be like a referee as well!"* (ACW1), *"[we say], 'take your domestic outside!' [laughs]"* (ACW2). Throughout this conflict stage, the assessment centre staff try and remain neutral and uninvolved, however, this is not always practical or easy to do. ACWs describe how public arguments can break out in the centre over anything from the cost of a stairlift installation (*"they have to weigh up the expense sometimes, and that sets them off"* (ACW2)) to the colour scheme of a particular modification (*"they both [had] conflicting views over what [colour scheme] would look nice in their bathroom.. there was a bit of a domestic."* (ACW1)).

Figure 4.3: The Assessment Centre, which provides a range of low-tech home modifications that can be trialled and/or purchased.

The ACWs highlight how the nature of this conflict could be linked to a sense of embarrassment experienced by the person receiving the home modification: *"they go 'oh, I'm ever so sorry, I wish I didn't have to be here'.. then turn round and carry on bickering."* (ACW1). This extends our findings from H-C who also experienced a sense of embarrassment when attending the assessment centre. Claudia describes how: *"I [tried] to climb the stairs [in the assessment centre] and just fell flat first time. It was so embarrassing."* (Claudia). Participants' experiences of embarrassment in the assessment centre were described as linked to their attempt to climb the stair case, but also with trying out the technology itself: *"I felt a bit embarrassed at first [trying out the stairlifts] just that I got to that stage to show how bad you are. [...] [daughter] said 'go on mum, put in for one.' and then I cried. Oh I cried."* (Claudia). This account demonstrates that trauma experienced by the stairlift owners is not necessarily a result of direct conflict or disagreement. In this case, Claudia was encouraged by her daughter but not confronted or coerced whilst in the assessment centre. Nevertheless, this experience is still described in traumatic terms by Claudia, as she had to come to the same realisation as with the other households that she must ultimately "give in" and get the stairlift for her own health benefit. Whilst these accounts provide an idea of how stairlift installations can be traumatic for households inside of a public space like the assessment centre, there is also a great deal of trauma experienced by all residents in their own homes, both before installation and after the stairlift has been installed.

4.4.2.2 Lived trauma in the home

Residents also provide accounts of their trauma with stairlift installations in their own homes. Doris recounted the experiences with her new stairlift only a few days after installation: *"[It's] Ugly and scary [...] It looks like - well, it's a monorail. [...] I think it'd be better suited to a ski resort than on my stairs."* (Doris). Doris's account attests to how the stairlift is not a 'neutral'

healthcare technology in the home Mol (2008), but rather intrusive to the space. She goes on to describe how the other members of her household have similarly experienced the stairlift: *"Even my granddaughter - and my grandson who's sort of frightened of nothing, he said, 'I can see where you're coming from, Nan, I can see you'd find it a bit scary."* (Doris).

The experience of the stairlift installation itself (the day of installation), presents a further traumatic experience in the homes of both H-D and H-B. *"...about a week before [installation] somebody had come and he'd put stickers everywhere and taken hundreds of photos. You know when you see these detectives doing crime scene things and they put little stickers there and they take photos, I thought, 'Any minute now, he's going to draw out a body on the . . . ' It was like that."* (Doris). She describes how, later on in the day of the installation *"I heard a bang, so I didn't say anything but they have scratched it [stairlift rail] [...] I saw him touch it, he thought I didn't see him. I sort of looked up and he's sort of touching it up with Tippex. [...] It was a bit of a shock really."* (Doris). H-B recount a similar experience of their own stairlift installation, which was provided by the local city council: *"It was actually quite traumatic. They arranged a date for the installation [...] The following morning they didn't turn up. This upset [Brenda], and she'd just come around to the idea [of getting the stairlift.] So we re-arranged."* (Bradley). Of the installation itself, Brenda describes: *"I found it very difficult looking at it. I got very emotional. When it was being put in, I got very emotional because it's like it's another thing to accept. That sounds strange but everything I've been through - it's accepting what I can't do any longer."* (Brenda). After installation, H-A also described a traumatic experience with the technology shortly after beginning to use it: *"there was a bleeping noise [...]"* (Andrew), *"we just couldn't turn it off at first [...] [it was like] my alarm clock."* (Abbie), *"[...] so we had to come and get someone out to tell us how to fix it."* (Andrew).

4.4.2.3 Risk in stairlift installation settings

The stairlift installers also recounted their own perspectives of changing installation plans that might cause stress or unease in the household: *"you have to assess the risk every time you go to a property [...] some homes may be unhygenic. I had a [client] who I turned up to, went into the hallway and had to politely leave. I then phoned my manager and said 'look, sorry, I can't do this job. It's not safe. [...] I'll re-arrange it though.' It's hard, because you know they need it."* (IS2). The installers described the wide variety of installations that they deal with day to day (e.g. *"six million-pound yacht [and] a high-security prison."* (IS1)) and the importance of being able to empathise with peoples' needs for stairlifts, despite their circumstances. In many cases, the installer described how it could *"take all day"* in order to teach new stairlift owners how to use the technology. Despite being provided a brochure on its use, the installer does not leave the property

until they are confident that the owner understands how to use the technology, *"otherwise, you just have to go back."* (IS1). To this end, he argues that *"patience"* and *"calm"* are essential to his role, even if not prescribed for every installer, as the learning process, particularly for people with different cognitive abilities, cannot be rushed. IS1 described how each installation provides its own challenges, which can be linked with the trauma of installations: *"I mean each job is different. Sometimes... if you've got say, a curved track, you need two guys going in and it can take all day. But if it's just a simple straight, it might take just a few hours. [...] Sometimes there's damage.. and you can't avoid that."* (IS1). Whilst this account does not provide contrary information to H-B or H-D's installation experience, IS1's experience of installations does show the challenges he experiences due to the diversity of stairlift products, home settings and challenging working environments.

These accounts from residents and installers show that they both understand the benefits of the stairlift and will work to make an installation happen, despite trauma from the installation itself (residents) or the challenges in working in environments with risk (installers).

4.4.3 Catharsis and independence

The challenges of making a decision and the trauma experienced during and shortly after getting a stairlift is compounded by residents' ongoing chronic conditions and care burdens. Despite this, participants also had positive discussions around the stairlift that emerged as adoption moved towards acceptance. After the initial period of trauma, most residents (not just the stairlift owner) experienced a strong catharsis. Within HCI, cathartic practises (or actions that "have a strong impact on humans by releasing tension" (p. 22:5) (Luria et al. 2020)) are described in a variety of ways; from the destruction of physical objects, to playing video games to relieve stress (Iacovides & Mekler 2019). Our findings see the stairlift used in a similar capacity - as a tool through which strong emotions, which have built up either in one resident or in multiple residents, prior to its installation, are released in a variety of ways after the initial installation.

The catharsis that is apparent in H-A comes in the form of shared play with the device. Once the stairlift was installed and *"playtime"* got underway with her granddaughter, Abbie discussed how she engaged with her grandchildren to share these experiences of fun and play with them: *"It's 'grandma's up and down chair.' It's a toy. It's a child's toy. [laughs][...] It's nice to be able to use it with them finally."* (Abbie). After 3 months of living with the stairlift in their home, Andrew also described a sense of relief and discussed the changes to H-A's household dynamics: *"[I] would never go out until [Abbie] was actually downstairs. [...] Now, because of the stairlift [I'll] go out knowing that [Abbie is] ok coming down the stairs. So I suppose it's made life a bit more easier for both of us actually."* (Andrew). In contrast, Brenda described a cathartic moment when she recognised how her household dynamics could remain the same because of the installation: *"[just*

after the installation] my husband said 'if you didn't have the chair we would've had to have moved - and lost this house and gone to a bungalow'. I cried. [...] I think they [husband, children] knew why. It was a relief honestly. It was the right decision." (Brenda). Similarly, Claudia discussed how her moment of *"relief"* came when she considered that she had full access to her own home again. Having previously been planning to restrict her daily activities to the downstairs of her house, Claudia experienced a strong relief and realisation: *"When I realised... I wouldn't have to be living downstairs for the foreseeable.. that was such a relief. And y'know it's given me that [upstairs of her house back]. Oh I cried."* (Claudia). Doris also describes a catharsis, albeit tempered by her ongoing fear of the technology: *"I mean... I know what it means to me, I came to that moment early on - bright light, aaah [laughs]. I know it's gonna do good. I think that helps me get over the fear! [laughs]."* (Doris). Despite this fear, Doris expresses that she can see the benefits of the technology for her own health and wellbeing. This is echoed by the stairlift owners, where their initial resistance to the stairlift has been reconciled with the benefits of their experience of using it.

Other residents in H-B and H-D also discussed a sense of relief, as well as a reduction in care burden and greater independence from not needing to be physically present in their house as often. Both Andrew and Bradley describe a much greater feeling of independence, with Andrew able to have greater freedom to exercise at their local gym "without worrying" and Bradley being able to visit their local allotment: *"I don't have to worry anymore that I'll get a call [from one of our kids], saying [Brenda] has fallen down the stairs."* (Bradley). Residents describe how they had benefitted (or would have benefitted) from greater freedom to engage in their hobbies and thus increase their own mental wellbeing. In H-C, Claudia's family, also discussed the greater freedom they experienced with her: *"means my granddaughter can go out and see her friends [...] my sister came over and said 'this ain't half bad [Claudia], is it' and had a go on it."* (Claudia).

These accounts reveal not only the extent of the stairlift owners' emotional struggle with their mobility (and subsequent sense of relief and release), but also the benefit of the stairlift installation to the quality of life of the wider household. Whilst the initial benefits to the stairlift owner become apparent almost immediately (e.g. Claudia being able to easily access all the parts of her house again), the benefits to the other residents become apparent after the stairlift has been installed for a longer period of time. From the accounts of residents who indirectly 'used' the stairlift, these benefits are apparent at the 3 month post-installation interview stage, with some residents (e.g. Andrew and Bradley) showing direct advantages to their physical Activities of Daily Living (ADLs) (Boström et al. 2018). Others, such as the non-resident children and grandchildren in H-B and H-C discussed more indirect benefits at 3 months such as reduction of care burden and less worry or anxiety about the stairlift owners' welfare: *"It's a relief for my daughter now too. She's autistic and she's seen me fall a few times and it scares her" (Brenda),*

"She [granddaughter] has to help me upstairs much less often. Still, a little bit time to time, but much less often" (Claudia).

4.5 Discussion

We have investigated how stairlift installations affect the primary user and the wider household to see how this technology enables people to age in place together. Our findings showed that actors both inside and outside the home engage with the stairlift journey in different ways and at different times, meaning that this type of domestic health technology is in fact collaborative and social. This visible assistive technology is interdependent, as Bennett et al. (2018) describes on others to be emotionally accepted, not just relying on acceptance from the stairlift owner. Therefore, the simple models that the occupational therapists and home installers described for the stairlift installation process (Figure 1a and 1b) are oversimplifications of a much broader, messier and more complex set of socio-technical activity in the home. Whilst each households' emotional experiences of the stairlift journey are incredibly nuanced, dependent on the health condition of each stairlift owner and the socio-technical interactions between all household residents, the authors developed a summarised 'view' of the emotional installation journey (Figure 4.4, below), which extends the simple model (Fig 4.1) and presents a more holistic emotional installation journey that encompasses all three aforementioned stages and where this journey is influenced by the wider household.

We next describe the stairlift's influence on the wider household, how to mitigate some of the problematic elements of the shared emotional journey and then propose research and design implications directly arising from each stage of the stairlift journey for technologies aimed at supporting the management of health and wellbeing conditions in domestic settings, including assistive technologies (Branham & Kane 2015), self-care technologies (Nunes et al. 2015) and smart home technologies (DanaKai Bradford 2016).

4.5.1 Supporting health and care technology journeys

Reflecting on the three main stages of the emotional journey, we can identify transferable research and design implications for visible assistive technologies like the stairlift, which are aimed at supporting the management of health and wellbeing conditions in domestic settings.

4.5.1.1 Mitigating conflict and empowering accessible technology use

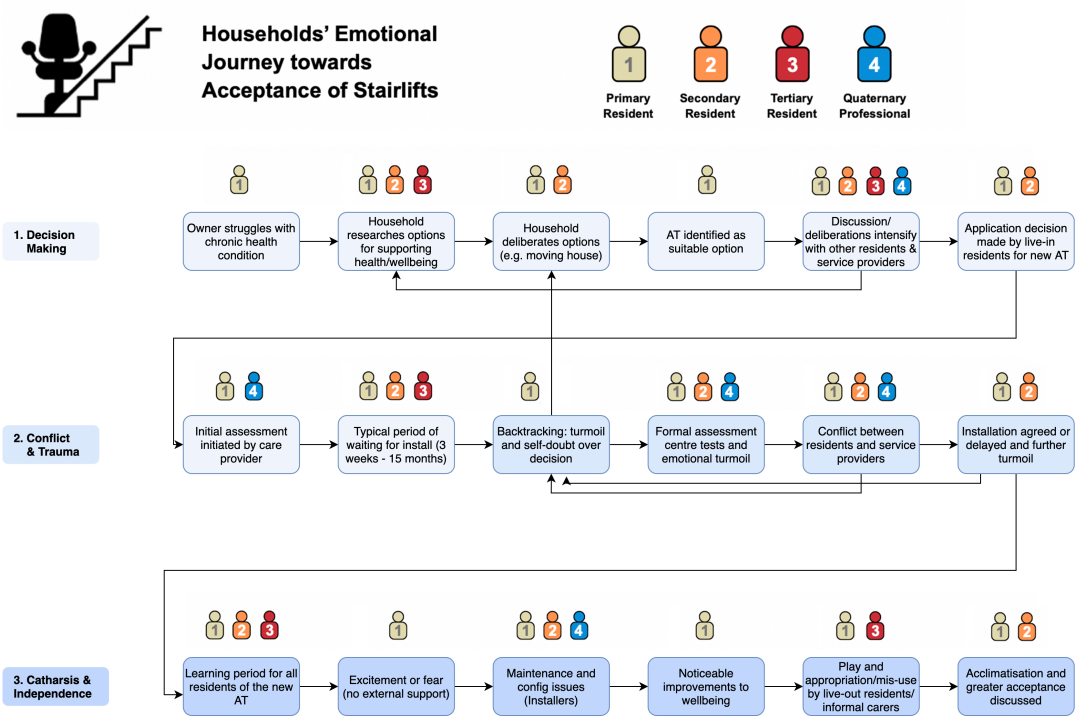
Due to the complexity of each stairlift adaptation journey, conflict and tension between the stairlift owner and other residents or professionals, was something each participant touched on, from conflicts with OTs to public family arguments, such as in H-B, in the assessment centre.

From our accounts of trauma in stage 2, we advocate for researchers, designers and care professionals to support the process of AT adoption and acceptance at each stage towards acquiring and using it, with the understanding that conflict arises around the technology, as part of a lengthy, often mentally and physically traumatic socio-technical process. Our participants' accounts showed that the strong emotional experiences, such as attachments to their home's physical space and not wanting to damage this (H-B, H-D), to worrying what others would think of the technology (H-A, C, D) and not wishing to come to terms with their own long-term health conditions.

These experiences around home health technology must be weighed equally as importantly as the practicalities of the installation itself; as the introduction of a new technology is going to affect the quality of life of the wider household care network, both inside and outside the home. This observation has been made by others too. Kraemer et al. discuss 'group efficacy', which refers to: "the ability of the group to exercise influence over the technology" (p. 7) (J Kraemer et al. 2019). Building on this, Gutierrez et al. (Gutierrez & Ochoa 2017) also observe "unbalanced" relationships that are "conflict-prone" (p. 1618) between older adults and the care stakeholders in household caregiving settings. Bennett et al.'s work. too (Bennett et al. 2018), shows interdependence between household residents on one another, for social support and catering for others' needs beyond the owner of the technology (a single person).

We see frequently from the stairlift journey, how power imbalances are apparent between residents, yet the pre-existing (simple) models of installation do not refer to any measures that would mitigate this conflict or any plans to support families during this experience. As such, a more comprehensive model of stairlift installations is needed, that can account for the nuances and complexities of the roles that different residents play within each home's installation journey:

Figure 4.4: Illustrated summarised view of the three-phase emotional journey, for households adopting and accepting a stairlift.



The view shown above is based on the findings from the first (stairlift) study and is used to illustrate the multi-resident view of the emotional journey towards adopting the stairlift. This view was chosen as an illustration as the stairlift study presented the most linear journey to envisage the intersection of roles and responsibilities as time progressed. However, this view is neither complete nor prescriptive. Instead, this view intends to summarise and exemplify our participants' lived experiences with the stairlift installed.

Schneider et al. (Schneider & Malin Eiband 2018) suggests that a structured understanding is needed in order to identify sources of disempowerment, which "requires a definition of the underlying maxim and goal of empowerment" (p. 10). Through understanding where difficulties such as conflict or trauma are arising e.g. from arguments with OTs (H-B, H-D), to multi-resident arguments in assessment centres (H-B) and emotional distress in these spaces too (H-C), actions can be taken to be able to prevent this and in turn support and empower the people getting a new home health technology. There are opportunities to prepare people for these conflicts and to reduce disempowerment in the multi-resident home by facilitating difficult conversations earlier in the adoption journey with the aim of reducing anxiety, apprehension or possibly resistance when encountering a new assistive technology for the first time. Potential technological solutions might help prepare households for the decision-making stage, by considering factors such as cost and downsizing their existing homes (H-A) to apprehension brought on by discussion with friends

and family members (H-C). Considering these factors could encourage discussion in situ, in the home, instead of in public spaces where arguments and subsequently, embarrassment may occur. To support difficult conversations inside of the home, for example, an augmented reality system could be developed, to let users experience the technology being placed in their homes virtually, before committing to a physical installation. Embedding technology into the stairlift journey as a support mechanism for the journey itself, could help to empower the multi-resident household and help all residents feel greater control. Moreover, health professionals who work closely with households during the home health technology journey could help to refine this technology, by using their own experience to identify potential coping strategies where difficulty or conflict typically arises within the adoption and acceptance journey.

4.5.2 Supporting complex and bespoke journeys

Beyond empowering each household and each primary user in decision making around the technology, it is necessary to consider how to cater to each new AT installation journey for each unique household. No two homes or installation journeys are the same; each come with its own set of challenges and rewards, showing again the fallibility of simple models for home health technology installations. Desjardins et al. (Desjardins et al. 2015) and Wolf et al. (Wolf et al. 2019) exemplify this, showing that homes themselves impact the activities that take place there (e.g. the way food is prepared (Desjardins et al. 2015)), which has implications for health and wellbeing technologies where unique household contexts can influence adoption and acceptance journeys. This reflects our participants discussions of the physical space of their homes and how permanent changes to their homes is of great concern alongside the desire to mitigate disruption (H-B), mess (H-B, H-C) or damage (H-D) to their properties. Here, technology could benefit households through e.g. designing online guidance for participants, that explains what physical changes to their home are likely to occur in a range of household varieties (e.g. houses, apartments, boats etc.).

In addition, people living with diverse health and wellbeing conditions tend to have idiosyncratic self-care needs and technology preferences (Ayobi et al. 2020, Branham & Kane 2015, Gu & Wang 2009), which further diversifies each household and makes designing tailored technologies even more challenging. The household context itself, the people within the home, and the technology that is used there will always be unique. As such, we encourage healthcare professionals and service providers to address this socio-technical complexity by supporting home healthcare technology installations journeys flexibly and not to adhere rigidly to standardised 'one-size-fits-all' models, that often inform health and social care policy (Dourish 2003) (e.g. considering the complexity of risk that our installers described in their visits to different types of homes, the difficulties of conflict that ACWs have to mediate in assessment centres, and the judgement that OTs used with those who were resistant to stairlift assessments). A change in

service design from the healthcare provider (in this case, the local city council) that 1) considers how the technology itself impacts the assessment and installation process, 2) considers what factors are known 'pain points' (e.g. instances such as the aforementioned conflict within the assessment centre), and 3) prepares residents for adjustments to their daily lives could improve communication and social interactions between the healthcare professionals (quaternary) and live-in (primary, secondary, tertiary) residents, throughout the stairlift journey. Adapting the provision of home health technology for diverse homes and to each household context should be a direct consideration for complex socio-technical journeys such as stairlifts installations, and also for new intrusive and emerging home health technologies.

Prior work has demonstrated the benefits of investigating a wide range of low-fidelity tools to inform emerging technologies, from examining tangible money practices to inform digital financial systems (Agency 2017, Gutierrez & Ochoa 2017) to exploring paper-based practices to inspire new self-tracking approaches (Ayobi et al. 2016, Carlos Rubino de Oliveira et al. 2015) and digital medical checklists (Geeng et al. 2019, Holroyd-Leduc et al. 2016). Digital health and care systems such as (Astell et al. 2019) and (Soro et al. 2017) have also previously supported holistic clinical interventions, so it is reasonable to propose that future smart home research and design could similarly support the varied duties of quaternary professionals using a combination of low-tech and digital systems to perform e.g. in-depth holistic assessments of technology interventions in multi-resident homes, with access to social data on the household structure that is made available to clinicians, on request.

4.6 Limitations

As our study took place over a 3-month period, it was not possible for us to understand the longer-term acceptability of the technology. Our data was also recollected by participants during each interview as opposed to gathering an understanding of lived, situated experiences. Although we were interested in the overall shared experience of the emotional journey, engaging with and analysing individual households provided further depth in understanding unique dynamics of those contexts for future work. Moreover, our investigation was only able to capture second hand accounts from other members of the household on the role that tertiary residents played in the stairlift installation. As such, we believe there is opportunity to further explore the use of LTHMs (or stairlifts) within the HCI domain.

While our qualitative approach provided retrospective accounts of the lived experiences of each household, further investigations of stairlifts could look at comparisons between e.g. stairlift usage log data, compared against people's self-reported accounts of stairlift use, to identify and probe discrepancies around perceived use. Further, whilst our study ran for three months, experience sampling of participants getting a stairlift over a longer period of time (around 1 year

post-install) could also be captured to further explore emerging issues we found in participants' interviews at 3 months e.g. investigating the impact of longer-term maintenance of the technology.

4.7 Conclusion

We detail how the journey towards the adoption and acceptance of a stairlift is impacted by the messiness that arises from the needs and wants of all the residents in a multi-resident household. Our findings focussed on the difficulties that arise from the physical and emotional impact of the stairlift installation journey on household residents, who are aging in place together. Our qualitative approach revealed non-linear improvements in the quality of life of the stairlift owners and a trend towards technology acceptance for members of the wider household. The case of the stairlift specifically builds on existing discussions of co-constructed support for care in the home. We found that the acceptance of the stairlift as an accessible health and care technology is reached as a direct result of being negotiated between all actors involved with the technology, across the decision-making and conflict and trauma stages - over time. It is adopted for all residents during the catharsis and independence stage and is used and even enjoyed, by family members once the earlier turbulent stages have been emotionally overcome. We propose that considerations for the adoption and acceptance of any home health technology take into account the four sets of actors that influence this emotional journey: primary residents relying on the technology, secondary residents living with the technology, tertiary residents regularly interacting with the technology, and quaternary professionals outside the home who specifically impact the journey through their service roles. The following chapter builds on these discoveries and looks at the use of an off-the-shelf consumer voice assistant technology with screen; the Echo Show, for health and care).

CHAPTER 5

VOICE ASSISTANT STUDY

5.1 Preface

This chapter showcases the second empirical study in this thesis which investigates how a voice assistant device with a screen affects the quality of life of shared households, with living at home together during the outset of the COVID-19 pandemic (March - July 2020). This study draws on RQ2 ("How are commercial smart home technologies being appropriated for self-care and collaborative care practises?") and RQ3 ("How is self-care and collaborative care work impacted by the introduction of complex smart home technology to support healthcare at home?") from Chapter One; identifying the shared and cross-generation impact of a commercial smart home technology on the lives of people living together in a household. In the previous chapter, we discussed the work of Höök (2010) in regard to 'transfer scenarios' that motivated the investigation of an inherently non-smart, low tech home modification (stairlift) to derive insights into its use and acceptance as a health and care technology. In this chapter and the following chapter, there is instead a need to motivate this work through investigating the acceptance of commercially-driven (Chapter Five) and research-driven (Chapter Six) smart home technologies to understand their impact again within shared households.

This study was again conducted in partnership with Bristol City Council and also the Milestones Trust in Bristol and investigates the impact of a commerical smart home technology's acceptability in the home and its impact on quality of life. As such (and akin to Chapter Four), this chapter uses the collective 'we' to reflect multiple authors collaborating on this research, where the author of this thesis remains the first author for the paper and this chapter.

5.2 Introduction

The impact of the COVID-19 pandemic on people's lives across the globe has been unparalleled (Miller 2020). The pandemic has put a spotlight on the importance of supporting health, wellbeing and care needs within the home, especially for those who do not have immediate access to the people and resources that they normally would. Social distancing during the pandemic is linked with social isolation, which occurs when people have "limited contact with others" (Waycott et al. 2015) [p. 241]. At the outset of the 2020 pandemic in the UK, some adults were instructed to reduce face-to-face engagement with other people, including family and friends, and therefore become more physically and socially isolated. These "shielded" adults were people who are at serious risk of illness during the pandemic due to being "immunocompromised or hav[ing] chronic conditions," and this included older adults (Amani et al. 2020). The act of shielding fostered a unique self-imposed social isolation for individuals and households, which is predicted to have long-term negative consequences on people's health and their own social efficacy (the ability of a person to collaborate with others for their own, or another person's benefit) (Saltzman et al. 2020).

The pandemic exacerbated a problem common to older and vulnerable adults, social isolation (Best et al. 2020, Comas-Herrera et al. 2020, Lopes & Jaspal 2020, Saltzman et al. 2020, Tyrrell & Williams 2020), with further restrictions on their physical and social efficacy, both self-imposed and due to circumstances outside of their control. This situation risks worsening existing health inequalities for specific demographics (e.g. culturally and linguistically diverse shielded people, who often depend on their wider community to support their physical and social wellbeing (Lee et al. 2020)). As shielded adults were recommended to isolate alone at home, we look to the home itself where self-isolation is enacted and experienced in order to investigate how technology can support older people here.

Smart homes and voice assistants hold great potential for helping people to live well at home. Recent research has shown how smart speakers such as Amazon's 'Echo' devices have been used to support older adults in their homes to live independently and support their own health and wellbeing (Abdolrahmani et al. 2018, Bickmore et al. 2018, Burdick & Kwon 2016). The HCI community has also taken a focused view of the ways in which this technology is used, mis-used and abandoned by older adults (e.g. (Mahmud et al. 2020)), and in particular why this technology is abandoned more commonly in shared spaces (Trajkova 2020). Smart home technology that is shared in the home has also been discussed in relation to the roles of family caregivers in the home (Foong & Zhao 2016), how privacy is preserved there (Geeng et al. 2019), and how technology can be used by non-owners to support the health and wellbeing of the people around them (Caldeira et al. 2017). Studies published at the outset of the 2020 pandemic also highlight

opportunities for design to support health and wellbeing using smart speakers, chatbots or voice assistants (e.g. Amazon's 'Alexa'), during the pandemic (e.g. (Miner et al. 2020)).

In this study, we take an approach that builds upon the opportunities for smart home technology to support health needs by examining the use of a next generation smart speaker with embedded display, the Amazon Echo Show 5 (below), by older adults social distancing in the UK. The Echo Show (an Amazon 'Alexa' device with a screen) provides a unique context, extending existing studies on voice assistants in this area and adding a visual medium, which has been reported to enhance social interaction in other health and care settings (Seuren et al. 2020*a*). We interviewed eleven households (16 participants) before they received the device, shortly after initial use and after three months of use in order to understand their individual and shared social isolation contexts and how the Echo device impacted each home. Through investigating the shared use of the device, we discuss how the Echo Show helped the wider household to 1) support their interpersonal care relationships, 2) seek and navigate important and mundane information online, and 3) step in as an online social presence to make residents feel less isolated during COVID-19 lockdown isolation conditions. In this study, we focus on experiences of health, care and wellbeing during the pandemic of both the individual (self-care) and collective (shared care) in each household, to explore the efficacy of a commercial, multimodal voice assistant with screen in delivering effective health and care in home environments. Our findings explore how the Echo Show provides social, care and information facilitation support to shared households who are isolated, which in turn supports their ability to look after one another, through making use of the device. We contribute to smart home health and care CSCW research by examining the use of voice assistants for health and care in households and describe novel, shared approaches for using voice assistants in the context of social isolation.

Figure 5.1: The Amazon Echo Show 5 used within this study. Image credit: Amazon.

5.3 Ethics approval and participant demographics

We conducted a qualitative study of how households with socially isolated older adults use Amazon Echo Show devices during the COVID-19 pandemic in the UK from March to August 2020. 16 participants from older households were recruited for a three-part interview study to investigate health, wellbeing and care practices in each home. This study was approved by the University of Bristol Faculty of Engineering ethics committee (ref 2020-7026-6973).

Table 1 (below) details each Household ID, which interviews participants took part in, their assigned pseudonymised name in this study, a brief description of their role in each household, and their self-identified age, gender and ethnicity.

5.4 Findings

Our data analysis of the three interviews with each household yielded three over-arching themes that informed our understanding of the use and acceptance of the Echo Show devices in each home. These are: social facilitation, care facilitation and information facilitation. Apart from 5.4.1, the other subsections within this section are not structured temporally (as in, when each interview took place), but instead focus on shared themes from across the three interviews. 5.4.1, instead acts as a point of reflection for the latter sections, to help ground and contrast people's technology experiences with their own devices before they received the Echo Show for this study. We also highlight when, within our findings, participants discuss aspects of health, wellbeing and care.

The social facilitation theme discusses how participants engaged in social interactions with one another and with the Echo Show, within their households, and where points of tension arose between people and the device individually or together, as a result of shared interaction with the device. The care facilitation findings showcase how care activities were fostered between people in the household, through the use of the Echo Show. We also show the limitations of the device as a care facilitator, and how households automated their self-care together, using the device. Lastly, the information facilitation theme discusses, more broadly, the social impact of the device as a means of sourcing information to support care in the household, of trusting that information and trusting the device to connect them to care authorities, and how the device's overall reliability as a source of information is discussed, that can be trusted and relied upon for self-care practices.

Table 5.1: Demographic data for Alexa study participants.

Household ID	Interviews	Name	Role	Age	Gender	Ethnicity
H-A	Pre, Post, Exit	Alan	Describes himself as "Britain's oldest lab rat", keenly takes part in clinical trials, embraces new technology having previously had cancer and pulmonary condition. Travels around the world, house-sitting with his wife.	68	M	White
H-B	Pre, Post	Bisma	Live-in carer for his aunt (68), during the pandemic; providing her daily meals, company specified and connecting her with friends. He has bought her smart devices to keep her connected to others.	Not specified	M	Indian
H-C	Pre, Post, Exit	Ceri	Normally lives alone, but has a son who has stayed with her during the UK lockdown. Keeps a small social circle and has diverse hobbies from knitting to cleaning for “grand houses” in the UK.	70	F	White
H-D	Pre, Post, Exit	Debbie	Device owner. Drug and alcohol rehabilitation worker. Lives with and self-manages her Type II diabetes. Keen swimmer. Struggled during the UK lockdown to maintain physical activity. Caring for older mother in her 80s who lives with her due to the pandemic.	52	F	White
	Pre, Post	Derek	Techno-enthusiast and spouse of Debbie. Initially set up the Echo Show in their home. Keen to embrace new tech and works in software development.	55	M	White
H-E	Pre, Post, Exit	Erin	Choir singer and self-described "people person". Prefers visual communication with others due to self-described high anxiety from the UK lockdown. Formerly a body posture coach, keen on movement, exercise and body language.	63	F	White
H-F	Pre, Post, Exit	Frances	A healthcare technology developer. Likes finding out about new ways to “fortify” her home. High-risk from COVID-19, so has compromised on lifestyle, which she hopes to retain through using the Echo Show.	59	F	White
H-G	Pre, Post, Exit	Guang	Keen storyteller and teacher. Likes engaging with others but has recently moved to a new city before lockdown, so has struggled to find new people. Describes how living with anxiety and depression is exacerbated due to COVID-19 lockdown conditions.	51	M	South Asian
H-H	Pre, Post, Exit	Hetty	Device owner. Activist and mother of a family of seven. Lives with multiple chronic conditions and uses a stair lift to support her mobility.	68	F	White
	Post	Henry	Spouse of Hetty. Supports her care in their home, Not along with their adult children. Keen technology specified adopter.	65	M	White
H-I	Pre, Post, Exit	Isaac	Former nurse and healthcare consultant. Keen to adopt new technology to look after his own health and his wife's who he is looking after during the lockdown.	65	M	White
H-J	Pre, Post, Exit	Jemila	Regular church-goer (pre-pandemic) and former nurse. Lived with chronic anxiety due to the pandemic and reduced social contacts. Cared for on alternating schedule by daughters.	80	F	Afro-Caribbean
	Post, Exit	Jani	Manages a local society to provide care to BAME groups. One of 3 carers (daughter) for Jemila.	Not specified	Not specified	Afro-Caribbean
	Pre, Post	Jala	Works as a lecturer and part-time paid carer. Also an informal carer and one of 3 daughters of Jemila.	Not specified	Not specified	Afro-Caribbean
H-K	Pre, Post, Exit	Kelly	Device owner. Worked in care for many years and has experience of different types of care delivery.	61	F	White
	Pre, Post	Kilian	Spouse of Kelly. Interested in new technology, nature and wellbeing.	68	M	White

5.4.1 Pre-Echo Show shared self-isolation experiences

This section discusses households' social isolation experiences from in the pre-installation interviews during the imposed self-isolation at the outset of the first COVID-19 pandemic lockdown in the UK (starting March 18th 2020). These interviews captured strategies that households deployed to stay socially connected, using their existing technology (e.g. smartphones, laptops etc.) and the ways in which households tried to protect themselves and practise care (in particular self-care) for one another, whilst also providing social support.

5.4.1.1 Changes in self and shared care activities

Participants discussed a range of shared physical and social activities that they were involved in with others, before being isolated by the lockdown, ranging from dinner parties (*"[I usually] have friends coming round for a meal, about twice a week*" - Ceri, PRE), group hobbies (*"I'm part of a choir group, so do that twice a week usually."* - Erin, PRE), to group exercise (*"I did [a] swimming group before all this shit kicked off!"* - Debbie, PRE), and exercise with their household outside the home (*"[husband] and I used to workout together three times a week at the gym"* - Frances, PRE). These accounts show the diverse range of social activities that our households engaged in with friends, acquaintances, and household members. These were often linked with aspects of health, care and wellbeing, and they extended beyond mundane self-care activities, to shared health and care practices as well.

These in-person experiences were contrasted against the ways in which participants had begun to make use of digital alternatives to these social interactions, that were mediated through their own smart devices. Nevertheless, participants described a sense of loss (compared to the directness of person to person interaction, or the difficulty in making new social connections online). Ceri describes; *"it just isn't the same. Something's missing..."* (Ceri, PRE) in relation to the loss of face-to-face contact with her extended family during the lockdown. Similarly, Erin describes: *"it's a different interaction [on Zoom] [...] I think you interpret people's body language when they're in the same room as you."* (Erin, PRE). Guang, having recently moved to a new city, discussed the drawbacks of not having a pre-established social network and living alone during the start of the lockdown, which greatly affected his ability to network with colleagues at work and make new connections, or to establish new friendships physically or digitally: *"lonely, yes. [...] But I don't think that's easy to do at first, to [find new friends]. [...] I mean the university's very good at talking to new starters [but], I think you miss [out on] something. [When first moving to the new city] it was very dark. I just [...] [couldn't] take on the day."* (Guang, PRE). Here, Guang describes how his lack of exposure to new social contacts, followed by the enforcement of strict restrictions through the lockdown resulted in a significant negative impact on his mental health, despite his workplace trying to support his arrival through technology.

5.4.1.2 Changes in household care and wellbeing

Health and care practices (both self- and shared) were compared with by participants against personal life experiences before the lockdown took place, with what changed during the restrictions. This included some major changes, for example, moving to care for relatives: *"my aunt [...] I'd go to see her every day and check she's ok [...] now, I'm living [with her] there [in her house] all the time, cooking, cleaning ..."* (Bisma, PRE). However, smaller changes were also noted in relation to the ability to enact shared care practices (*"they [daughters, husband], sort of, help me with preparing my meals and different things"* - Hetty, PRE), as well as changes in the quality of shared care experiences (*"I'll go and get [wife's] prescription most days now [...] [I] will pop it on the calendar [...] she's shielding you see [...] before she would, or we'd both go out and get things together. Now we can't of course."* - Isaac, PRE). In these cases, participants who may have had less care-focused contact with their loved ones describe the investment of considerably more time into providing care with restrictions in place, as well as changes in the fundamental ways that shared care is practiced.

For digital-social engagement, most participants indicated that they regularly used a smartphone (Kelly, Alan, Guang, Erin, Isaac, PRE), less commonly, a tablet (Ceri, Guang, Hetty, Erin, PRE) or a laptop or desktop PC (Debbie, POST; Alan, Frances, Isaac, PRE). Some households used older or non-digital technologies to stay in contact with people outside their household: *"I'll call up [using a landline telephone] [doctor] and check-in from time to time. We go back you see, so while he's over in Guernsey, I can just drop him a line now ..."* (Alan, PRE) and *"we have an old rotary phone, my wife uses more than me [...] if you remember such things!"* (Isaac, POST). Some preferred the use of pen and paper letters over the use of digital devices; *"yes, I'll write [daughter, overseas] sometimes, she gets back to me, yes. [...] we don't call..."* (Jenny, PRE). However, participants also discussed the ways in which their use of online services and their own devices changed to help combat the new curbs on their social lives: *"As soon as I wake up, I usually WhatsApp my daughter, my son-in-law and my son-in-law's mum"* (Ceri, PRE). Using social media and messaging applications for smartphones and tablets was quite common for our participants, citing a range of online and mobile services that they used during lockdown, including: *"weekdays [...] for my job [...] Skype*" (Guang, PRE), *"Facebook for my friends"* (Hetty, PRE), *"[the choir] is on Zoom now"* (Erin, PRE).

However, drawbacks to these tools were apparent fairly soon after they replaced in-person social encounters:

5.4.1.3 Exercise experiences with technology

Exercise and the ability to socialise was impacted too for participants during the lockdown, where online substitutions were not equivalent in enjoyment to their offline counterparts: *"I*

love swimming. Or loved it. [...] I have to shield in the bloody house and the garden and that's my lot really. [...] I'm not a person that can lie on the floor and start doing [online] yoga classes and stuff like that." (Debbie, PRE) and *"well, it's all online, I know and some people have these FitBits and do their workouts, [but] [...] that's not for me, my highly flexible limbs don't have the concentration, or motivation [laughs]."* (Alan, PRE). The reasons for this lack of enjoyment was cited by participants too, where they described e.g. technological fatigue: "well, I think there's only so much Joe Wicks [Youtube online] classes I can take [...] before I go mad." (Frances, POST). This disillusionment at technology replacing a shared physical activity between household members was also made difficult due to shielding restrictions outside the home, where devices could not replace an experience, such as taking a walk together: "We [Debbie, Derek] can't really go walk the dog together now [...] and I can't really take a camera out with me [for Debbie to join in]." (Derek, PRE).

5.4.1.4 Information seeking expectations for Echo Show

During the beginning of the 2020 UK lockdown, our isolated participants had to alter significant parts of their lifestyle, including the everyday self-care and shared care activities. Our participants looked to technology to support these activities—from the mundane cleaning tasks and informal social engagement, to medication reminders and online searches for information—and had expectations for positive benefits from the use of the Echo Show during social isolation.

Participants described frequently seeking out information and services online during the early lockdown to mitigate their isolation where possible. Here, a participant speculated on how they might source information from the Echo Show to reduce isolation and maintain health-related safety: *"I suppose it'd be useful [...] if you wanted to find places where you could go outside. Where's safe and that [during the COVID lockdown], you could ask it"* (Debbie, PRE), whilst others speculated about know more on how the device could support personal security: *"I'd love it to tell me how it can secure my home..."* (Frances, PRE. Some participants theorised how the device could prompt them with health-related information they had input: *"if it [Alexa] was set at a predetermined time, '[Hetty], take your tablet', and things like that, yes, that would be brilliant."* (Hetty, PRE). Alan, Ceri and Isaac all echoed this sentiment in their PRE interviews, saying that if Alexa was reminding them about their, or other people's, medications in their households, this would significantly improve their care experiences during the lockdown.

Participants who cared for others living with them during the lockdown described Echo Show's possible use in providing input information about more mundane aspects of in-home care: *"yes, I think it will help me prioritise chores, cleaning, which will benefit [aunt] long-term."* (Bisma, PRE). Jenny's daughters described the disruption of their everyday in-person support for their mother (*"we see mum most days. One of us [her daughters] is always with her. [...]"* - Jala, PRE), and how

they felt the voice modality of the device could replace her other device use and supplement some of the more mundane aspects of support provided for her: *"[I think] being able to just speak to something to navigate some of the things that are available will be much easier [for her mother] than trying to use the keyboard and buttons [on computer, phone]."* (Jani, PRE).

5.4.1.5 Echo Show as a household care intermediary

Using the Echo Show to contact others about their health, care or wellbeing (e.g. informal caregiving family members or clinicians) was a common practise for many of our participants. After being probed about the use of the Echo Show skills in this context, Jemila responded: *"Oh yes, I call my daughters every day now. Every day. [...] They [...] look after me."* (Jemila, EX). During lockdown before receiving the Echo Show, Jemila would make frequent calls to her doctor whenever she had even a minor problem with her health, however Jani and Jala both described how the introduction of the device supported their mother (who has low vision) with her health related queries that they would have normally engaged with when they were able to visit her: *"It was difficult. [...] We found out she'd had these sort of panic calls that's she was making to the doctor [...] whenever [...] we weren't around to help her out. [...] because they [GP] have an easy [to remember] number for her."* (Jani, EX). With the introduction of the Echo Show, both Jani and Jala were able to video call their mother and found that the calls to the doctors had reduced, which contributed to their characterisation of the device as *"part of our family"*: *"It's been.. I hesitate to say, but a lifesaver. [...] It's been part of our family, in a way. [...] [those] panic calls [...] Nowhere near as much now. [...] We can check in on her [using drop-in function on the device]."* (Jala, EX). In another household, the Echo Show is shown to be used to support conversations between people directly, in this case, for Alan, between himself and a healthcare professional. Alan described his use of 'her' (Alexa) to call multiple doctors across different countries, all who provide different medical expertise to him: *"I used to have [one] really good GP and had a good dialogue with him, [...] so I have others all around the globe who [help with] different problems, back with [one GP] in Oz, and another I can get on the phone to, about cancer [...] I like that she [Alexa] can store all their names, where they're at and I can get in touch [...] without my little address book to hand."* (Alan, POST). These accounts, which describe the Echo Show facilitating both human-to-device interaction and human-human communication show that the device can provide both relief (Jemila) and convenience (Alan) respectively to support care in the home.

5.4.2 Echo Show as a social facilitator

In the POST and EXIT interviews, participants described how the Echo Show device facilitated, supported and enhanced social interaction for their existing shared activities, including care and searching for information. Whilst there are overlaps from the social activities described in this section with other activities described in both the 'care' and 'search' themes below, in this section we focus predominantly on accounts from participants which describe engagements in everyday

individual and shared social activities to specifically support their wellbeing, with support from the Echo Show device. In particular, this section focuses on participants' wellbeing, especially their mental wellbeing through making use of the device.

5.4.2.1 Echo Show as a household social intermediary

The Echo Show facilitated a range of social activities in people's homes across the three month duration of the study. One participant, Guang, took it upon themselves to learn more about the back-end functioning of the Echo Show, and developed an Alexa skill to share with their friends and greet visitors to their home (when social contact was able to resume). This followed from a conversation about the Positive News skill: *"It greets [them] as they enter like 'Welcome [friend] to [Guang]'s home. How are you today.' [...] I used the Amazon Blueprint to make it."* (Guang, EX). Early on, during his initial interview, Guang described his enthusiasm for generating social support amongst new neighbours when he invited them into his home: *"Like [...] my Indian neighbours. [...] there's an advantage and a disadvantage to different types of [technology in the home] environment [...] and I wish I could support that. [...] Make it work [better] for some people who visit [me] to feel accommodated,"* (Guang, PRE). Guang also took the skill development further once he received the Echo Show and experimented more, thinking further about ways to entertain new friends with this social interaction in his home: *"I did discover that there's an option that you can actually create a story for my friends to follow, but that one sound a little bit complicated, so I'm still working on it."* (Guang EX). In this way, Alexa was used as a playful intermediary to engage socially with other people in a shared setting, which also sparked conversations: *"[they'd] comment, something like 'ooh, look at that' [laughs]"* (Guang, EX). Building on Guang's activities between him and the device, we also see the Echo Show benefitting established relationships and habits in the home, between people, with Isaac using Echo Show to plan activities outside with his wife, as the lockdown restrictions eased: *"my wife and I think it's lovely, because we ask it what the weather's going to be like before we go for a walk [...] it integrates into [the family] the more you use it."* (Isaac, EX).

The Echo Show also supported the social activities that participants felt had suffered from being moved online due to the lockdown. For instance, its ability to support video calling through its multimodal screen and voice capabilities returned participants a greater sense of the embodied presence for others, which participants use here instead of e.g. text-based apps used PRE-Echo Show: *"it's real time [video], [so] you can see people's faces, read their body language"* (Erin, POST). Although some participants struggled to immediately use all the social functionalities supported by the Echo Show, (*"I haven't investigated it fully [but] I like [that] you can facetime through it, I suppose just by saying. [...] It wouldn't have a camera otherwise, would it?"* - Ceri, POST), some found that it made calling others easier: *"very easy to follow. [...] It's very useful that obviously she [has] a touch screen. [...] Calling's a lot simpler."* (Kelly, POST).

5.4.2.2 Echo Show as an interpersonal experience

Participants described in greater detail too, how the device was shared not only with live-in residents, but with their extended household as well, with Ceri describing her son's actions when visiting: *"Oh, my son was mucking about when he came in. [...] I think he might have been swearing at it. [...] making it say bad things. [...] I said, '[son], behave yourself.'"* (Ceri, POST). Erin described anticipating the enhanced social engagement with her son through activities on the device: *"[son]'s coming here again tomorrow so I'm sure he will be asking it things and doing other things with it."* (Erin, POST). Probing as to the 'other things', Erin described using her tablet for antique jewellery shopping and the added benefits of using the Echo Show with her son to attend online viewings of pieces of jewellery: *"I like to go to car boots and antique fairs and things like that [...] I think because we're so confined at the moment for shopping [...] it's a bit like a virtual shop. [son] and I can look at something in real time [on a video] call, which makes it a lot easier to shop."* (Erin, POST). When asked why she prefers this method, as opposed to using online listing sites such as eBay, Erin described the interaction between the Echo Show, herself and her son: *"it's real time, so somebody is actually holding up the broach or the ring or whatever, and you get a better idea of the quality of it rather than looking at a photograph. [...] [Then] [son] and I can say 'oh yeah, I like that one.'[...] it's a better experience."* (Erin, POST).

Other households who owned pets commented on the advantages of having the Echo Show facilitate interactions between themselves and their animals. Erin and Hetty separately reported their amusement at their birds responding with fully-formed words to Alexa's speech, saying: *"Oh yes, my [budgie] responds to her [Alexa]. Long conversations those two!"* (Erin, POST), *"[I've tried] different things [with] the parrot and that, I'd be really interested to see how far those two could get if [I] just left them at it!"* (Hetty, POST). Debbie and Derek described using an Alexa skill to try and get vocal responses from their dog, and indeed using this functionality as a form of entertainment and interaction between Debbie's mother, the device, and their dog, following a conversation about the Care skill probe: *"We've been using that app [PetTalk skill] on Alexa... I'll get [husband, Derek] and my mum to entertain the dog with it."* (Debbie, EXIT). Whether human to human, or human to animal, these interactions demonstrate positive social engagements fostered through use of the device.

Participants described some of their mundane self-care activities that contrasted with their earlier accounts of similar activities. The Echo Show is described as socially facilitating and supporting self-care here. In one case, shared exercise for extended households, where family members were separated due self-isolation, was supported through the use of the device. For instance, Frances used the device to do a guided video workout whilst also on a call with her partner remotely. She described how its voice and screen functionality could allow for the avoidance of awkward social aspects of public exercise: *"you're doing it on your own in your own*

home, you wouldn't feel intimidated by anybody, whereas I know if you go to the gym it can be a bit intimidating. But, yeah, [with Alexa] where you can keep going back and repeating it, and asking her to repeat it, which I thought was a good thing." (Frances, POST). Contrasting this, Kelly's previous experience working as a healthcare professional influenced her view on the usefulness of Echo Show. She describes the perceived benefits of exercise support during social isolation for someone older than herself, who would need a continued or guided programme of exercise to follow (a routine) to be delivered for the device with another person, to be able to give a lasting impact: *"No, I don't have any challenges [using Alexa for exercise]. The [online videos] you get are all fine. But then I'm relatively young and fit. [...] But for an older person [...] Doing isolated exercise [...] really is of little benefit. You need to do an exercise programme [...] with maybe a health visitor or [friend] [...] to be of any use to an older person."* (Kelly, POST). Kelly's last point contrasts with the other accounts here, showing that people understand that the device cannot simply be deployed for novel effect without sustained human social facilitation present.

5.4.2.3 Echo Show as a source of social tension

We also see negative interactions between people living in the same household (facilitated through Alexa) and negative interactions between an individual and the Alexa device itself. Whilst the device provided opportunities for social engagements and acted as a positive social actor itself, tensions also arose where shared use of the device occurred. Debbie describes an interaction between herself, her mother (who was temporarily shielding with her family) and the device: *"she's often asking it various questions on things that she wants to know, or is trying to tell it to play her Latin music, and [researcher] it's [expletive] awful listening to them because she talks to it too fast and it never works, drives me up the wall."* (Debbie, POST). This ongoing annoyance at the disjointed interactions between the device and her mother caused Debbie to move the device to where she could intervene: *"it's currently in the dining room because it's where I'm working, and when mum comes in now, I can just go alright - mum, slow down"* (Debbie, POST). Guang and Alan also experienced situations like this, with Alan describing impatience with the device when conversations with it broke down: *"you find yourself shouting [...] 'play me the bloody music.'"* (Alan, EX). Guang describes how these frustrations could lead him to be mean to 'her': *"She doesn't hear sometimes [...] But, I get embarrassed. I couldn't kind of shout it at Alexa – 'Alexa, show me the to-do list' or something. [...] [laughs] No, that's too mean."*, after discussing the reminders skill probe (Guang, EX).

In the situations described here, interactions with the agent (Alexa) showed frustration, resulting from breakdowns as well as inciting frustration between household members in one another. Nevertheless, Alexa continued to foster social engagement here, as an emotionally oblivious non-human actor. This contrasts accounts in the previous section, that show that in

some cases, another human is required (or desired) to be present to ensure accurate or prolonged use of the device.

5.4.3 Echo Show as a care facilitator

This theme focuses on the ways in which Echo Show was used by our participants to support more clinically-related self-care and/or shared care in the home and as a result how the use of the device impacts their health in the home. Whilst the findings in this section do not show overt changes to participants' physical health (e.g. through their self-care routines in the home), these findings show how the most positive impacts of using the Echo Show, benefit our participants' mental health, through e.g. feelings of relief from their own anxieties about their day to day health at home. Participants used the Echo Show in a variety of ways to support their care at home, from contacting others to discuss healthcare, to automating previously manual care tasks using the device, to sharing in activities related to care by including the device in everyday care-focussed routines.

5.4.3.1 Clinical limitations

Despite the aforementioned self-care benefits, the limitations of the Echo Show in facilitating interpersonal health and care were also discussed, with participants describing boundaries to what types of clinical interactions they would want through the device (*"I don't mind if it's just [arranging] an appointment. [...] but beyond that... I've just had it as a guard dog. Did you know it has a 'guard mode'? [...] I found that out."* (Frances, EX)). For instance, they did not want to receive sensitive, personal or 'bad news' from Alexa, but would use the calling function to talk directly to a clinician: *"If it was the bad stuff, I still go to the GP [...] Don't want to ask the internet for that! [...] But I will use it [Alexa, to make the call]"* (Ceri, EX).

Some participants did not even want to use it for health calls, describing how its qualities/functionalities, its placement in the home and its perceived purpose prevent it being used for serious calls: *"I think that I see Alexa as part of a multitasking situation. So, because I have placed Alexa in the kitchen that is where I'm most comfortable with her. And so therefore, I'm on my feet. [...] But to receive a call from the doctor, to discuss how I'm feeling or if I'm ill, I would prefer to have a sit down and I wouldn't use Alexa for that."* (Kelly, POST). Her partner Kilian agreed that a telephone call would be more appropriate in their household: *"But I think I'd just use my phone for that, to be truth[ful]."* (Kilian, POST).

The accounts above amount to a lack of trust in the Echo Show when holding up the abilities of a human clinician against the limits of the Echo Show. Contrasting these accounts though, other households demonstrated greater confidence in the device bridging the gap between people when care-related administrative tasks were required. Participants speculated on the benefits (for

them and for others e.g. health service providers) of letting Alexa convey important or sensitive information about their health: *"I'd be very happy if Alexa said in the morning, 'your blood tests are coming today [...] at what time would you like to be told?' And that would be a really useful thing" that would "take the load off the [GP] surgery"* (Derek, EX). However, even Alan conceded that 'she' (Alexa) is not human enough to deliver bad health-related news: *"I worked in radio production for a number of years [...] voice is powerful. That's why people listen to radio [...] She's [Alexa is] powerful with that, but for telling me something like 'it's terminal [Alan]', I don't know."* (Alan, EX).

5.4.3.2 Health and care automation

Other uses of the Echo Show also focussed on the automation of previously manual self-care and shared care activities to support self and shared care in households. Before the Echo Show, non-digital tools (e.g. Isaac's household using a shared wall calendar to place medical reminders on) and other technologies (e.g. smart phones) were used manually to store important health-related information and reminders. After receiving the device, many participants described how care information had been consolidated and automated in one place, the Echo Show, for simpler and convenient retrieval (using voice): *"a lot easier than using my phone. 'Cuz I don't have to look up [from phone screen|other activity] now. I just know it [will remind me]."* (Ceri, EX). Participants also described how the device allowed them to multi-task and better manage their household duties around other important self-care tasks: *"it's all to do with multitasking for me."* (Kelly, EX), *"a person of my age [...] they wouldn't spend their time [jumping between] all these different things [devices] [...] pill bottles [...] so I like having things in one place, yes."* (Killian, EX). However, some participants were skeptical about the benefits that the Echo Show would provide beyond available tools: *"It's just the same as using your phone, isn't it. [...] I'm not sure what it's doing that I can't already do on my phone."* (Frances, EX).

Many participants described how Echo Show was useful for automated medication reminders, but also described frustration that the multi modal nature of the device was not used to provide a more salient voice and visual alarm: *"it's become so much easier now I can just say 'remind me to [take insulin] at 6 o'clock'. [...] But, I wish it spoke it to me [at the time], rather than just showing on the screen."* (Isaac, EX). Hetty and Henry also described their frustration that the device did not verbally remind them about a medication, when looking after one another: *"[We] got annoyed about that. I did do a reminder, but it just flashed up on the thing, it didn't make any noise or anything, so I thought that was rather a waste of time."* (Hetty, POST). Despite some disappointments, some participants saw potential for the device to support their bespoke health and care needs: *"it's clever, but I just think creatively it could probably do a great deal more. [...] I'd like to dictate notes to it [...] when I will next talk to my GP let's say"* (Isaac, POST). Here, whilst the Echo Show provided a simple digitalisation of some care activities (e.g. asking Alexa to call

someone using the device), the scope for extended features to allow for voice to text transcription and combined audiovisual prompting were desirable.

However, there were also instances where manual self-care practises did not translate well onto the device, such as the use of a Dossette (medicine) box with small labelled compartments that is used to store different medications *"that gets delivered once a week."* (Hetty, PRE). There was initial enthusiasm for the positive impact of translating complicated practices of self-care to the device (*"oh yes, I'd order these [medication] over Alexa if I could [...] Save me a bunch of hassle."* -Hetty, POST) and supporting complicated shared care practises with the device: *"[daughter] would just come in and ask it what I need, if it was set [up on the device at a predetermined time] [and she told me], [Hetty], take your tablet, and things like that [...] brilliant."* Describing her own positive thoughts on interacting with the device, she even mentioned: *"I mean you just tell it – tell Alexa what you want, a lot easier than a phone, yeah."* (Hetty, POST). Yet, the replacement of a physical 3D care tool by a 2D screen and voice device was not successful: *"I didn't like that. It didn't work for me. Bit too complicated [...] 'cuz everything's in one place, I can go to [the medicine box] for everything I need [...] with [Alexa], you've got the whole spiel to get through first. [...] Don't think I'll go back to it for that."* (Hetty, EX).

In these accounts, we see mixed feelings towards the Echo Show's ability to automate manual self and shared care tasks for convenience in the home. On the one hand, the device coped well with automating simple everyday tasks like medication reminders, and the simplicity of voice over manually searching using a smart phone. However, more complex non-digital devices (Dossette box) had no digital equivalence on the Echo Show and as such, the process of trying to automate such a manual object became convoluted resulting in the perceived usefulness of the device for care, decreasing.

5.4.4 Echo Show as a searching facilitator

Beyond the direct aspects of health and care it supported, through being a social and care facilitator, the Echo Show also supported online information search; the ability for our participants to collect, organise and comprehend information, primarily about their day to day health and care, retrieved using digital tools (e.g. the web) [59], which our participants made use of to support either themselves, or to enact shared care when being supported by others.

5.4.4.1 Shared care-enacted qualities

Some participants actively encouraged other people in their extended households, e.g. spouses and adult children, to use the device and find information for them, when they could not (due to e.g. perceived personal inexperience with technology): *"I'll always make [husband] go and look up*

GP drop in times for mum or something, or [. . .] what we can do round here [. . .] with COVID" (Debbie, POST).

In their Pre-Echo Show interview, Jani and Jala described how the household phone was their mother's go-to device to find information about her wellbeing. With the Echo Show, her daughters became nominated information finders, which they performed using both their own devices and the Echo Show: *"Mum [Jemila] likes to get me and [Jala] to look things up on line for her. That happens pretty often actually. [...] We do [...] visit regularly, so it's taken getting used to [finding information on the Echo Show] for us [daughters] as much as her."* (Jani, POST). These nominated information seekers also gained expertise in using Echo Show for shared care queries: *"[aunt] may ask me a question about [how to treat] her back and I'll say 'I don't know really' but I can ask Alexa and she'll give me what I need to know. [...] I can [...] change my question if she doesn't understand."* (Bisma, POST).

5.4.4.2 Trust in care information quality

The quality of information that the Echo Show provides to participants was also discussed, including the variety of quality in online health information: *"you take it with a pinch of salt [. . .] [you] realise what sites are good and what sites are bad [at being credible sources]"* (Isaac, POST). Some participants discussed the device's ability to provide 'credible' (accurate, reliable) information from online sources that they could also trust: *"It's about credibility [. . .] It would have to be saying to me, this has come from such and such a place and I would then say, OK, I believe that because it's come, for example, from the NHS."* (Isaac, POST). In the search for information through the Echo Show, cross-checking information from different sources emerged as a practise which our participants deployed in order to determine information's credibility, with Debbie joking: *"If it says, you're going to die, I'd just generally take that answer [researcher]. [...] No, of course, we cross-reference stuff like that [...] if I Google something and it comes up with Mr Magic Wizard Wonder answer as opposed to the NHS, I'm like, well, I'm going with the NHS' answer"* (Debbie, POST).

5.4.4.3 Trust in Care-Related Messaging

Trust in the device for health information was comprised of the trust in the information's source. For some types of health information, a trusted clinical source was preferred to navigate information (*"I really prefer to talk to the GP than finding some sources of information on Google because that would give more clear picture than getting lost with all the information on the internet."* (Kelly, EX). However, this was not always possible, so participants described relying on other household members to use the device for information seeking: *"if she [GP] wasn't available then I would get somebody to go on the internet with Alexa and find out."* (Hetty, POST). Some participants still preferred speaking to another person over asking the Echo Show to find

information, and in some cases only used the device as a secondary resource for their searches: *"yeah, if [son] was here, I'd ask him, but otherwise, Alexa's the next best for me. [...] It'll make sense [to me] when I ask her too."* (Claire, POST).

Voice interaction with the Echo Show influenced the preference for it as a messenger over other technologies, with the added benefits of its timeliness: *"I mean, it's probably slightly longer just typing the information in than speaking the information [into Google] [...] I mostly [...] use it for every day facts that I need to know now."* (Guang, POST). Some participants looked towards what they might expect the Echo Show to be able to accomplish in the near future with health information, and described how it would need to provide this information in a similar format to other trusted messengers, for instance to a health provider phone service: *"So, I think I would trust it [Echo Show] [. . .] if I could go as far as I could to say, well, look, Alexa, should I worry about this, that and the other [. . .] I would trust it to do that, as I would [the UK's NHS] 111 [phone service]."* (Alan, POST). However, similar to literature that shows attitudes to health information shift with temporal health changes (O'Kane et al. 2016), individual circumstances influenced the trust of the messenger of health and care information. For example, Jemila's low vision influencing her trust in herself to get health information: *"If I can get it from someone, I will do that [referring to daughters and own GP], because it's much better than looking through it [information online] myself. [. . .] I wouldn't ask anybody and everybody, I would ask somebody that I know can give me an answer."* (Jemila, EX). From this, we can see a trust-driven, information search hierarchy emerge that is related to the levels of trust placed in caregivers (whether formal care providers, through to informal caregivers in the home), who select and mediate the information that a person receives. Whilst the Echo Show's voice interaction was considered quicker for information searching for some participants, the interaction itself influenced trust in the device as a reliable messenger in relation to its quality of information.

5.4.4.4 Trust in Echo Show's voice actor reliability

Some participants discussed that they considered Alexa another layer between them and the health information with the voice interaction, giving them less perceived control than other interfaces: *"the difficulty is [...] it's bad enough on the internet [trying to find information][...] on Alexa [...] you wouldn't be driving it [...] Alexa would be driving it."* (Alan, POST).

Participants found conversational breakdowns influenced trust in the device's reliability, and indeed the reliance on voice interaction for important information was not strongly trusted by some: "*I don't trust anything with searching [on Alexa]. I always ask the question one way and then try asking the question another way."* (Derek, POST). A tension arose between Debbie (who works in healthcare) and Derek (who works in IT) when discussing their methods of searching on the Echo Show and their trust of it: *"We've argued about this you see, [researcher]... do we, don't*

we trust Alexa for our work life as well as our home life [laughs] [...] because [...] she's not always right like Google, you know." (Debbie, POST). Derek interjects, *"and that question I was asking Alexa this morning about giving honeydew melon to the dog, didn't I? I thought 'that sounded weird', so I asked it differently, and it came up with some different stuff."* (Derek, POST). This discrepancy also influenced Alan's (who has hearing loss) trust in the device's reliability, despite the visual back-up of information on the screen: *"I also have to admit I am deaf, so [...] if I don't hear [Alexa's] answer terribly well [...] so [if] I only get it [Alexa's response] the first time round, then I have to say repeat it, and I'm being more led, so it's more unnerving, it would be to me, to hear it from Alexa, because I can't re-reference it very quickly at a glance in the way that I can on Google on its screen."* (Alan, EX).

Despite the screen on Alexa, the participants described a less straightforward 'path' to credible information: *"it's not easy [to] know right away, if what you asked her is leading you down a wrong path [because] you have to think 'hmm, hang on a minute', is that really the case. Does she [Alexa] know herself that this is right?"* (Guang, POST). Participants noted that the lack of visual options and visual credibility could lead to stress or misinformation for those who are vulnerable, as the first results on health and care information searches can often not be the appropriate information: *"I mean most people turn into Dr Google don't they [...] As soon as they feel not well with something they will Google it [...] [it] could be quite terrifying [...] it gives you broad spectrum. You then need to close it down to what it actually is so always go to your GP for advice, get rid of that fear."* (Guang, POST).

From these discussions we can see that the Echo Show sits somewhere between mobile or desktop screen-based devices and in-person interactions with other humans when it comes to sourcing information but is not considered a trusted (and often unreliable) messenger of serious health information, with the voice interaction creating an additional layer of mistrust.

5.5 Discussion

In this section we discuss the qualities of the Echo Show's interactions with our participants; highlighting those interactions that were successful in supporting health, care and wellbeing needs and those that can be improved. Through examining the use of this device in older adults' households during a time of health uncertainty and restrictions on movement and socializing, this section provides insights based on our understanding of the use of this multi-modal smart home technology for health. Whilst our findings expanded on how interpersonal health, care and wellbeing practises in the home were facilitated through the use of a digital medium: the Echo Show (with social, care, and information facilitation), we consolidate in this section, both the social and technical aspects of supporting health, care and wellbeing at home here. As such, these discussion points in this section build directly on our findings, and we discuss inclusivity and

accessibility, credibility and intersubjectivity, closeness and comprehension and transferability, which the authors found to be key to understanding and talking about this type of multimodal voice assistant within HCI and CSCW research.

5.5.1 Accessibility and detriments to care provision

Our study suggests that the Echo Show was capable of supporting accessibility in a range of ways. Positive support for the accessibility of voice assistants has been seen in research on people with Parkinson's (Duffy et al. 2021) and this was seen with Jemila's experience with low vision - the use of the Echo Show reduced her reliance on physically dialing her telephone. Instead, she could use her voice to ask Alexa to call her daughters frequently and easily, making their relationship easier, which is in line with existing work on supporting those who are differently abled in using technology to augment or replace manual operations (e.g. through using voice control or VR) to support their health and wellbeing (Mott et al. 2020). The Echo Show's voice interaction was inclusive with regards to vision, thereby improving people with low vision's access to everyday shared wellbeing and care activities with their informal caregivers, allowing for visual presence during video calls even at a distance, which again supported long-distance household relationships during enforced isolation. These interpersonal shared care benefits have been documented previously within HCI and CSCW due to the reciprocal nature of informal caregiving relationships (Chen et al. 2013). In Jemila's case, this inclusivity, built into the Echo Show, may have reduced the burden on the health service as well because all three household members suggested the "life saver" device reduced her anxiety and so-called 'panic' calls to her doctor, thus saving the GP time spent during interactions and improving their relationship. This care burden reduction here (both formally and informally) is significant in comparison to the cost of this off-the-shelf, non-medical, popular, commercial technology. The opportunities for extending the device's range of support include providing better support for formal care through integration with health and care providers, as well as the informal care support observed in this study. This is an important consideration beyond the COVID-19 pandemic, but in light of preparation for any future pandemics or unforseen periods of mass social isolation, where individuals may be physically cut off from health and care service providers. The efficiency of remote consultations through e.g. voice assistants is essential to consider to ensure a robust continuity of care between patient and healthcare provider, for those who are isolated.

However, there were downsides to the device's inclusivity and accessibility that impacted its ability to support health and care in relation to hearing. Hearing issues could make the back and forth searching interactions with Alexa disjointed, and therefore not useful. Discussions of medication reminders highlighted that whilst the device will respond to its users' commands (e.g. to set a reminder), the static nature of the device meant that sometimes it could not be heard in all places in the home, or where reminders would only appear on-screen without being spoken, thus

making it less inclusive for supporting hearing. Our participants described both individual and shared frustrations directed at the device, but beyond poor user experience, there is a wellbeing (Thieme et al. 2012) (sustained, positive, mental and physical functioning) concern here related to relying on Echo Show as a critical part of healthcare. Missed or mismanaged healthcare tasks, such as taking medication, can lead to safety risks if the device does not inclusively support users (or fails for other reasons e.g. where there is no habit formed by a person with their medication and over-reliance is placed on the device's use (Stawarz et al. 2014)).

The newness and the unfamiliarity of this technology may have resulted in a feeling of exclusion with the device for some older participants. The device's ability to facilitate online searching through its voice and screen supported the use of the device for much needed health and care information searching during the pandemic. However, participants still described asking others in the household or extended household to use the Echo Show for them to find this information. This indicates that some older participants may not feel very comfortable with the technology or familiar with its functionalities. There are significant opportunities here for creative, inclusive approaches to the design of multimodal voice assistant interactions with people with less technology experience, to maximise these devices' usefulness and user experience to support health and care in their households.

5.5.2 Credibility, intersubjectivity and lack of confidence

Credibility was crucial to participants' engagement with the device and their ability to trust and use the information the Echo Show provided. However, shared use of the device influenced how trustworthy (Seymour & Van Kleek 2020, Seymour et al. 2020) the device was perceived to be, with differing opinions on trustworthiness within households. Tensions around trust issues with the device share similarities to feelings of trust in other smart home technologies, discussed in studies situated in other shared household settings (Geeng et al. 2019, Kraemer & Flechais 2018). In particular, when participants searched for information, they demonstrated the greatest levels of trust in 'official' (clinical) sources (e.g. doctors), followed by trust in another person (e.g. relative), followed by trust in the device itself at the lowest point. This was likely due to the variation in answers that participants captured, when asking questions in different ways. As such, and unlike a human, the Echo Show does not demonstrate the ability to reason, as it also has no internal experience to draw upon (Schutz 2019). In contrast to this, we see again the worthiness of the other human actors in each shared home, when residents would ask one another to cross-check information or look it up again for them to be sure (e.g. Debbie's household). This indicates a far lesser sense of trust in the device to check itself, as opposed to another human actor to be the one to verify the trustworthiness of the information source, especially in cases of care in the home. This not only adhere's to Moran's (Moran & Anderson 1990) principle of devices which enable people to follow their own conventions of social interaction (and not with

the device), but builds on Schutz' work about how individuals will reason together until they reach an "approximate value" (Schutz 2019) [p. 109] (or agreement), upon a topic.

Nevertheless, the device was often personified (e.g. "Dr. Google", "her", "she), yet this is not discussed as generating any stronger confidence in the device's ability to provide credible information, as has been discussed in previous HCI and CSCW literature around fostering shared use (Richards 2019), and it is in fact suggested by participants that sustained human use is required in order to make (e.g. exercise) a credible long-term health benefit. This holds implications beyond the pandemic, for households who wish to continue to use devices such as the Echo Show for remote exercise and for healthcare authorities who wish to develop new means of engaging with isolated older individuals, to ensure that their overall health is not deteriorating at home, due to lack of sustained exercise.

The Echo Show also encouraged a higher level of scrutiny and crosschecking, which has previously been observed with other smart home technology and VAs (Porcheron et al. 2018). In our study, the seriousness of the information impacted the experience: safety-related health and care information (e.g. deciding together whether or not to feed a dog a new fruit) were repeated and additional follow-up searches were made on the device, where participants asked their search query in a different way or re-phrased a question with another household member present. This is in contrast to their other, less safety-critical information searches related to wellbeing (e.g. weather for a shared walk) which was welcomed and enhanced shared care activities. We found that there is less trust overall in the Echo Show's ability to return accurate online information compared to traditional screen-based interactions, but the context of use and importance of a particular situation determines whether people will deem it necessary to seek verification of this information obtained by voice.

As seen in previous investigations into VAs, conversational breakdowns between participants and the device (Beneteau et al. 2019, 2020) quickly led to reduced perceptions of trust in the device. Whilst some participants experienced breakdowns due to vision or hearing loss, the act of repeating their question to the VA caused unease and anxiety in the credibility of the information. It was indicated by a number of participants that the mode of interaction generally impacted trustworthiness (e.g. whether the information was mostly conveyed through the device's voice or screen). This added an additional layer of uncertainty, that at times made people feel less in control with the device (e.g. seeing a reminder but not hearing it). This understanding suggests that future investigations should focus on continuing to support nuanced and human-like conversations, where VAs can provide e.g. reassurance around the credibility of information sources and the modality through which this information is conveyed. Providing greater support to informal caregivers and other household residents who may interact with the device and perform actions with it, on behalf of another resident, should be considered. Investigations into

this type of feature support could build on existing work in the AI domain, detecting multi-user interactions with smart devices (Masullo et al. 2020, 2021).

5.5.3 Understanding opportunities for multimodal caregiving through commercial voice assistants

It is important to understand technology-driven social presence in the context of this study, as the ways in which a technology (e.g. the Echo Show) can behave in proximity to other people, in a way that it can emulate certain human qualities (such as voice) or be included in discussions of the home, as other people might be, thus making it a part of the home's social fabric (Nass et al. 1994). Within this study on voice assistants, the use of the voice assistant (Echo Show's) screen in the context of interpersonal social engagement did not strongly add a meaningful additional 'presence' to people's homes beyond the spoken capabilities of the device. The screen instead, was mostly viewed as supplementary to Alexa's 'voice' and did not substantially extend its functionality. In some cases, the screen even hindered people's experience of the device (e.g. with H-I or H-H's use of reminders). The most meaningful benefits of the Echo Show's screen for care purposes in the home, therefore becomes accessibility-related (as discussed in Chapter Four, section 5.1) and its use is not tied meaningfully to interpersonal social support. The discussion by H-E and her son on engaging with the device together in a shared e-commerce activity goes some way to showing how the screen could be better leveraged in future. This could be done by allowing others in the home to gather around the device and enable a shared social presence in proximity to the voice assistant, as opposed to e.g. relying on one person to bring the device to others (such as in the case of an iPad). If leveraged in the right way, screen-based voice assistants have the opportunity to enable useful shared audiovisual and social experiences in people's homes.

With this in mind, it is beneficial for future research and design on screen-based voice assistants to also consider whether the social presence of the conversational agent (e.g. Alexa) could be adapted so that the device can be more convincing and supportive of diverse and complex self- and shared care activities that were met with skepticism in this study (e.g. collecting and storing medication ('digitising' a medicine Dossette box), reducing anxiety etc.) that are specific to each home and household. Equally, supporting device failures (e.g. if the Dossette box cannot be digitised, or a healthcare search returns conspicuous results), seems equally important, in order to help reassure household members and as discussed previously, to give the device's owners a greater sense of understanding of its operation, to reduce time spent e.g. asking multiple queries about the same topic. Investigating the ways in which a device's social presence can be balanced in household settings, so that the device does not become dominant or overbearing and detract from existing human-to-human social interactions is also of interest for future research and development.

5.5.4 Closeness and visual and physical cues

According to Schulte et al. (Schulte et al. 2020), *"many instances of intimacy take place in the home..."* (p. 124) and the qualities of intimacy in relation to the acceptance of technology can be largely defined as: *"the social closeness [or] connectedness"* between people and between people and artefacts. Whilst our findings did not reveal a specific intimacy between the Echo Show and its users (in fact, many remained skeptical of its social abilities), our findings did support our isolated households' closness with one another (human to human). Therefore, this understanding of the relationship between the Echo Show, the primary users, and others in the household frames the discussion of our participants' social experiences of the Echo Show within beyond the home.

With regards to human relationships within the home and outside of it, the Echo Show facilitated closeness. This was between partners preparing for a shared walk, connecting physically separated family members through video calling, looking after pets and through shared use of the device to experience hobbies (e.g. collect antique jewelry) that were made difficult in isolation. Although social isolation is a significant issue for older households generally, isolation experiences were exacerbated during the lockdown for older adults (Lopes & Jaspal 2020) who were restricted in the social support they normally received through social engagements outside the home. The type of social support experienced by our participants is in line with Towey et al. as: "An established social network of other people including family, friends, who a person can turn to in times of need or crisis, to enable broader focus and positive self-image [and] a sense of security." (Towey 2014) [p. 177]. Considering this context and the qualities of the device discussed above, we observed social support being provided with the Echo Show in a distinct way; not focussed on intimate interactions between a person and the device itself, but through the device acting as a proxy to support pre-established social relationships between people (which existed either before the pandemic or during, as the lockdown restrictions were eased). From Jemila's discussion of their daughters' closeness, to Debbie's caregiving to her mother and pets; these accounts, along with related research shows that there are opportunities to enhance human interpersonal relationships using the device as opposed to, for instance, simply supplementing conversation in a social setting with an additional virtual 'personality' (Lopatovska et al. 2019). This too, builds on the work of Moran and Anderston and Stahl which describes how different types of technology affect the strength of social interactions, and how they can be disruptive too (Moran & Anderson 1990, Stahl 2016).

With regard to the vocal qualities of the conversational agent (Alexa) on the Echo Show, participants likened the facilitation of information through the device, to that of receiving news or information from a radio presenter. This finding builds on the work of Kuzminykh et al. (Kuzminykh et al. 2020) and Voit et al. (Voit et al. 2016) who found that when prompted with visual aids (different computer-generated faces), participants either anthropomorphised the

conversational agents in a way that suited them. For some participants, the vocal qualities conveyed an understanding between the listener and the device, that was not apparent in their discussions of visual information retrieval. This lack of an auditory barrier between the information recipient and the device in this study, is in line with the work of Parviainen et al. (Parviainen & Søndergaard 2020) who discuss how the quality of whispering brings humans closer to a more empathetic experience of interacting with machines. The household's likening of being in receipt of 'bad news' (e.g. outcomes of cancer diagnoses), from the Echo Show shows some personification of the device, although it was not recognised in the same vein as a human actor giving the same information. There was also little discussion or strong feeling from households about their feelings towards Alexa revealing this type of information to them in a shared space and no strong indication provided (e.g. from Alan here), whether he would be comfortable with another household member overhearing this 'news' from Alexa. For these more complex emotional engagements, a human was always discussed as an alternative (either e.g. to facilitate long-term use or to support health or care). Instead, the Echo Show was viewed again as a device to facilitate closeness between people who were isolated (e.g. through video calls). As such, future research and design work should consider how the qualities of voice connected with the screen, could be built on further to convey (and reciprocate) more nuanced interactions to support self- and shared care, or the benefits of substituting in-person interaction with audiovisual communication that can better extend health and care from formal care settings (e.g. GP practises) and into the home.

5.5.5 Opportunities for audiovisual social engagement

The use of the Echo Show's screen in the context of interpersonal social engagement did not strongly add a meaningful additional 'presence' to people's homes beyond the spoken capabilities of the device. The screen instead, was mostly viewed as supplementary to Alexa's 'voice' and did not substantially extend its functionality. In some cases, the screen even hindered people's experience of the device (e.g. with Isaac or Hetty's use of reminders). The most meaningful benefits of the Echo Show's screen for care purposes in the home, therefore becomes accessibility-related (as discussed in section 5.1) and its use is not tied meaningfully to interpersonal social support. The discussion by Erin and her son on engaging with the device together in a shared e-commerce activity goes some way to showing how the screen could be better leveraged in future. This could be done by allowing others in the home to gather around the device and enable a shared social presence in proximity to the voice assistant, as opposed to e.g. relying on one person to bring the device to others (such as in the case of an iPad). If leveraged in the right way, screen-based voice assistants have the opportunity to enable useful shared audiovisual and social experiences in people's homes.

With this in mind, it is beneficial for future research and design on screen-based voice assistants to also consider whether the social presence of the conversational agent (e.g. Alexa) could be

adapted. This could help understand how the device can be more convincing and supportive of diverse and complex self- and shared care activities that were met with skepticism in this study (e.g. collecting and storing medication ('digitising' the Dossette box), reducing anxiety etc.) that are specific to each home and household. Equally, supporting device failures (e.g. if the Dossette box cannot be digitised, or a healthcare search returns conspicuous results), seems equally important, in order to help reassure household members and as discussed previously, to give the device's owners a greater sense of understanding of its operation, to reduce time spent e.g. asking multiple queries about the same topic. Investigating the ways in which a device's social presence can be balanced in household settings, so that the device does not become dominant or overbearing and detract from existing human-to-human social interactions is also of interest here.

5.5.6 Emotional journey with the Echo Show

In Chapter 4, we introduced the emotional journey as a means of understanding how the stairlift was accepted with and between residents in each household. Whilst in this study, there is not a distinct emotional journey emerging towards acceptance (likely affected by the circumstances around when this study was run, during the COVID-19 pandemic), we do see individual households make moves towards greater acceptance of the technology in some cases. Whereas all households in the stairlift study took time to reach a point of acceptance for the technology, the owners of the Echo Show VA's largely demonstrate acceptance of the device up front, although their are some who engage with the technology in more ways than others, increasing the device's acceptability.

In H-G, Guang initially described how he had engaged with the basic functionality of the device (e.g. using it to store tasks, and alert him to important information), but as he engaged more with the device's more complex features, such as designing skills using the Amazon Blueprint tool, he described enjoyment at the integration of the device into his daily activities and social structure of his home became greater too. Similarly, for Frances who found and used the guard mode, as more of the device's features were discovered and utilised, she described greater enthusiasm and interest and ultimately acceptability increased for them. In shared households, emotional acceptance was less clear. For example, for Debbie and Derek, the device did not reach the same level of emotional acceptance as for Guang and Frances, instead showing interest but not emotional fulfilment by the Echo Show. By contrast, Isaac and his wife found little integration and emotional acceptance of the device, instead reporting negative feelings due to not being able to integrate the device's screen into their TV setup.

Emotional acceptance therefore varied around the use of the Echo Show but was mostly determined by the level of engagement with the VA device's more advanced features as opposed

to whether it could fit into the material and social fabric of the home, as was discussed within the stairlift study.

5.6 Limitations and future work

We acknowledge limitations to our study method and execution. Despite the value of capturing qualitative data over a three month period, it would be of benefit to go further still and understand the use and acceptance of Echo Show devices (e.g. after one year of use) to identify further ingrained patterns of use in homes with residents and their extended households. Beyond this, it would be of interest to capture the views of healthcare providers and other formal care providers, to understand their views as to the benefits and detriments of this multi-modal device, for households they provide care to. Whilst the voices of some informal caregivers (household members) were captured within the scope of this study, there is scope to better understand the complex interplay of roles and exchange of information, activities and resources through these devices, for supporting both formal and informal caregiving.

The authors acknowledge the impact that providing Echo Show devices to participants entails; as opposed to studying participants who have purchased these devices of their own accord. In particular, we acknowledge this impact and suggest that future researchers consider how this may affect the frequency of use of the devices, the ways in which participants used the Echo Show devices together and also how power imbalances can occur as a result of researchers gifting technology to participants. In particular, it is important to consider how gifting technology can impact the process of e.g. informed consent and also participants willingness to engage with the study itself, based on their perceptions of the device. Nevertheless, the nature of 'in the wild' research [15] and the compounding difficulties of conducting research remotely and in a timely manner, during COVID-19, reassured us that it was correct to gift these devices, both as financial compensation, but also as an reliable means of studying their use during a pandemic. As a result, there is a need to conduct further longitudinal studies engagement with voice assistants beyond the pandemic. to understand for example how use of multimodal VAs might diminish as social contact is restored between friends, family members and neighbours.

A further limitation sits with the fact that the Echo Show and voice assistants more generally, are targeted predominantly at young audiences in their design (Sayago et al. 2019). This builds on the previous limitation we discussed, around who may inherently have access to this technology outside of a research setting, where these devices are not being provided to older adults by the researchers. This is a necessary consideration for the validity of studies in this area, and when considering more broadly, aspects of responsible innovation, for who can and how best, older adult populations can access and obtain voice assistants for the benefit of their health and wellbeing.

Lastly, we acknowledge the benefits of quantifying these qualitative accounts in future investigations into voice assistants. Whilst our qualitative study provided a rich variety of accounts of use of the Echo Show, a quantitative or mixed-methods approach could yield additional or supplementary data to inform further longitudinal or larger-scale rollouts of these devices to specific health communities or individuals with specific needs. This could be extended further by capturing log data from the devices and performing analyses on these to derive, e.g. specific design requirements based on usage, voice or screen initiated requests or based on specific engagements with the device from different residents.

5.7 Conclusion

Our study provided a range of in-depth qualitative accounts of the use of the Amazon Echo Show; a multi-modal voice assistant (speech and screen), for socially isolated older households during the 2020 COVID-19 lockdown in the UK. Our engagement with eleven older adult households showed that whilst the Echo Show provides clear benefits to health, care, and wellbeing needs through supporting social engagement, specific home-based care practices, and health information gathering; the social benefits of the device primarily arise from supporting new and existing human-to-human social interactions as opposed to those with the conversational agent. Although useful for many participants (and a so-called lifesaver for one household), more work can be done to better tailor the device to inclusively support unique and nuanced household-specific healthcare activities, synchronise audiovisual accessibility support features, foster trust in the device's abilities through fostering better human to human relations and supporting more the increasingly complex nature of shared healthcare tasks in the private realm of the home. Overall, there is great potential for further engaging with multi-modal voice assistants like the Echo Show to make use of their versatile functionality for delivering health and care support to people who are aging at home together.

CHAPTER 6

SMART HOME HEALTH SYSTEM STUDY

6.1 Preface

This chapter contains the third empirical study of this thesis that explores the use of a smart home sensor system for health and care in the home. The smart home sensor system was deployed and used in order to address RQ2 ("How are commercial smart home technologies being appropriated for self-care and collaborative care practises?") and RQ3 ("How is self-care and collaborative care work impacted by the introduction of complex smart home technology to support healthcare at home? ") from Chapter One, identifying the impact of a smart home sensor system on the lives of older residents and cross-generational carers. The previous chapter explored the intersubjective (person-to-person) communication that was facilitated through the use of the Echo Show. In this chapter, a research-driven smart home system was deployed in a similar fashion to the stairlift and Echo Show devices in Chapters Four and Five. The outcomes of this deployment and the impact of the technology within each household are documented fully.

This study was conducted in partnership with Bristol City Council and an independent smart home research group with the aim of investigating the impact of the technology and its acceptability in the home and its impact on quality of life. The work within this chapter has been submitted to an HCI conference publication venue. As such (and akin to Chapters Four and Five), this chapter uses the collective 'we' when referring to the multiple authors who collaborated to conduct the research for this paper and this chapter.

6.2 Introduction

The proportion of older adults in the UK who are aging into older adulthood has increased exponentially in the past decade (ONS 2017). As older people are living longer, the requirement for a higher level of care has increased in proportion to this (Service 2014, Humphries et al. 2016). Informal care (where a person is cared for by a friend, family member or other close relation) is the most common type of care provided for older adults in the UK (NHS 2022). As a result, these informal caregivers (who are often younger and of working age), must make sacrifices from their own lives and livelihoods in order to care for an older person, usually a relative. Similarly, for those who live alone and have fewer close social connections, formal care (where a person pays for the time of another to care for them), is often the only option available (Doyle & Smith 2019).

Both informal and formal caregiving come with their own drawbacks. Informal carers must not only sacrifice their personal time, spend money and energy looking after an older relative, but they also must bear an emotional burden of being called upon at almost any time to provide for the person they are caring for (Doyle & Smith 2019). Formal caregiving too, is expensive and, particularly in the UK, seeing high demand as National Health Service (NHS) and local council resources are already over-extended in the wake of the COVID-19 pandemic.

Moreover, providing informal care together in a home requires collaborative effort (Procter et al. 2018), time, commitment and cost (NHS 2022), which HCI and CSCW have explored in depth. For those caring for older adults, such as an informal caregiver, the burden of caring is often unpaid, cutting into a person's working and personal time to instead look after e.g. older relatives (Humphries et al. 2016). For the year 2020/21, the UK's Family Resources Survey, commissioned by the UK government estimated that 4.2 million people (around 6% of the population) were providing informal care for another, of which around 10% are of working age and disproportionately 1.5 times more likely to be from a black or minority ethnic community (Census 2021).

Smart home technology itself is mostly designed with a single individual user in mind and not how the people around them will make use of or appropriate those devices in the home (Wilson & Hargreaves 2017, Zallio & Casiddu 2016, Castelli et al. 2017). Whilst in recent years, studies in HCI and CSCW have dealt with concepts such as the household care network (Wolf et al. 2019) and multi-resident home, additional consideration is still needed for how care work is accomplished with the addition of smart home technology and how this impacts caregiving work.

Given this gap in the consideration of the complex sociotechnical shared care work by the wider household of informal and formal caregivers, we take a qualitative approach to examine the impact of deploying and using a bespoke smart home health system (SHHS) on caregiving.

We contribute an empirical account of the different types of technical work and care work and how it is impacted by the introduction of a SHHS. We contribute a new understanding of the types of care work done by the wider household and how it is impacted by the introduction of an SHHS and provide implications for the acceptance and adoption of future smart homes to support shared care work.

6.3 Ethics approval and participant demographics

This work was a qualitative study of five shared households (eight participants; with two households where only one resident was interviewed, but where others lived). The study took place between September 2021 and May 2022. All eight participants were recruited for the interview study which consisted of three stages (Pre-installation, Post-installation and three months post-installation of the smart home system). The interviews focussed on technology use and each household's unique health, care and wellbeing practises. This study was approved by the University of Bristol Faculty of Engineering ethics committee (ref 2020-7938-7885).

The complete table of participants below (Table 1) details each household ID, participants' (pseudonymised) names, age, gender, ethnicity, self-described household role (derived from interview data) and socio-economic status (relevant to council-funded home technology discussed during initial interview stage).

Whilst some participants are listed as the sole resident enrolled onto the study within a household, all participants had social contacts who either lived-in or visited to care for them, and so all households were 'shared' homes. These visitors and carers interacted within the context of the household and with the SHHS, so are described within the qualitative accounts described below, although they did not directly take part in interviews.

6.4 Findings

The key outcome of these findings shows how a series of problems with the SHHS compounded work to such a laborious extent, that many residents eventually abandoned their systems. All households that took part in the study eventually gave up using the SHHS due to the excessive time spent trying to make the system respond meaningfully to them. This is of interest, when comparing this experience to participants' early experiences, using their own off-the-shelf consumer technologies.

Participants' experiences of using every day (off-the-shelf) consumer technologies in their homes and managing activities of daily living (ADLs) using smart phones, other voice assistants and low-tech home modifications (such as walk-in shower rooms) impacted their expectations of the SHHS. For instance, going *"online to book [GP] appointments"* (Daisy, PRE), Alexa (HA, HD,

Table 6.1: Demographic data and participant information for households recruited during sensor study.

Household number/ID	Name	Age	Gender	Ethnicity	Household Role/Description	Caregiver Status
H-A	Angela	85	F	White British	Angela is the home owner and only regular user of the SHHS in her home (for whom it is set up). Angela has previously had a stroke and is living in a single storey, assisted living household. She is also frequently visited by her son and daughter who will come and help her with household tasks.	Formal care (assisted living) and informal care (daughter, son)
H-B	Bob	77	M	White British	Bob lives with Barbara and they have been married for approximately 40 years. Bob needs extra assistance with his mobility, for which he has a walking frame and scooter. The SHHS is set up for Bob to use.	Informal care (Barbara)
	Barbara	77	F	White British	Barbara, who describes how she supports Bob also uses a walking aid (stick) having had a hip replacement a year previously. Together, they live in a 4 bedroom, 2-storey house.	Not in care.
H-C	Clive	Not specified	M	White Irish	Clive and Cheryl live together in a 2-storey, 3 bedroom house. Clive lives with early-stage Alzheimers so is supported in some daily activities by Cheryl. The SHHS is set up for Clive to use.	Informal carer (Cheryl)
	Cheryl	62	F	White British	Cheryl, who looks after Clive and their two cats is regularly visited by their two grandchildren and wider families. Cheryl shares simpler household activities like cooking with Clive, so that he can remain active.	Not in care.
H-D	Daisy	68	F	White Irish	Daily and David live together in a 3 bedroom, 2-storey part local authority owned home. Daisy lives with Multiple Sclerosis and is helped by David who assists with organising her daily life	Informal carer (David).

Household number/ID	Name	Age	Gender	Ethnicity	Household Role/Description	Caregiver Status
					activities and helping her to go places. Daisy also makes use of a wheeled walker and wheelchair when going outside. The SHHS is set up for Daisy to use.	
	David	65	M	White British	David, who still travels frequently for work, uses spare time to arrange their house and plan trips with Daisy. David also owns a van which can store Mary's mobility equipment inside and also willingly intervenes for Daisy in setting up technology and mobile devices.	Not in care.
H-E	Evelyn	96	F	White British	Evelyn lives predominantly alone, but has a wide network of informal supporters who frequent her home on a regular basis. Evelyn does not have any chronic conditions but experienced a fall and was hospitalised just before the study took place, so makes use of a wheeled walker when going outside, for the duration of this study.	Self-care, formal support from paid workers (e.g. technical supporter).

HE), Zimmer frames (HD, PRE), stairlift (HD, PRE), *"a crutch or a stick"* (Clive, PRE), or C-pap machine (Bob, PRE). For the set-up, use and maintenance of these systems, participants often relied on informal carers, formal carers and other professionals: *"My daughter does everything for me that my carers won't do. [...] [she'll] leave out some paper with how to record the tv programmes or when I've got people coming to fix things."* (Angela, PRE). They also had experience of abandoning some of these health and care technologies if they did not fit into their lives or were inclusive to their abilities *"I had a smartwatch you wear on your wrist, that told you your temperature and everything. Stopped using that because it's hard to press [the buttons, having experienced a stroke] you see."* (Angela, PRE). These experiences impacted their expectations and experiences of the SHHS, and allowed them to understand its influence on self-care and shared

care work in the home, specifically learning and set-up work, maintenance work, interaction work, data work, care work and emotional work.

6.4.1 Learning and set-up work

Considerable effort was exerted to understand the SHHS collectively in each household. Whilst different households describe different types of work, all households invested time and energy in order to use (or know how to use) the SHHS. Angela describes how, even with the offer of help from her caregivers, she had to figure out how to use the system on her own: *"I did it. I had to, all by myself. They [carers] wouldn't have been able to make heads or tails of it. [...] It didn't make sense from the instructions until I had tried it."* (Angela, POST). Some were not as successful setting it up independently: *"I've never used an app in my life, so for me to figure this all out from those little pictures..."* (David, POST). This reflects the work of Rode (2011), Strengers et al. (2019) who suggests that this type of work is essential to caregiving and daily living activities.

When participants struggled to learn how to use the system, they often worked together with others inside the home in order to get the system working, sometimes relying on contacting the research group for further assistance. Clive and Cheryl explained how they worked together when Clive's fine motor skills would not allow him to complete the more intricate parts of the sensors' setup process, naming this the most laborious part: *"[Living with] Alzheimers [...] I tend to have paddy paws rather than fingers and I find it very difficult to get on to the bit of the watch that I want it to be on. That took a long time."* (Clive, POST). Cheryl explained her involvement at this point: *"I could do most of the things [Clive] couldn't. [...] the Wi Fi setup was a challenge for us both, because [SHHS research group] had to dial in and do our network and everything for us. [...] [Getting] a time when [Clive] and I could be there made difficult too."* (Cheryl, POST). For participants who did not have others in the home to help, they relied on close informal carers outside the home to collaborate on its set-up, such as who Evelyn described how her friend came and set up the system for her when she struggled to do so herself: *"[It was] quite a lot [of effort] because I kept thinking have I got it in the right place. [...] eventually a friend helped me. Came round and stuck them all up for me and turned it on."* (Evelyn, POST).

The learning and set-up had some significant labour costs for people outside the home who were not regularly involved in everyday care. Angela required assistance from her son-in-law in order to set up her system and describes time and effort put in in order to have her system work: *"No way I can do it. I'm chair bound [after stroke]. [Son-in-law] came over to do it. All the way from [north of UK, to the south]"* (Angela, POST). David and Daisy professed to not be technically literate and were mostly helped by their children to set up and learn about their system, but this work was welcomed by their children: *"my daughter put the app on my phone [...] she was quite excited about it for me"* (Daisy, POST). However, Daisy explained how her daughter was really

lacking time and money and they were conscious of creating more responsibility for her: *"We got her [daughter] round. She did the whole thing and it took... about a day. [...] she didn't want to be paid to set it up for me but I insisted to pay her because she's a single parent, she hasn't got that much money."* (Daisy, POST).

These accounts show how collaborating to setup the SHHS was often essential for its initial function and that despite being framed for setup by an individual older adult, shared and costly effort was required for learning how to use the system.

6.4.2 Maintenance work

Beyond set-up and learning to use the system, there was work involved with the continued use and maintenance of the SHHS. Issues experienced with the system were initially troubleshooted by the primary users and others in the home, and participants showed dedication to trying to fix issues by themselves before reaching out to others outside the home: *"We tried. We really tried everything"* (Cheryl, P3M). This included sometimes repeating the same maintenance tasks repeatedly (*"... and then the third time..."* (Evelyn, P3M)) before their frustration made them give up: *"I've tried to change her. No point in me trying to stop it, any more... it's just programmed wrong."* (Evelyn, P3M).

This type of maintenance often required outside labour to be resolved. Angela tried to rectify an error, but did not succeed and needed to ask a formal carer to attend to the issue in addition to the care work planned for the visit: "*I don't hear from [HealthHelper] until 3 O'Clock in the afternoon when she tells me to take my tablets. [...] I am meant to take my tablets at 9 in the morning. [...] [carer] came later and tried to adjust her, but no use."* (Angela, POST). In addition to formal carers being involved in maintenance, frustration with issues with the SHHS led to participants reaching out to informal carers to visit to maintain the system: *"[HealthHelper] was always interrupting a conversation I was having with a friend or a programme I was watching. [...] I'm going to get [technician friend] to come and try and straighten her out next time he's over."* (Evelyn, P3M). Evelyn even went so far as to pay out of pocket for maintenance of the system: *"I couldn't get on. And that was another thing [technical paid helper] had to come and sort for me. So it's cost me too."* (Evelyn P3M).

When collaborative efforts to maintained the system failed, participants had to reach out to the SHHS research group to try to get professional help to maintain aspects of the system that "sort of stopped working" (David, P3M): *"I had an hour's telephone conversation with [SHHS research group] to try and fix it for [Debbie], but nothing. Such a waste."* (David, P3M). Even with the addition of professional help from the SHHS research group, this still required labour from the household members to organise, plan and engage with the maintenance work, including long

phone calls. This finding directly builds on Tolmie et al. (2007)'s work, which suggests the need to keep devices in "good order" over a longer period of time, as a household grows to accommodate them [p. 339].

Maintenance work for the system was the source of a lot of labour for the participants and their informal and formal carers. Unresolved issues of maintenance caused a lot of frustration and wasted time, which led to partial and full abandonment: *"I got so annoyed with it in the end, I turned half of it off."* (Clive, P3M). However, the sunk cost into maintenance also impacted decisions around abandonment too: *"I just thought of just sending the whole thing back, and [husband] said don't do that because you've invested so much time on it anyway. So I'm not going to send it back at the moment."* (Debbie, POST).

6.4.3 Interaction work

The interaction work in this section describes the ways in which participants engage with the system, with their vision, voice or when thinking about the system itself. This work comes about through the difficulties participants found in being given reliable information and being able to use this for any meaningful purpose in their homes .

In order to derive benefit from the SHHS, households had to actively engage with the SHHS, interacting through voice, on a computer or phone. Although the system added additional work through engaging with it, the interaction work for health and care needs sometimes replaced existing interaction work, both in positive and negative ways.

In some cases, routine interaction work was improved through the introduction of the SHHS into the home: *"I like her hands-free-ness. Because I struggle [with MS] [...] I haven't always got the coordination to balance things with both my hands and ask [type], so I can just ask now."* (Debbie, POST). Cheryl described how the use of the SHHS app removes the need for manual self-tracking of Clive's weight, and, as a person living with dementia, removes the need for additional remembering for him: *"we've got the scales so that will keep a track of [Clive's] weight because that's one thing we do monitor anyway. And because that has the advantage then of going directly to the app rather than him having to think 'oh I've got to write that down in my diary'"* (Cheryl, POST).

However, some interaction work was not beneficial to the participants. Many participants had issues with the voice assistant, including interruptions and voice recognition that required additional interaction practice: *"[SHHS UX researcher] did say that my voice when I say [Health-Helper] goes up and she said try speaking down."* (Cheryl, POST). However, there were other aspects of the system that caused frustration in the interaction work that was needed to properly

gain care benefit, including the dashboard. Evelyn wanted to access the sensor data collected from the system, but the dashboard was not accessibility-friendly for her: *"I don't have time for [dashboard]. It affects my eyes. [...] I'd rather [HealthHelper] just told me what data she has on me."* (Evelyn, POST).

6.4.4 Data work

Data work conducted using the system came about through need to source information from the system's sensors, for participants' own benefit. Accounts show that participants found it difficult to source data from the SHHS's devices as there were either struggles retrieving the data due to clunky interactions e.g. with the watch, to source heart rate or BP data, or when trying to determine whether exercise data has been recorded accurately.

Engaging with data through the system provided another source of additional work for residents, with varying opinions on whether the SHHS appeared to store information of any use and whether it was even possible to access this data. Clive discussed how he put in effort to engage with data from the system, including struggling to view information on the smart watch, saying: *"I find it very difficult to get on to the bit of the watch that I want it to be on. It's like now it's gone on to a sleep thing, but it hasn't got any information on there."* (Clive, POST). Bob explained how he'd worked hard speaking to the SHHS research group to try and allow him to view his step count over his phone: *"We spent a couple of hours talking it over but they just can't integrate my phone. [...] Even though I can take the data off [the system] and put it on to my phone, they can't take it off my phone."* (Bob, P3M). The placement of different parts of the SHHS also impacted data work, as some of the sensors were quite far from where the data could be accessed: *"the only place that you can speak to [HealthHelper] is downstairs. And if you're upstairs with [the] scales for example, I don't know where that reading's gone then. I can't ask her [HealthHelper]."* (Cheryl, POST).

There was data work done as well to see the limits of what could be stored on the SHHS, which often involved people inside and outside the house: *"Well we've [technical friend and I] put a fair amount of time in to decipher what all that dashboard is storing on me."* (Evelyn, P3M). When trying to make sense of what information the system had captured, Angela and "friends and family" worked hard trying to find out the information that the system stored, ultimately making Angela feel guilty for the work they put into it: *"I can't find out anything from [HealthHelper] about my pulse, or BP or my heart rate or anything. [...] I was thinking 'I'm wasting your time really'"* (Angela, P3M). Errors with some of the sensors could also cause distrust in the data, meaning that data work could not be accomplished in order to support health and care by residents: *"[HealthHelper] suddenly piped up and said, 'Well done, [Debbie], you've done so many steps today,' and [Debbie] would sort of look aghast and say, 'Well, I've literally just*

come downstairs [in the morning]"' (David, P3M). This builds on Kennedy et al. (2015)'s work, exemplifying the use of the *HealthHelper* as a task that everyone in H-D was waiting to "get around to doing", to understand how it operates [p. 418]. Despite some issues with the accuracy of the system, participants still saw benefit in the data work it would support, despite the increase in effort by themselves and their carers: *"I would still need help, but would be useful for physical health, even if you're looking at how many steps you do and things like that. I don't move a lot. But it would be good to know that and more."* (Angela, P3M).

6.4.5 Care work

Three types of care work were conducted in our households: self-care, shared care and multi-resident (Alemdar 2014, Soubutts et al. 2021) care (incl. people from outside the immediate household). With regard to self-care, the system's presence itself without functionality reminded people of good practices, such as keeping hydrated. Evelyn enjoyed the physicality of the sensor-based mug, although acknowledged that she did not use it for tracking how much she'd drunk, instead turning it into a low-tech convenience: *"...you could keep a drink hotter for longer and I could carry a hot drink upstairs with the lid on. So I did like that."* (Evelyn, P3M). Daisy was tracking her liquid intake more, but was not using the system for this (although it inspired the change in health behaviour): *"I am drinking water more than I did before, even though the mug doesn't work, the importance of drinking water [is there]."* (Debbie, P3M).

With regard to providing shared caregiving, positives were also found across households with the system in supporting care-related work. Cheryl expressed satisfaction with how the system would notify her if it detected a change in Clive's temperature: *"and if his temperature drops between a certain level or goes above, I've set it up, I'll get a ping on my phone*" (Cheryl, POST). *"Oh yes... I get [Cheryl] to start my day out right as they say. Programme in how much she wants me to do for the day and then sets me running like a hamster [laughs]."* (Clive, POST).

Evelyn explained her GP's interest in her monitoring her own blood pressure and how between her and her GP, she would create a recording of her blood pressure so that her doctor could stay informed about her wellbeing: *"I was talking to [doctor] about looking after my blood pressure. And he said, 'oh good idea. You can show me what you've got [BP reading] next time you're in then' [...] I'm going to keep a little chart for him for next time that I'll bring with me to an appointment I think."* (Evelyn, P3M). Although this was causing more care work for both her GP and her, this change (and increase) in care work was welcomed.

However, some of the aspects of the new care work could be disempowering for the users of the SHHS: *"I need someone to do this [put pulse oximeter] on for me though. I can't do it myself. Someone like me, couldn't do it by themselves."* (Angela, POST). Angela described another issue of

disempowerment, which caused additional work for her carer and for her GP. She was ultimately unable to be the source of data so that they could accomplish data work to better provide her care: *"I need [carer] to tell me what the little numbers mean [on the watch]. [...] She'll come weekly but last time I asked her what they meant. And we found out my [blood oxygen] together. I wasn't doing well, at that time. [...] I called the doctor, but I couldn't tell [him] what was wrong because I didn't understand [numbers on the watch]"* (Angela, POST).

6.4.6 Emotional work

Support by another resident or caregiver to use the system was often required, and this elicited additional emotional work by their carers. The introduction of the system caused additional anxiety management work in some households: *"[Bob]'s got AF - Atrial Fibrillation. If he was looking at the [dashboard] all the time, he'd be saying, 'oh dear, this is wrong, oh dear that's wrong.' So I have to intervene and point to things [on phone] and say, 'you don't need to worry about this, or that'"* (Barbara, POST). Cheryl described how HealthHelper caused anxiety for her husband Clive by producing unwanted sounds, which involved both additional unsuccessful maintenance work and then emotional work to deescalate the situations it caused: *"He gets a bit stressed when anything ... different sounds and things.. and that thing's [. . .] going off at the most unexpected times even when we've tried so much to change it."* (Cheryl, P3M). The system also afforded additional checking on the person in care, which could be a new source of emotional work for the carer to alleviate their own anxiety: *"obviously it will send a notification to my phone to obviously say there's been no movement, perhaps I ought to check on [husband] kind of thing [...] but I get worried then if I'm out that it's something worse, like he's fallen and I panic and call him and then [Chris] will say 'oh, stop bothering me I'm just up in the shed' [laughs]"* (Cheryl, POST).

6.5 Discussion

Through the study of the use of the SHHS in five different households, unique forms of work were observed both with the system and around it. Findings contributed a holistic overview of the different types of care work and labour that are performed specific to the smart home. Here we discuss the impact of the introduction of a smart home health system on shared care work and labour, and how this extends prior research on labour in the 'smart home'. The following three sections of the discussion focuses on mitigating and supporting households to avoid such labour-intensive outcomes from interaction with smart home technology.

6.5.1 Reducing care labour burdens with a smart home health system

This section proposes that to improve shared care in the home through interactions with the SHHS, there is a need for greater simplification and bespoke technical support for specific care tasks.

6.5.1.1 Recommendations for reducing household care labour

Our participants' accounts showed that doing care work with the SHHS was more labour intensive and that as a result, meaningful care tasks (such as taking blood pressure in H-A or taking Clive's temperature in H-C) did not get performed correctly. As such, participants fell back on making use of the system for more mundane purposes (such as using the smart mug for beverages in H-E). Whilst the learning and setup process could mitigate these failures, there is consideration needed for how participants' own abilities and disabilities were not considered in the design. Despite the system being setup for a single user, the ability for caregivers to reason DanaKai Bradford (2016) about the sensors and use them to support the person they are caring for, was not designed for. Moreover, visualisations of sensor data (akin to (Eardley et al. 2022)) could better support understanding of 'black box' data recorders such as the HealthHelper. This points to a greater need to develop bespoke care support tools (similar to Wallace et al.'s investigation of empowering personhood with dementia technologies: (Wallace et al. 2013)) that are designed the wider household that is involved in care. This could range from better visual interfaces, helping the caregiver to see what the sensor is currently monitoring about the care recipient or even auxiliary technical documentation that helps them navigate the sensors to perform specific care tasks (such as, a guided set of instructions that show how to check if someone's temperature gets too low).

Self-care (sometimes mundane (Ayobi et al. 2016, Nunes et al. 2015)) work using the SHHS was performed by residents who e.g. measured their weight, drunk more water, or counted their steps. However, shared care inside and outside the home was also impact by the introduction of the SHHS, such as an informal carer setting up a step counter (H-C) or a GP learning about how the SHHS can track blood pressure (H-E). This mirrors related work by James' James (1992) conceptualising caregiving as a combination of "organisation + physical labour" and Ming et al.'s description of the 'invisible work' that is often performed above and beyond by caregivers as part of their daily duties. There is a significant issue with smart home systems generating additional work for already over-burdened formal and informal caregivers. Harmon et al. (2017) describe care taking place as a 'philanthropic biography' that does not just happen in isolation. Instead, care happens over the lifespan, and the act of being philanthropic is a physically and mentally demanding form of labour that becomes a caregiver's life, often for many years consecutively. Nevertheless, for others, the act of caring with technology (with an SHHS) is also an expression of love, that provides a sense of fulfilment and purpose to people's daily lives (p. 18) (Mol 2008).

Although, the SHHS studied has primarily been described as a form of labour that is prolonged and exhaustive, so we suggest that reducing caregivers' unnecessary interactions with smart home systems should be prioritized to better support collective responsibility in caregiving and ultimately reducing risk. As Kraemer et al. identify Kraemer & Flechais (2018), effectively caring together in the home requires both vigilance and skill to not overburden dependents and we suggest that there is an opportunity for e.g. research through design (RtD) Zimmerman & Forlizzi (2011) activities with the care network to ensure that the link between unnecessary interactions and enacting a care task is broken. Previous research has illustrated the benefits of RtD in care settings by helping caregivers devote time to more meaningful care tasks Threatt et al. (2014), helping those with a high cognitive load and worried caregivers Morrissey et al. (2022) and using physical technologies (robots), to mitigate exhaustion in human caregivers by taking on simpler social tasks in the home such as reading stories, or singing to someone living with Alzheimers too (Simão & Guerreiro 2019).

6.5.1.2 Clarity for laborious interaction and data work

Interactions with the system's sensors showed a significant amount of labour (in particular for H-A, H-B, H-C and H-D), with in the moment interpretative data work and data reflection work. Smart home data work has been described as off-putting or scary, particularly to older adults (Callejas & López-Cózar 2009), and as Escarcha et al. (2022) describe, can even be 'spooky', when considering smart home system AI and their associated 'black boxes' that are seen as trapping and storing information that is often inscrutable. To support the demystifying of personal data that SHHS's collect, there are a number of actions that SHHS developers could take. For one, combined voice assistant and sensors systems could better leverage VAs such as HealthHelper and make them act as spoken interpreters of the data that is collected, potentially reducing both interaction work and data work. Moreover, this could make evident to users and caregivers that the system will support care, rather than only being usable by the SHHS research group (Desjardins et al. 2015). This could be scaffolded at the set-up process with additional calibration and configuration work, which has been discussed in the self-tracking literature (e.g. (Ayobi et al. 2018, Harrison et al. 2015)), but with a broader focus on collective monitoring with shared configuration by users and caregivers, as seen in this study for example, H-E having their system configured by an expert or H-D delegating configuration to their spouse. For instance, upfront configuration work could involve shared visualisation exercises to find out which types of visualisations are easiest to understand, with simple pathways to data access that in turn will be useful for self-monitoring or administering care (Brotman et al. 2015, Morgan et al. 2021, Williams et al. 2019). Providing a range of visualisations could, as Strengers et al. (2019) also suggest, account for the diversity of and specialised needs of relationships between older adults and their caregivers and potentially help recipients to communicate their lived experiences, for instance representing their chronic pain pictorially or numerically (Adams et al. 2017). Co-design

workshops to identify the data that both older adults and their caregivers need could further help to develop tools to support shared household understanding.

6.5.2 Reducing labour through simplicity and autonomy

One of the key barriers to the use of the SHHS was a holistic understanding of how the system works (for both care recipients and caregivers; see following section). This juxtaposes early notions of the smart home where the use and function of so-called 'domotics' devices (such as fold-away ironing board and beds built into walls), were obvious in their affordances (Heine et al. 2016, Hutchison 2014). In contrast, much of the SHHS in this study obscures the inner workings of the system through it being largely a 'black box' and that whilst data is accessible (H-A, B, C), it is difficult for older adults to generate their own mental models either easily or quickly, as gaining an understanding of the system as a whole takes time due to its complexity. Only by the end of the three month period of the study, did we see greater understanding (albeit dissatisfaction) emerge around what the system actually does (e.g. H-D's accounts).

Our pre-installation accounts show that the system brought with it an expectation of simplicity and that caregivers would easily be able to set the system up on the system owner's behalf (e.g. H-A, H-D), but this was not the case, as emerges later, due to the complexity of the SHHS which could not be overcome. This contrasts participants' early discussions about some of the other, simpler smart devices they own, such as their 'Alexa' smart speakers, which worked as expected after being plugged in 'out of the box' (Zubatiy et al. 2021). Having high expectations up front of the SHHS, combined with the ongoing issues of understanding and physically interacting with the sensors (e.g. wearing the watch (H-C), filling the mug (H-E)) showed the labour intensiveness of this system by contrast.

Whilst we provide suggestions towards improving the learning and setup and ongoing maintenance work around the system in the following sections, avoiding abandonment (which can be common for smart health technologies (Clawson et al. 2015)) of the SHHS additionally requires SHHS developers to make older adults and their caregivers aware of and actively support the effort involved in the learning process. The disparities in the learning (and onboarding) process discussed in section 4.2 only show further how the inconsistencies in onboarding, lead to the inconsistency in residents' understanding of the system, resulting in the latter abandonment seen here. This extends previous work by Sixsmith et al. (2020) showing individual assistive technologies are often abandoned due to lack of sufficient social support from the care network. However, this is not to say that abandonment in this instance is inherently bad.

Through abandoning the system, participants likely returned to the same (reduced) levels of labour seen prior to getting the technology. Although marketed as technology to be used to

support older adults with chronic health conditions lasting over a period of years, the SHHS does not demonstrate the longevity required to maintain interest or usefulness in the long term. This has parallels to Garg & Kim (2018) who show the abandonment of IoT devices that do not meet people's longer-term, health-related targets. In this current study, these evolving health needs are not catered for by the SHHS for the individual, let alone for the wider household. Through 'showing and telling' (Trenner 1995) older adult households what a 'sensor' is and through to explaining the interactions of all of the sensors with one another within the system can go a long way to achieving this.

Abandonment of the SHHS is not inherently bad within this study, as households will likely see a reduction in effort and labour simply through no longer using the equipment. Further, whilst households abandoned the use of the system as a whole entity, for its intended purpose; some devices were re-appropriated and now fill other, less laborious roles (such as with Evelyn now owning a handy mug to keep her drinks warm).

6.5.2.1 Reducing learning and setup labour's mental and physical demands.

Significant time was spent by all participants trying to learn how to use the system and set it up, including writing notes to remember how the system works (H-D) or phoning a member of the SHHS research group for assistance (H-C). Language used when explaining smart home systems has also been shown to affect understanding (Burrows et al. 2018, Harper 2006*b*) and as such, mental labour during the learning and setup process could be reduced through providing visual aids (for sensor setups) and further interactive documentation. Interactive 'translation' tools (Eardley et al. 2022) accompanying the system could be tailored to the individual needs of older adults to aid the understanding of the setup process. This setup process could start the learning process for both recipients and informal and formal caregivers, showing them how to interact with the system, similar to what has been found with commercial smart home devices (Soubutts et al. 2022, Porcheron et al. 2018). Tangible tools also show promise in reducing learning work by aiding understanding, particularly for people living with dementia (Bennett et al. 2016, Czech et al. 2020, Houben et al. 2022). Beyond the recipient, more design focus should be on the caregivers' learning processes as they share the use of smart devices (Geeng et al. 2019, J Kraemer et al. 2019). This is especially true for informal caregivers who are often over-burdened already (Chen et al. 2013), and we have shown to be additionally burdened at the onset with set-up work.

6.5.2.2 Support for ongoing maintenance work.

A great deal of the labour also arose from doing maintenance work with the SHHS, for instance involving error correction (H-A, B) and irritation in managing the voice assistant (H-E). Sixsmith et al. (2020) identify the importance of systems that can be maintained cooperatively (not co-dependently) and how a 'gradation' of responsibility is needed between caregivers and care

recipients in order to effectively maintain together. Lazar et al. (2015) too, have talked extensively about the consequences of when smart device use becomes unmanageable when too much extra work is required to maintain devices. In Lazar et al.'s study, like ours, the labour of maintaining devices eventually led to abandonment. However, it is possible to envision more optimistic solutions for systems where maintenance is appropriately scoped by an SHHS provider and coordinated up-front with caregivers and care recipients. This could indicate what problems may arise and help to set expectations for the benefits of the system, but also its limitations.

6.5.3 Supporting gendered and emotional household labour

Whilst this paper dealt explicitly with the emotional work experienced by each household in order to setup, maintain and use the system, it is also important to acknowledge how this labour is also gendered (Ruppanner & Huffman 2014). As De La Bellacasa describes, care is not a neutral practise; it is inherently gendered Puig de la Bellacasa (2011) [p. 43], and, as the UK's Office for National Statistics suggests, 58% of UK caregivers are female, as opposed to only 42% male (Census 2021, Cocker & Hafford-Letchfield 2022). Puig de la Bellacasa (2011) goes on to further exemplify that the act of caring for and with technology requires both the aforementioned ongoing maintenance, as well as "ongoing [...] responsibility." [p. 43]. Whilst H-B, C and D all had a caregiver who was caring for another participant using the SHHS, in H-B and C saw a female caregiver supporting a male care recipient. In H-A and E, female participants were performing self-care as well as learning how to use the system without the live-in support of another resident (albeit with other live-out wider household members intervening). Evidently, there is a need to re-balance this dynamic, although the route to doing so is complex and the route to reducing labour for these predominantly female caregivers will be different. Such an approach to provide greater support here could be based on whether there are live-in or live-out residents present. For example, for those with other live-in residents, support could focus more on enabling interventions from other residents and providing clear instruction from the SHHS provider that can be understood within the household's context. For those living predominantly by themselves, but with live-out support (such as H-E), there is a need for more direct intervention and physical presence from formal carers or the SHHS provider to have another human presence in the home, to steer the learning process early on and reduce the labour cost.

6.5.3.1 Supporting emotional labour through familiarisation.

Emotional work emerged in the three month deployment as time progressed, with anxiety expressed in H-B and H-C. This was not just the recipient expressing worry over the health and care data available to them, but also carers expressing anxiety with trusting the system to monitor the person in need of care, which has parallels to other care monitoring systems that had unintended impacts on anxiety (Wang et al. 2017). Emotional labour, by contrast, is a resource in the home (as described by (Raval & Dourish 2016)) and the SHHS was pulling on

this resource in inefficient and effective ways, causing stress, and ultimately resentment. Prior descriptions of labour that take place both inside of home and residential care settings, tend to focus on one specific form of labour such as the implications of emotional care work (Raval & Dourish 2016). Lazzarato (1996) describe 'immaterial labour' as mental adjustments and responses to higher levels of work, which was present in the repeated experiences of frustration with the SHHS expressed by both recipients and carers. As the SHHS was a closed ecosystem of devices, participants seemed to have a lack of control over tailoring the system according to their personal and shared emotional needs within their unique households, again pointing to the potential of upfront configuration work to reduce unintended emotional work. As Easthope (2014), Gruning & Lindley (2016) both describe, people develop strong emotional connections to their dwellings and their possessions and as such develop specific expectations and affordances (Rooksby et al. 2014) to these possessions that determine their future interactions with them. Further work to understand with more completeness people's complex social and emotional interplay with their possessions and devices in their home, could go some way to help understand the emotional context for introducing new smart home technology and ultimately, reducing unintended emotional labour so care recipients and caregivers can reduce their overall shared care burden.

6.5.4 Emotional journey with the smart home health system (SHHS)

Building on the discussion of the emotional journeys with the stairlift and voice assistant, found in chapters 4 and 5, it is important to recognise the emotional trajectory of the SHHS and how participants' feelings towards the system were reflected through the use of the devices and ultimately its abandonment.

For the most part, the emotional journey seen around this technology is inverse to the trajectory seen for the stairlift study. For that technology, as people grew to use the stairlift more often, and it became woven into the social fabric of the home through necessity and shared use, emotional acceptance increased over time. Whereas with the SHHS, as participants engaged more with this system over time, more emotional distress became apparent, resulting in lower acceptance to the point where the system was ultimately abandoned.

This shows that despite both the stairlift and the SHHS being quite large and invasive technologies in the home, the journey towards acceptance can vary widely, dependent on the labour required to continue to use the devices, especially if the difficulty increases further over time, there is no scaffolding for the use of the technology (as with the SHHS) and the perceived benefits and payoff to the residents is not guaranteed.

6.6 Limitations

The authors acknowledge limitations with the study methodology and execution. Firstly, we recognise the limitation of our sample set. Our sample was comprised of low-middle income white UK households due to the nature of access to participants in the area where the study was conducted and also retention for the full duration of three months. Whilst households did initially come forward from black and minority ethnic communities, there was difficulty retaining these participants for the full three month period as the study period would not have worked alongside their personal caring commitments. In future therefore, we would seek to find alternate ways to diversify of our sample set to recruit and retain those from e.g. ethnic minority communities and queer communities. This may require different means of structuring study formats to accommodate participants' varied responsibilities.

The authors also acknowledge the impact that providing the SHHS for each household entails. Instead of participants purchasing the devices for themselves, the authors were gifting this technology to households to use. It is important to acknowledge this impact and propose that there are alternate means of delivering and studying this technology 'in the real world' (Rogers 2006). Gifting technology can bias processes such as informed consent and also shift power dynamics between researchers and participants. To try and mitigate this effect, the researchers did separately compensate participants for time spent taking part in interviews. Conducting this study remotely and taking mitigations to limit the spread of COVID-19 with a population of older adults, informed this decision and reassured us that this was the most appropriate means of conducting this study given local restrictions on data collection.

The authors also acknowledge that the SHHS research group developed the system (an IoT sensor system and voice assistant) for individual older adults who live alone. Whilst this does not change the evidence collected here, it is important to note that the technology's designed purpose is different from how it was predominantly used in this study (as a shared household). The authors advocate looking at the interplay of sensors with one another and their individual and shared impact when used both indidivudally and together in a household setting.

Lastly, the authors acknowledge that whilst some informal caregivers were interviewed as part of this study, it would be of benefit in future studies to interview further members of the household e.g. children and grandchildren of smart home technology owners, rather than just hearing anecdotal accounts of their use through the technology owner. This study focussed on interviewing the SHHS care recipient and their immediate caregivers (usually a spouse), who lived with them, though in future it would also be of interest to also interview formal caregivers and clinicians to identify e.g. clinical feasibility of SHHS's.

6.7 Conclusion

We conducted 15 semi-structured interviews across five older adult households over a period of three months to understand the impact on shared care work after the introduction of a smart home health system (SHHS). Our findings reveal several types of labour that arise when an SHHS is deployed and we suggest ways to support or mitigate labour that could result in the abandonment of the system.

Engagement with the SHHS showed positive benefits for mundane self-care activities, such as tracking weight, water intake and BP for older adult care recipients, while caregivers benefitted from control over setting daily activities or tasks for care recipients to undertake, such as number of steps walked in a day. Despite these benefits, there is scope to remove or reduce labour to allow recipients and caregivers to understand and utilise the SHHS in the best way possible for their home context. Specifically, reducing the set-up labour, learning work, interaction labour, data work, care work and emotional work could be possible through human centred approaches that included both the recipients of care, and the formal and informal carers. A wide range of people are heavily involved in the successful adoption, appropriation and use of the SHHS, and careful design around their shared care work could allow these complex home healthcare systems to be better integrated into the sociotechnical fabric of the home for older adults.

This marks the conclusion of the empirical chapters for this thesis. The following sections summarise the key contributions from the combined empirical work across Chapters Four, Five and Six. The implications for future research and design in the smart home for older adults who are aging in place together are then outlined. This thesis closes with a general conclusion chapter and reflections on conducting this research.

CHAPTER 7

GENERAL DISCUSSION

7.1 General discussion and future work

This thesis has drawn on qualitative methods to investigate how older adults and their wider household make use of, understand, reason with emotionally, and ultimately accept or reject the use of smart home technology. In this chapter, a general discussion for this thesis focuses on implications for the multi-resident home, for care and audiovisual social engagement, and for the understanding of the different types of labour that arise in the home through the use of a smart home health system. The implications for the wider health and care technology approach to aging in place together are then outlined.

7.1.1 Emotional journeys with household technology

One of the consistent themes across each study within this thesis has been an emotional trajectory (or journey through) the use of the different types of technology that have been explored. The deployments of all three technologies show how they impacted residents' psychological wellbeing at different times. For example, in study 1, most households experienced very strong and polarised feelings about the stairlift, where the interaction between residents caused e.g. conflict and stress, but eventually led to relief. In the study of the Echo Show, the moving of typically in-person social activities that had human nuance and connection embedded within them, towards a relatively unfamiliar communal smart home technology resulted in missed connection, feelings of isolation and difficulty sustaining social relationships where previously this would have been easier; the Echo Show could not replicate the nuances of intersubjective human relationships. In the third

study of the SHHS, households also experienced feelings of stress and frustration with the system and within the care network, as time progressed. The more time spent with the system, the more negative emotions to user experience and labour were discussed, until eventually, the system was abandoned by all households.

The fact that there is a distinct emotional journey attached to the use of each of these technologies shows that emotion is closely tied to the aesthetic and interactive elements of each technology, as well as how people in the household engage with it. Desjardins et al. describe how some household objects can elicit emotion simply through touch or being in proximity to them (Desjardins & Tihanyi 2019). In a similar way, the Echo Shows facilitated positive interpersonal emotional engagement even if the feelings towards the device were negative or ambivalent at best. So too, Dixon et al. echo how home technology can provide people with emotional outlets or conduits through which to express negative emotions such as frustration, similar to how participants in the SHHS study perceived their systems (Dixon et al. 2021). Unique then to our studies was how the stairlift created an emotional journey around the technology itself, rather than impacting existing emotions e.g. about other household or technological issues.

All three studies also had both a positive and negative psychological impact on households. Whilst these were not neutral additions to the home, this thesis has respectively discussed how to mitigate e.g. negative impacts of household technology deployments, there are broader questions to be asked still around older adults and co-habitants' responsiveness to change with the introduction of technology, of particular concern is to what extent technology negatively affects care, which is an inherently altruistic and well-meaning process (Mol 2008). To what extent technology should be a part of care altogether, is a question beyond the scope of this thesis and technology will be impossible to ignore given the financial crises in the NHS and social care. However, the emotional labour described in the third study in particular suggests that psychological effort of some type will inevitably be needed (and should be expected) whenever new care technology is introduced to older adults' shared homes. The extent to which individuals in shared household emotions can be regulated, prepared for, or designed around in the development and adoption of smart home care technology is instead an interesting avenue for future research within HCI and CSCW. Whilst the emotional acceptance journey of the stairlift is outlined in detail in chapter 4, as this is integral to this study's discussion, it is also possible to show the emotional acceptance journeys for the other studies too. The diagram below shows the trends of each of the journeys in each study, and how this differs for each technology being investigated. Whilst this interpretation of the emotional journeys is subjective to the thesis author, the bubbles are loosely representative of major events and points along the journey, whilst their size indicates the significance and weighting within the qualitative accounts. Researchers and designers could use a similar visualisation in future when investigating the emotional trajectories of technology installation journeys again.

Figure 7.1: Maps of the emotional acceptance journeys with each technology chosen.

The table below describes how the emotional acceptance journey trajectories in greater detail for each study, as well as any research and design recommendations stemming from these investigations.

Table 7.1: Discussion of emotional acceptance journeys across all three studies, research and design implications.

Study	Journey Description	Research and Design Recommendations
1	For the stairlift, the journey trended toward acceptance for all household residents and saw increased acceptance after a prolonged period of conflict.	• Using the model to inform policy e.g. by countering simplistic models already in place (e.g. Chapter 4). • Moving beyond up-front technical support towards 'emotional support documentation' for complex technology installations. • Moving beyond simply emotional 'acceptance', to other emotions including long-term 'fulfilment'. • Factoring in the impact of competing interests of residents and non-residents in technology installations. • Incorporating period of learning and 'scaffolding' into installation journeys (e.g. moving from basic to advanced understandings of sensors, without additional stress or labour).
2	For the voice assistants, there was no strong trend to the acceptance journey and the technology was largely accepted up front, upon receipt of the Alexa devices.	
3	For the smart sensors, this journey trended from greater interest and acceptance up front, to disinterest and abandonment as people found the use of the system to be emotionally draining overall.	

7.1.2 The social and multi-resident home

All of the studies in this thesis have been concerned with the shared impact of different types of technology on the lives of older adults who are aging in place together with others in their homes and the wider household outside their homes. The case study of the stairlift showed how the journey towards the adoption, use, and acceptance of a visible domestic health technology is impacted by the messiness (events, places, people, emotions (Callejas & López-Cózar 2009)) of everyday life. The findings from the stairlift study exemplify this messiness as part of a complex and non-linear emotional journey that is shared through the adoption and acceptance of an intrusive domestic health technology, that ultimately supports aging in place together. This first

study showed how this complex sociotechnical system is influenced by a range of actors, each with competing interests in the stairlift journey that often veer away significantly from the primary purpose of the technology to support the quality of life of a person with mobility needs. The second and third studies built on this, showing that the use of off the shelf consumer technology or smart home health systems both require the attention and support of a diverse range of household residents. This is particularly the case with informal and formal caregivers who will setup and manage the technology for an older adult (study 1-3), who will help to facilitate social connection (study 2), and who will provide specialist technical and care labour, to learn about and use complex sensor systems on behalf of an older adult (study 3) These care roles and technology roles become woven into the social fabric of the household. Actors within and outside of each household can be delineated into four roles: *primary, secondary, tertiary and quaternary*, that make up each home's unique care support network around the technology. Findings across these studies illustrate that residents and non-residents can be characterised by these four care and technology roles which expand on accounts to existing descriptions of primary, secondary and tertiary residents in care networks.

The understanding of these roles extends Buyuktur et al.'s work (Buyuktur et al. 2018) work on caregiver dyads, that describes people's experiences of technology that improves e.g. quality of life and independence with others in the home as being "collaboratively constructed" (Bradford et al. 2018) [p. 2] and Zallio et al.'s work which introduces the notion of "primary" (those who own the technology), "secondary" (those who share the technology) and "tertiary" (dependents of primary and secondary and those who share in the use of the technology in the home e.g. children) users (Zallio & Casiddu 2016). The defining characteristic of these roles in delivering care is both social and technical (sociotechnical) by way of providing care support to both the everyday care routines (incl. ADLs) of a person in care as well as support with the everyday use of their care technology. This reflects and directly builds on Branham et al.'s work (Branham & Kane 2015) which suggests co-constructed support of accessible technologies is vital for their adoption. Building on this further, work from Abowd et al. (2006) has presented similar caregiver network terminology, adopting e.g. "primary" to denote the person with technology in receipt of care. Amiribesheli & Bouchachia (2018) [p. 1761] extend this to describe how "care stakeholders" (what is termed in this thesis as "secondary" and "tertiary") play informal and social caregiving roles respectively; where the former assists in monitoring incidents, repairing broken devices and generally maintaining the device infrastructure in the home while the latter performs a more remote role, checking in on the technology users, using devices themselves and making suggestions for improving the day to day use of the care technology, or contributes by making suggestions for purchasing new equipment. These primary, secondary and tertiary characterisations are similar to study 1's own findings with the stairlift. In study 1 and 3, we also see the role of quaternary (formal professional care, GP or technical providers) bring their role out in meaningful ways for residents. In study 1, H-B, C and D, all had visits from occupational

therapists (a state-funded care professional who lived outside of their home), who became a part of the social fabric of the household, through frequent visits. For example, in study 2, H-J had regular contact with a GP through the telephone, and then the Echo Show. In study 3, H-E also repeatedly employed a "handyman" technical helper to manage the technology she owned for her and who was specifically nominated to support her with the smart home health system. In both these studies, the non-resident and socially unfamiliar quaternary residents also became prominent parts of each household as they interacted with the wider household over time.

All three studies found that the primary (live-in) resident, whilst still the owner and user of the care technology, is also a conduit through which other socio-technical activity (e.g. decision making), is centred around.

The following descriptors for primary, secondary, tertiary and quaternary residents below help to understand the multi-resident home.

Drawing from our findings, across all three empirical studies, we saw that ***primary*** residents demostrate the following characteristcs:

- demonstrate self-awareness of their health and any chronic conditions, seeking advice from clinicians and carers, albeit reluctantly at first.
- engage with clinicians with reluctance, if they feel their autonomy is being removed.
- share knowledge from and to other residents, e.g. around the stairlift, so that upkeep and maintenance of the technology becomes a shared practise.
- source relevant, local information that affects their own health or that of their spouses, thus protecting them.
- change the physical layout of their homes to accommodate new healthcare technology, despite any emotional difficulty.

To support the primary resident in the use of their technology, **secondary** (live-in) residents (spouses and live-in family members in our studies):

- perform research and source information to inform decision-making, usually on behalf of the primary resident.
- provide encouragement, emotional support and persuasion during out-of-home assessments (e.g. mobility assessments).
- go beyond persuasion, often resulting on conflict, in order to convince primary residents to adopt a technology for their own wellbeing.

- volunteer themselves to support the physical, technical setup of new technologies in the home.
- learn how to use the technology in question in order to help maintain it along with the primary resident.
- seek out information with other residents about how to improve the experience of using the technology (e.g. through finding out about new features or shortcuts).
- assist with the fine-tuning of the device for the specific sociotechnical fabric of and integration into each household.

Beyond this, the studies revealed the role of tertiary live-out residents who would come into each household to purposely or incidentally interact with the technology. These people are categorised here as those living outside of the home, who do not have a clinical role, but who provide e.g. informal care and are socially related to the primary and secondary residents of the household. Those who might visit the home include adult children, grandchildren, relatives, close friends of the household. **Tertiary** residents:

- support decision making around healthcare technology choices, either through positive reinforcement or coercion.
- contribute to purchasing technology that will support other residents' health, through what they perceive to be a net benefit to those residents.
- provide informal care support e.g. by assisting other residents' with their physical mobility.
- using social influence, story and metaphor to support their positions in favour of, or against the adoption and use of healthcare technology.
- helping primary and secondary residents together, to adapt the physical layout of their homes to more easily accommodate new technologies.

The primary, secondary and tertiary residents, descriptions of duties from the three studies, show how live-in and live-out members of the wider household interact to support the technology installations. What is less explored in previous literature, is how OTs, Clinicians, Social Care workers, Installers, Care Reps, GPs, formal care supporters and paid technicians, influence the adoption and acceptance of these care technologies. These **quaternary** (live-out) professionals roles, performed mobility assessments, identified primary residents' cognitive capabilities, performed physical installations and setups or took measurements of a person for a home adaptation. Extending previous research, our findings shed light on the influence on technology acceptance and adoption and additional social support they provide that goes beyond their job roles. They

become over time, more familiar and interact more closely with the social fabric of each household, ultimately supporting the people receiving new technology, and influencing its adoption, acceptance and use. Their duties typically include:

- intervene during conflict between residents to reach positive resolutions and set expectations appropriately.
- acting as a trustworthy, independent source of information about the technology that households are collectively looking to adopt.
- providing structured and supervised learning and support for residents adopting a new technology together.
- providing a wealth of advice and insight that can help other residents to physically restructure their homes, or re-structure their lives socially, in order to accommodate new ways of living with healthcare technology.
- supply specialist, technical advice around maintenance of specific technology, maintenance of the home (e.g. resulting from installation damage occurring), or how to continue to use and tailor a new healthcare technology, to make the most of its more advanced features.

The support for smart home technology installation adoption and acceptance journeys must be holistic and therefore supportive of all the actors in the multi-resident care network. However, this should also take account of the fluid roles that quaternary professionals perform themselves, in order for them to provide individualised, sociotechnical support to each household (even though there are numerous possible people playing the same professional role). Therefore, future research and design should consider the versatility of quaternary professionals' duties, from being socially engaged members of a household (albeit temporarily, for assessments), to understanding and having to judge the long-term impacts of smart home health technology on each member of a household. Consideration should specifically be given to how technology can be used to help quaternary professionals in their holistic understanding of each household, reducing the potential for misunderstandings of a home within an assessment (e.g. in study 1), or the hand-over between professionals.

7.1.3 Societal implications for smart home health and care technologies

Besides the technology deployed in these three studies, it is important to recognise the wider societal impact of smart homes for health and care. Organisations and individuals across society have influence over supporting aging in place together through technology. Local councils and organisations that facilitate stairlift installations were engaged early on and through study 1. In this study, it was shown how councils will do their best to engage and adapt to the complexity of residents' lives throughout the stairlift installation process. Similarly, the assessment centre

workers and installers all provided social support and engaged directly with emotional aspects of decision making for stigmatised intrusive home health technology. This was a more complex and messy process than the simple insytallation model that was described by OT's 1-5 in Chapter Four, with considerably more social engagement with residents during this process (for both the private and funded routes). Future smart home technologies provided for health and care might also see this engagement with future asessors and installers. Conversely, the consumer, off-the-shelf devices (Echo Show) had no formalised process for social engagement with the technology journey. Although the SHHS system developers had help documentation, onboarding support, a telephone call-in line and some online resources to assist with the devices if needed. Much was left to the initiative of the residents in each household to seek out and troubleshoot when needed.

For those who are aging in place together with people inside and outside of their home, these consumer smart home solutions that come largely unsupported out of the box are problematic and raise questions for researchers regarding what can be done to better facilitate the introduction of consumer smart technologies for older adults and their caregivers so that they are able to be functionally emotionally and socially integrated into the household. There is an extensive body of literature both within and beyond the HCI community on smart homes, and whilst studies of consumer-grade systems mostly make suggestions towards supporting activities of daily living (with inclusion of caregivers to varying degrees), the complex and messy 'journey' that this thesis has explored towards aging in place together is largely neglected in studies of consumer-based smart home technology (e.g. (Kowalski et al. 2019, Mennicken et al. 2015)). Interestingly, whereas the body of work on consumer smart home technology within HCI and CSCW has grown in recent years to include shared aging experiences, interest has also grown towards the intersection of these experiences with Trust, Identity, Privacy and Security (TIPS) and risk Bahirat et al. (2021), Chalhoub et al. (2020) balancing this against socio-technical issues such as designing for existing needs in each household up front (Salovaara et al. 2021). For society, for future smart home research and for commercial smart home developers, it is beneficial to develop research methodologies that do not examine smart home technology deployments or interventions at singular points in time. Instead, taking a temporally-fluid approach to looking at the home is necessary in order to understand the complexities of a home's history and its place within its local community. Homes, as Desjardins et al. have suggested (Desjardins et al. 2015), exist on a continuum both backwards and forwards in time, and user research typically presents only a snapshot of concurrent experience, within which lies the evaluation of a smart home technology. One approach to understanding emotional, or shared care journeys that support aging in place together therefore, could be to look more extensively at the history of the space (the physical home) and the place (the multi-resident community that make up the social structure), inside and out. Methodologically, there is a drive within the HCI community to make studies of technology more longitudinal (Kjærup et al. 2021). However, the pre-installation experiences leading up to technology installation are still largely overlooked in the home, and could be used to ground

a more in-depth understanding of the shifts in social structure and health, and also to better contextualise why such strong emotional or social changes occur when technology is introduced.

It is unclear whether examining the smart home over a greater span of a person's life course is either feasible for HCI and CSCW researchers, or whether this would yield greater insight into the health and care opportunities for older adults in their homes. Nevertheless, to understand the emotional trajectory of, and to design for a person's changing emotional state is difficult and undoubtedly requires a greater understanding of the individual and their social network than is feasible within the timeframe of most user-centered studies. Working more closely with health professionals who know the individual and their household structure well, may be one approach to better positioning smart home health and care research here, though this risks exacerbating researcher-participant power imbalances (Schneider et al. 2018).

Instead, it appears more ethical and practical to provide information regarding the location of the home that is being studied, to position and understand local and external environmental factors acting on a single household and an individual older adult's social network and to include more information about this within e.g. the methodologies or limitations of specific household studies (if appropriately anonymised).

Whilst the studies in this thesis have not looked in-depth at the societal factors affecting the acceptance and adoption of smart home technologies for health and care, it would be of great benefit for future HCI and CSCW researchers to critically engage with the wider social contexts that are relevant to their studies, in order to appropriately frame the highly nuanced emotional and social dimensions of the home.

7.2 Reflections on key thesis contributions

This section reflects on this thesis' key contributions from each of its previous chapters.

Chapter 1 articulated a research question (RQ1) to understand how 'invisible work' was conducted in the smart home, to provide care. Throughout the empirical chapters, we have seen ways in which this invisible work takes place: from the anecdotal accounts of people being emotionally coerced into installing a stairlift, to the investigative work done by participants to fully utilise the features of the voice assistant, to the complex data work done by residents to make sense of the SHHS.

Much of this work was negotiated between residents according to the social structures of their homes and as a result, both the physical and social boundaries within these homes shifted to accommodate new technology.

The whole system approach identified in chapter two's literature review, became the starting point for understanding the multi-resident home in totality, and built on Zallio & Casiddu (2016)'s existing model of residents, adding in the quaternary role. The quaternary resident role brings together the other three (primary, secondary and tertiary) roles, reducing disparities between other residents' roles (through negotiating conflict in the case of the stairlift), or by scaffolding and structuring understanding (technical supporters for the sensor system). The introduction of the quaternary resident to the MRH model, also shows that these actors kept the emotional journeys moving, through difficult points, such as the conflict and trauma stages of the stairlift emotional journey roadpmap.

Age, and to a varying extent, vulnerability was an over-arching concept that this thesis tackled too, identifying the roles that caregivers of different ages played in supporting technology owners in their homes. In the stairlift study, we saw younger tertiary residents supporting the installation journey directly, before the stairlift was installed. Similarly, live-out residents in the voice assistant study often called their older parents to support them in using the device for social activities during the pandemic e.g. online auctions, which altogether helped to provide answers to RQ1. The voice assistant, also had direct, positive impacts, such as reducing anxiety for the vulnerable person (due to her self-described low vision) in H-J, and also reducing clinical cost to GPs, resulting from less phone calls.

Social presence, social facilitation and the appropriation of technology for social purposes was also introduced in chapter 2. This phenomena became apparent in our voice assistant study where older adults living with others during COVID-19 lockdown appropriated the VA for a variety of tasks, which were not fully supported by the device at the time e.g. entertaining pets. We also saw how work was done collaboratively through the VA, helping to provide answers to RQ2, where its users would modify the device to greet guests e.g. in H-G or take on the role of a care actor, reminding the wife of Isaac in H-I to take her medication, once he had set the device up to remind her.

Knowledge sharing, which is addressed in chapter two, became integral to understanding RQ3 and its outcomes. The understanding of the negative effects of complex systems such as the SHHS, that are unsupported and to a lesser extent, the stairlift (which was more supported), were addressed. The ways in which smart home system complexity invites additional shared labour was an important outcome and recognising that systems that contain many devices are harder to understand and develop mental models Rogers (1992) for, is important to highlight, when considering these system's are not used by just once person, but their associated caregivers too.

Table 7.2: Overview of key research, design and policy contributions provided from each empirical study chapter within this thesis.

	Stairlift Study	Voice Assistant Study	Sensor System Study
Research	• Consider emotional impact of technology on socio-technical networks of older adults and caregivers.	• Identify 'trusted sources' of health and care-related information and how multi-resident households identify these together.	• Understand how sequential, scaffolded support can be provided that promotes long-term, non-laborious SHHS use.
Design	• Provide structured support mechanisms for non-tangible artefacts from technology installations (e.g., emotions). • Support the wider care network of individuals involved in technology installations.	• Provide conversational support features for residents interacting with healthcare professionals (e.g. autocomplete in-conversation). • Identify GP-surgery enabled skills or features to support heath and care activities.	• Avoid 'dumping' too much information on people up front. • Reduce technical labour, by supporting complex sensor interactions. • Do not rely on care burdened residents to remember complex technical details, provide this support by other means.
Policy	• Avoid overly simplistic models of technology use when installing complex systems	• Connect local authority services to people's homes, cutting costs on telephones through advocating VA prompts.	• Develop distribution, recall and upgrade cycles for sensor systems at a local authority level to provide continuous support.

This collective understanding informs a range of research, design and policy outcomes that are provided within the empirical chapters in this thesis. We also provide a summative table below of some of the key contributions of each of these chapters and how they inform each of the above areas.

Articulating these individual recommendations from each study go towards helping to provide answers to the over-arching research question for this thesis (TRQ1), showing that to greater or lesser extents, people come together in vastly different social, technical and emotional ways across generations to either come to accept, or at the very least tolerate for a short time, different types of smart home technology for their health and wellbeing.

7.3 Limitations

This section explores the methodological limitations of this thesis as well as contributions to the broader HCI and CSCW research communities within which the studies were conducted and the

methodological contributions of this work within smart home research. Specific limitations for each study are found in each empirical chapter.

7.3.1 Methodological limitations

This thesis focused on the global challenge of the aging population, taking a specific focus on how people age in place together. To examine this research area, an exploratory ethnographic approach was taken that used qualitative semi-structured interviews and technology deployments across three empirical studies. Arguably, an entirely qualitative approach could have been taken, examining technologies already deployed 'in the wild' (Rogers & Marshall 2017), however by combining technology deployment alongside qualitative investigation, it has been possible to gain a more robust understanding of adoption and acceptance from the outset of technology use. Nevertheless, this has not been without caveats, as it has been difficult to ensure people can use the technology they have been given (e.g. access to a reliable internet connection, particularly in studies 2 and 3) and sustaining participation in qualitative interviews for a prolonged period of time has proved a challenge too.

The decision to run three separate sets of interviews with the different health and care home technologies across the three studies has also provided a useful understanding of adoption and acceptance over time (up to a period three months). However, older adults' life circumstances often change frequently, for better or worse (e.g. house moves or poor health (see further in 7.2.4)) and it has been a challenge to sustain engagement between interviews too. The pre-installation interview method (and the benefits of this, as described by Carlos Rubino de Oliveira et al. (2015)) were where the majority of this thesis' contextual enquiry (Dekker & Nyce 2002) took place. For our stairlift study, it was possible to run in-situ contextual pre-install interviews in person (as well as the rest of that study's interviews), however, for the second and third studies, due to the COVID-19 pandemic, virtual interviews all took place. Holding entirely virtual interviews limited the contextual nature of our interviews. For example, some participants preferred video-based conversations where it was possible to pick up on visual contextual cues in their homes, whilst others preferred entirely audio-based conversations over the telephone, where it was necessary to listen carefully to what was being said and largely imagine what their homes were like whilst the interviews were taking place.

As discussed in 7.1.3, it would be beneficial to expand the three-interview methodology used for this thesis, if further studies into aging in place together were conducted. The benefits of this are many, including gaining a greater understanding of people's emotions and life experiences (before receiving any smart home technology) and also to gain greater location-specific contextual awareness about their homes that could help to direct interviews.

7.3.2 Recruitment

A further limitation of this thesis' studies is the recruitment approach taken. Whilst qualitative accounts are presented here, it was decided not to quantify (or indeed to present quantitative descriptions of) participants' experiences with the differing fidelities of smart home technology that have been explored. All of the older adults that took part in these studies (from young-old (50-65) and older-old (65+)) were able to articulate complex accounts of their shared experiences of the technology with others in their homes. Participants also had an appreciation of how their contributing to research could have a net benefit for local or national care services, through their experiences being documented and some even altruistically offered to volunteer for future research on aging in the home. All of the participants were open and frank about their health conditions. Nevertheless, future research with older adults in the home could further widen inclusion criteria to look at, for example, more younger or vulnerable adults, who are transitioning into older age. It would also be beneficial for future HCI and CSCW researchers on the smart home to diversify participant samples of those engaged with research where possible. This can be challenging depending on the social makeup of the location where research is being conducted, as access to diverse communities without, for example, community liaisons or pre-established outreach networks can make recruitment for e.g. ethnic minority or LGBT+ communities, difficult. Nevertheless, the benefits and challenges of recruiting diverse participants, have been well documented in e.g. Retrum et al.'s work (Retrum et al. 2016). The priority for establishing community contacts should therefore be given greater weight within HCI and CSCW researchers' time and ethics processes, to ensure that when the recruitment process occurs, it is possible to extend this research participation to any interested minority communities.

7.3.3 Societal and local authority impact

The work within this thesis has been closely entangled with the aims of local authorities who provide technology-enabled care and as such has dealt with the societal impact on service provision for different technologies. It has been greatly beneficial to engage with local authorities for technology deployments throughout these case studies. For the stairlift study in particular, which had a range of local authority stakeholders and technology providers as part of the interview study, it was possible to see how the outcomes of this work could impact service provision positively. The change for example, from the stairlift installers' and OTs' 'simple' journey to the more complex one presented through Chapter Four has been seen by and evaluated by the OT team within the local authority, who will perform future stairlift assessments. For the Echo Show study, the local authority provided recommendations for contacts within the area to reach out to during the pandemic and who the devices could be offered to, to benefit most. For the SHHS study, the local authority put the author and study researchers in touch with the

SHHS company initially to establish dialogue and discuss the parameters within which research findings could be shared with them upon completion of the study, to improve their own products. It is realistic to say therefore that this work has contributed direct benefits (bordering on action research (Hayes 2014)) to both individuals' lives (e.g. H-J in study 2) and organisations' work in helping others to age in place together.

Well documented in this thesis are also the negative consequences of this research too, in particular for study 3 and the additional work that introducing the SHHS added to households. As Waycott et al. (2015), Taylor et al. (2021) both point out, doing technology research in sensitive settings, especially with vulnerable people present is precarious and the need for sensitivity and empathy is paramount. The impact that doing research on older adults within society has on both the researcher and participant should not be understated too and targeted training e.g. through discussions of vicarious research trauma with supervisors or other trained professionals (e.g. counsellors) should be advocated. Likewise, offering follow-up support to participants who have engaged in qualitative research and who are also discussing and bringing up through conversation topics that are potentially difficult to talk about, should be supported too once the research has concluded. Such support typically goes beyond the scope of institutional ethics processes and should therefore be encouraged in HCI and CSCW research in the future.

7.3.4 Thanatosensitive concerns

It is important to discuss thanatosensitivity (the process of dying) within the context of this thesis and aging research more generally. During the course of conducting research for this thesis, two people who had participated in the research sadly passed away. This thesis has not dealt with death as a topic of academic enquiry, although acknowledging dying as coming at the end of old age is equally important to state here. Whilst these studies of technology that are intended to support aging in place together deal with a later life stage, it is of interest to consider what happens to devices once someone has passed too.

It was discussed within chapter 4 that the stairlift is a reminder of frailty for older people and for those living together where a loved one passes away, the technology can be a reminder of both the person and of their own mortality (Harleman 2003). For consumer smart home devices too, there are considerations for loved ones of the deceased after death such as what is the process of digital inheritance, how will attitudes and behaviours in the home need to change both with the device (e.g. a voice assistant) and interpersonally when a loved one is gone (Massimi & Charise 2009). Ferguson et al. (2014), Massimi & Charise (2009) discuss the implications for sharing technology once someone has passed and recommend that comfort be both sought and provided by friends family, or social workers, around returning or disabling technology that was important to their relationship with a loved one. There is also the possibility to introduce technologies that

re-affirm life and provide emotional support and connection too, (such as digital photo frames or auditory memory books) without removing or obstructing the grieving process (Ferguson et al. 2014).

The body of literature on aging and death is beyond the scope of this thesis to evaluate, however, from this thesis' studies of technology in the smart home, it is recommended that researchers in HCI and CSCW maintain a realistic awareness that dying is a part of the process of studying aging in place together and, as discussed in the previous section, that support for researchers for their own personal trauma should be promoted and included as part of supportive research teams.

7.3.5 COVID-19 pandemic

A further limitation of this thesis' work was the COVID-19 pandemic that occurred in between the first and second studies taking place. As such, only one study (the stairlift study) was conducted in-person with the author and other researchers physically present in peoples' homes. In the Echo Show and SHHS studies, there was a need to pivot to entirely online interviews, not only to protect older and vulnerable adults from exposure to the COVID-19 virus, but also due to the shutting down of industries and transport services required to get to people's residences.

Whilst the pivot to online research for the second and third studies proved a challenge at first (the Echo Show study was conducted 1 month after the onset of the COVID-19 pandemic, in April 2020), there have also been benefits to conducting online-only interviews, such as reduced travel time and environmental cost of travelling to participants' homes. Nevertheless, these benefits have made other aspects such as contextual enquiry within the interviewing process more difficult, when participants have only been interacting with researchers via audio and it has not been possible to see their homes. In these cases, the researchers have probed for in-depth descriptions of people's homes, and where they have been comfortable or willing to describe them, this has helped to aid understanding of what their homes look like instead.

Should these studies have been run again, or for future research in the smart home domain within HCI and CSCW, it is prefereable that reseaearchers are able to perform at least one (ideally pre-installation) contextual visit to participants homes, in order to understand the space in which the participants live inside their homes, the location of the house and the social context of the neighbourhood environment within which they live and the introduction of smart home technologies.

7.3.6 Transferrability of findings

This thesis demonstrates how different fidelities of smart home technology affect the ability of older adults to age in place successfully together. Whilst it is unrealistic to say that this thesis will solve the aging population crisis through its findings of home health technologies; it is possible to say that these findings contribute to the body of knowledge on aging as supported by technology which will be needed to tackle the aging population crisis. These studies are also relevant to specific research domains (e.g. on aging and home modifications (Callejas & López-Cózar 2009, Amiribesheli & Bouchachia 2018)), aging and voice assistants (e.g. (Beneteau et al. 2019, Abdolrahmani et al. 2018)) and aging and smart home sensor systems (e.g. (Soro et al. 2017, Aceros et al. 2015)). This thesis therefore contributes to these research domains and acts as a step towards a better understanding of how technology can impact the aging population crisis.

Our studies contribute to research across different domains beyond aging. The emotional journey stemming from research on the stairlift could be extended for example by assessing those at risk of needing mobility assistance earlier in the diagnostic cycle, to understand how this might affect the trajectory of the emotional journey later on, if households are made aware of needing a stairlift considerably earlier. Interrelated to this is the role of quaternary residents whose involvement could also be explored at an earlier stage, to understand e.g. when their involvement within the fabric of the home becomes transcends being solely medical, to being social. This would help to understand to what extent they are embedded into the fabric of each home from this earlier stage too. The findings from the Echo Show study suggest directly transferrable findings for promoting: i) actions for enhancing interpersonal social connection when physical, person-to-person interaction is not possible and ii) co-designing functionalities of devices, for supporting sharing with clinicians and formal carers via audiovisual contact on the device's screen. Lastly, transferrable strategies from the SHHS study could involve i) providing appropriately supported learning materials that support SHHS system experts to support the installation and setup process, and reduce labour and critical incidents leading to abandonment and ii) reducing the emotional impact on caregivers and household members of having to do laborious work to remember and use the system in a way that seamlessly integrates with residents' daily lives. These go beyond supporting older adults, but rather a range of people who might benefit from the health and care technology in their homes and households.

These recommendations are not exhaustive, but demonstrate some ways in which this thesis' work could be transferrable to the aforementioned domains and work that has been done there previously.

CHAPTER 8

General Reflections and Conclusion

8.1 General reflections

This section aims to provide a reflexive account (as per Rode (2011)) of decisions made and thoughts taken during this thesis.

The author endeavoured to conduct an investigation through this thesis into how people age in place together, in response to the global aging population crisis. The scope and international breadth of this challenge was set out in the introductory chapter. The literature review chapter focussed this challenge on how smart home technology can support people who are aging in place, but who live with others, or have some social connections. The impact of smart home technology on the lives of older adults is well discussed within the HCI and CSCW literature, however, meeting, talking to and working with older adults in their homes provided a humanistic perspective and showed how important their social ties and the makeup of their homes is, and also what they value most as they age. Some of these were tangible things such as the physical security of their dwelling, or having medication delivered regularly, while other things were more ephemeral, such as recounting treasured memories with other residents or seeing the value in sharing their life experience with grandchildren and younger people. The continuity of these physical and ephemeral experiences was apparent throughout, whilst engaging with the diversity of participants that were interviewed. Observing these lives and learning from, sharing a laugh with or empathising with an experience from these people has been vital to the contribution of this PhD thesis.

Being open and honest about the life experiences of the researcher, was important in creating and strengthening these connections with participants. Being present during interviews and

engaged with the conversations and topics discussed has also been vital to sustaining these relationships with participants. As I was in my twenties at the time of writing this thesis, it has been incredibly humbling and insightful to learn about the process of aging and the positive and negative aspects of that from older adults. Many, such as H-D in the stairlift study, were quick-witted and humorous about their loves and hates, failures and successes with the technology and were quick to tell the researchers what it reminded them of. Others such as H-C in the stairlift study, H-I in the Echo Show study and H-A in the SHHS study, were frank about when they were struggling. Many of these participants were not wealthy and struggled everyday with debilitating and deteriorating (e.g. S1, H-B) chronic health conditions. As a researcher, being exposed to people from these diverse walks of life is equally eye opening as it is humbling, and it was important to acknowledge this in conversations, and not to shy away from talking about difficult topics, which became easier as more people were engaged with through this thesis.

Nearly all of the participants involved in this thesis were involved because they described a feeling or need to contribute to improving the lives of those younger than them and that by using this technology or participating in this research, they felt that they would contribute in some way, towards improving the quality of life of future generations (this was well beyond being financially reimbursed for their time). They recognised that while the technology may not be directly beneficial to them (although in some cases it was), that there was greater opportunity for their involvement through using the technology to benefit future generations. The author hopes that further research on shared aging in the smart home continues to engage those who are seeking to improve the lives of existing and future generations of older adults within society.

8.2 General conclusion

New and upcoming developments in smart home technology such as sensor systems that monitor movements, fall detection and vital signs such as BP and heart rate, all provide robust means to monitor and support older adults whilst they age in place. However, these need to be designed with the complex, socio-technical context of the household in mind. Aging in place together is the shared experience of conducting a life with diverse activities at home, with the use of technology and in the presence and support of other close social contacts. Research has established how quality of life can be assessed through indicators such as Quality Adjusted Life Years (QALYs) and other quality of life measurements, yet this does not capture the nuanced experiences of aging in place together that this thesis has sought to do. N

This thesis applied qualitative interviews, deployments and contextual enquiry both in-person and online, adopting an ethnographic approach to understand how different types of smart home technology could support the shared wellbeing of older adults. Following three interview studies of the deployment of a stairlift in five households, an Amazon Echo Show voice assistant in ten

households and a smart home health sensors system in five households, this thesis identified the importance of people's emotional journeys around the adoption of these technologies, the shared social intersubjectivity of the multi-resident support network around an older person and the labours of learning and about and setting up new and previously unknown devices for older adults' households. These findings show the importance of understanding non-traditional means of engaging with technology, the role of emotion in the adoption and acceptance process, and the benefits to households of altruistic informal carers and paid experts as part of complex sociotechnical care networks around an individual older adult. This thesis' work builds directly on literature that addresses the older adult at the centre of the care network as they age and promotes the importance of considering the wider complex interplay of social actors around an individual older adult, to effectively help them age in place with technological support and reduce the need for unexpected or unnecessary and costly health interventions from within society. It is hoped that this work will ultimately help older adults as they age in place together to have longevity and prolonged quality of life through engagement with and improvement upon these technologies by HCI and CSCW researchers and designers.

Future exploration of this research area should see continued engagement with the multi-resident care network and expansion of this as applicable to other roles within society. Work could also draw on the complex nature of aging across different populations and regions to evaluate regional applications and discrepancies across countries to understand aging in place together insightfully as a global phenomenon.

APPENDIX

APPENDIX A - EMPIRICAL STUDY ETHICAL APPROVALS

A.1 Stairlift study: ethics application approval

Faculty of Engineering Research Ethics Committee (FREC)
Queens Building
University Walk
Bristol BS8 1TR
Telephone: (0117) 331 5830

19th February 2019

Mr Ewan Soubutts
Dr Aisling O'Kane
Department of Computer Science
Merchant Venturers Building
Clifton
Bristol
BS8 1UB

Dear Ewan,

Ref: 80462
Title: Acceptability of smart homes for health and care

Thank you for responding to the issues raised by the Faculty of Engineering Research Ethics Committee (FREC) as stated in our letter dated 19.02.19. Your response to the issues raised by the FREC has been reviewed by the chair of the committee who has agreed to grant a favourable ethical opinion for the above-named study.

The committee recognises that you have been diligent in anticipating and responding to ethical issues in your preparation for the research. Please note that the FREC expects to be notified of any changes or deviations in the study.

Good luck with your research.

Liam McKervey
Research Governance and Ethics Officer

pp
Dr Conor Houghton,
Engineering Faculty Research Ethics Officer (FREO)

A.2 Voice assistant study: ethics application approval

Faculty of Engineering Research Ethics Committee (FREC)
Queens Building
University Walk
Bristol BS8 1TR
Telephone: (0117) 331 5830

Mr Ewan Soubutts
Dr Aisling O'Kane
Department of Computer Science
Merchant Venturers Building
Woodland Road
Bristol
BS8 1UB

4th March 2021

Dear Mr Soubutts,

Ref: 102503
Title: Exploring the use and acceptance of Amazon Echo Show for health, care and wellbeing needs for residents and carers

Thank you for submitting your amendment request for review by the Chair of the Faculty of Engineering Research Ethics Committee (FREC) as detailed in your amendment notification provided on 03.03.21. The chair of the FREC has reviewed your amendment request and I am pleased to confirm has granted a favourable ethical opinion for the changes outlined in your amendment request to be implemented.

The committee recognises that you have been diligent in anticipating and responding to ethical issues in your preparation for the research. Please note that the FREC expects to be notified of any further changes or deviations in the study.

Good luck with the continuation of your study.

Yours faithfully,

Megan Wood-Smith
Research Ethics Assistant

pp
Dr. Conor Houghton
Chair- Faculty of Engineering Research Ethics Officer

A.3 Smart home sensor system study: ethics application approval

Faculty of Engineering Research Ethics Committee (FREC)
Queens Building
University Walk
Bristol BS8 1TR
Telephone: (0117) 331 5830

16th February 2021

Mr Ewan Soubutts
Dr Aisling O'Kane
Department of Computer Science
Merchant Venturers Building
Woodland Road
Bristol
BS8 1UB

Dear Mr Soubutts and Dr O'Kane

Ref: 114104
Title: Investigating the acceptance of a bespoke smart home system for residents and care providers

Thank you for responding to the issues raised by the Faculty of Engineering Research Ethics Committee (FREC) as stated in our letter dated 27.01.2020. Your response to the issues raised by the FREC has been reviewed and the above-named study has received a favourable ethical opinion.

Please note that the FREC expects to be notified of any changes or deviations in the study.

Good luck with your research

Yours Sincerely
Nathan Street
Research Governance Administrator

pp
Dr Conor Houghton,
Engineering Faculty Research Ethics Officer (FREO)

APPENDIX B

APPENDIX B - EMPIRICAL STUDY TOPIC GUIDES

B.1 Stairlift study: interview topic guides

B.1.1 Occupational therapists topic guide

1. What factors do you consider when prescribing a specific technology to a patient, to use?

2. How do you consider alternatives for different home healthcare technologies?

3. How do you engage with handypersons and suppliers of different types of technology?

4. What is the process of consultation between yourself and a patient to decide on what technology should be used in the home?

5. What is the consultation process between yourself and the patient/carers for how the technology should be installed in the home?

6. Do you/How do you involve families in conversations regarding a patient's health?

7. How do you involve families in the decision making process regarding their home healthcare technologies?

8. What types of assessment do you carry out to determine whether a patient requires a specific home modification?

9. Are there any concerns/What steps do you take to address patients' concerns regarding their home modifications?

10. What steps do you take to address patients' family's concerns regarding the home modifications?

11. How do you engage with the use of new and emerging technologies for patients?

12. Are there any technologies you are currently exploring to assist patients' healthcare in their homes?

13. How are they taught and trained about new technologies?

B.1.2 Stairlift installers topic guide

1. How did you consult with the resident regarding what technology should be installed in the home?

2. How did you consult with the resident about how the technology should be installed in their home?

3. Do you find people are receptive to having home modifications installed in their homes?

4. What do you feel is most challenging about installing home modifications in people's homes?

5. How do you work with suppliers to coordinate the procurement and delivery of this home technology?

6. How do you find working with residents in their homes?

7. How do you find working with the service provider?

8. Can you describe the process of procuring the technology, arranging to install it, meeting the residents and installing it?

9. What types of challenges do you typically face going into people's homes?

10. What types of properties do you typically work within?

11. Which types of properties (if any) produce the most work for your job?

12. How do you feel more advanced home systems would impact your work?

B.1.3 Stairlift assessment centre workers topic guide

Question Set 1 - Day to Day Role

1. Thank you again for taking the time to talk to us today. To kick off, can you briefly describe for us, what you do in your job(s)? 2. What is the most memorable conversation you've had with a customer during an assessment? Probe: Was this around stair lifts? - Why is this? - What happened? 3. You told us that your most memorable conversation involved [describe response to above question]. Can you think of any other questions customers ask? Probe: Is this about stair lifts in particular? 4. We would like to learn more about the conversations you have with customers: - What does a conversation about getting a stair lift involve? Probe: Their hopes and fears about getting the stair lift installed. - Do you talk to them about installations? What do you discuss? 5. How do you handle customers' questions about the stair lift installation? Probe: Most commonly, is this over the phone, via email, in person etc.? - Have you ever had to deal with stair lift removals? Probe: What things can motivate someone to want to get a stair lift removed? - Do you handle queries about maintenance? - if yes: How do you deal with these queries?

Question Set 2 - Working with others 6. As you know, for this project, we are working with Bristol City Council's OT team. We have also interviewed a representative from Stannah about the installation process. Can you talk to us a bit about how you work with external partners like Bristol City Council and Home Installer companies, to facilitate stair lift installations? - Who do you work with most frequently? Ask which teams. - Are there any challenges you've come across with the process of working with these teams? 7. We spoke with Bristol City Council previously

about measurement sheets. Do you use these in your roles? - Are these important? Why? 8. Are there any other tools that you use in your roles to help with the assessment process? - Could you tell me more about your experiences of using those tools? - Did you experience any issues with the tools you mentioned?

Question set 3 - Assessments 9. From our previous discussions, you mentioned that the assessment process can be quite extensive and nuanced depending on the route that a person takes to having a stair lift assessment. Thinking again about the assessment process from the beginning... How do you start the discussion with a customer about having an assessment? Via email, in person, how do you get in contact? 10. Where do the assessments normally take place? Probe: In the assessment centre, in people's homes? - Who, from the centre is involved in doing an assessment. 11. Outside of the assessment centre team, is anyone else present when someone is having an assessment? - Who does the person having the assessment bring with them? - What preparations do people have to make for an assessment? - Are there any memorable conversations you've had as a result of doing assessments? - Have you ever had medical professionals attend a stair lift assessment other than OTs? 12. You mentioned previously during our recent email discussion about how acceptance of help in the home can vary throughout the year. Can you tell us any more about this? - Probe: The seasonal changes mentioned during that email conversation. - Is there anything else that you've noticed that affects uptake of technology or support throughout the year? 13. Are there any barriers that you've noticed around the use of stair lifts or of people in having assessments?

B.1.4 Stairlift households pre-install topic guide

So as you've just shown us where the stair lift will go, let's talk a bit more about your home.

1. Firstly, how long have you lived in your current home? [If they've lived here a long time, don't ask about their previous homes.]

2. Who else lives in your home? - Has this changed at all whilst you've been living here? - Has anyone left or joined your home whilst you've been living here?

3. What do all the different people coming into your home do on a daily basis? - Do they help you out at all? Probe: How? - What do they add to your home?

4. How often do you normally do things with the other people in your home? [e.g. once a day/once a week? I know I try and do something with my housemates at least once a week.] - If yes: What activities do you do? Board games, going outside?

5. What technology do you share with other people in your home? - So for example, does anyone else use your tv/kettle/radio?

6. How do you, as a household decide what technology you'd like to use?

7. Have you ever gone out of your way to get a piece of technology for someone else who lives here?

—

Lifestyle

3. What's your favourite part of your home? - So mine's the living room for example - it's just the best place to get people together. - What is your spouse/child/other resident's favourite part of the home?

4. Can you tell me about a typical day in your home? - I'm always the one that's doing the cleaning in my home. - For instance, what did you get up to yesterday [earlier time if they can't remember]? - Was this a normal day for you?

5. What's a typical day for the other people [spouse/child/other resident in your home? - My housemates are always inside whilst I'm out! - What do they normally get up to? - Do you join in with them?

6. Who else can come into your home? - Family, friends, neighbours? - Anyone outside of this?

7. What things would you change if people come into your home? I know what it's like for me - It's always a race to tidy up after my housemates! - Do you organise things differently, for example if one of your neighbours came over, instead of say, one of your children?

—

Technology and Mobility

1. Let's talk more about the technology that you use in your home at the moment. - I see you have a TV/fridge/iPhone/etc.! I'm a computer science student, so I'm interested in all different kinds of technology. Can you tell me about what technology you use in your home on a daily basis? - For example; do you have a landline/mobile phone that you use?

2. Why was it important to you to get an iPhone/Alexa/smart device?

3. Tell me about how you get around. You're expecting to get a stair lift. How do you get around (inside and outside your home) at the moment? Do you use any technology to help you get around? Probe: outside activities.

3. Can you tell us how you manage to get upstairs and downstairs at the moment? Probe: Do you use any technology to help you with this?

That's great. Thank you. It's really useful to know how you use the technology in your home.

—

Ease of use/understandability

So let's talk about how much you use and think you will use technology in your home.

1. How easy do you find it to use your TV/fridge/kettle say? - I know that a lot of my kitchen appliances are quite fiddly! - Did it make sense when you first used these things?

3. Do you find it easy to say, change the batteries in your TV remote? - How do you update your home PC? Who would do this in your home? - Is this the same person who you would normally go to for technical problems?

2. Bearing this in mind, how often do you think you'll use your stair lift? - Do you think you'll use it as much as say, your telephone/fridge/TV?

—

Customisation and Trust

That's very helpful. Thank you for all your answers so far. For these next questions, we'd like you to do a bit of creative thinking for us!

1. So bearing in mind you're soon going to be getting a stair lift put into your home. Do you think it will suit your home? - Are you happy with the way you've been told it will look or feel? - Did you have much choice on deciding on its look/feel? - If money wasn't an option, would you change anything about the look/feel of the stair lift? - Is there anything you'd add/take away from it?

2. How do you think you'll feel about other people using your stair lift? - Would you be happy for them to use it as well as you? - Would you change anything about it, if someone else wanted to use it? [If they say yes to the previous question.]

3. Do you think the stair lift will do everything that it has been promised to do? - How do you think the stair lift will impact your life? - How do you think the stair lift will impact the life of [spouse/child/other]?

4. Do you have any worries about using the stair lift when it arrives? - Do you have any worries about the stair lift for anyone else in your home?

5. Let's imagine we're a year in the future. What do you think will be different about your home than it is now?

B.1.5 Stairlift households post-install topic guide

1. How long have you had the stair lift now? - Who went on it first? - What were your first impressions of it? - How do you feel about using it? - Have you timed how long the ride is? - How do you pass the time while you're going up? - How comfortable are you using it so far? - How do you feel when you are on it? - Has anyone else had a go on it? - What do they think? - Have you talked to other people about it outside of the home? - How has it changed your typical day in the house? - How has it changed the day of anyone else in the house? - Is there anything that surprised you about it? - Have you had any issues with it so far other than getting up and down stairs?

2. How was the installation? - How many people came to install it? - How long did it take? - Did you take part in helping to install it or did you just observe? - Did you do anything to prepare for it? - How did it go on the day with the installation team? - How did you know how to use it? - Does it remind you of any other technology?

3. Can you talk me through what the first time using it was like? - Was anyone else there? - Did you get any training from the installers on how to use it? - How about any manuals or paper booklets to tell you how to use it? - How do you feel about the controls? - Do you have a good understanding of how to use them? - How are they to use compared to say, your TV remote? - Do you have to concentrate much on using the stair lift? - Are you thinking about anything else while you're riding it? - Has anyone else in your household learned how to use it?

4. The stair lift must still pretty new and exciting for you. How do you feel about the future with the stair lift? - Do you think it will continue to be good/awful/other?

5. We talked before about your feelings about 'not giving in' around getting the stair lift. Do you still feel like you have that attitude towards the stair lift now? - What would you say got you over that line? Probe: person or value - How valuable would you say the stair lift is to you now? Probe: why? - How do you think you would feel if the stair lift hadn't gone ahead? - Does anyone from your household still follow you up the stairs for support? - Has the stair lift changed your house? - You mentioned before you don't follow a particular colour scheme, but does the stair lift aesthetically suit your home? - Would you change anything about its appearance if you could now?

6. What does everyone else think about it? - Is that just people inside your home? - Have any guests or visitors commented on it? - What do your extended family think? I remember last time, you said you've got a lot of people coming in and out. - Is it being used for anything other than getting you up and down stairs?

7. How do you think it's going to fit into your home after a few months or years?

B.1.6 Stairlift households 3-Month Topic Guide

Technology Use Evaluation

1. How long have you had the stair lift now? - How does the stair lift make you feel now? Probe: safety. - How frequently are you using the stair lift? Is this more or less the same as our last visit? - What are your thoughts of it, now that you've had it for 3 months?

2. You've now had a stair lift installed for 3 months. That's quite a while! Tell us about how the stair lift is affecting how you get around on a daily basis. - Has the stair lift affected how you move around inside your home? - Has the stair lift affected how other people you know move around inside your home? - Is there any technology that was here when we visited before, that you've gotten rid of? - Tell us what you think about the look and feel of the stair lift in your home after 3 months? - Have you done any maintenance on the stair lift yet?

3. Last time we talked about how you use other technology/devices in your home. - Do you have any new technology in the home, since our last visit? - How much are you using the stair lift compared to other devices? (e.g. mobility scooter, phone?) Why do you think this is? - What are your thoughts of getting new technology like the stair lift in the future, now that the stair lift has been installed? - Has the stair lift changed the way you think about technology? Probe: How so?

Lifestyle, Motivations and Wider Household

So let's talk again about your home more generally again and bit more about the people in your home.

6. Do you think the stair lift is doing everything that it has been promised to do for you? - How do you think the stair lift is impacting your life at the moment? - How do you think the stair lift is impacting the life of other people in your household?

7. Let's talk about your life with the stair lift. - Last time, we chatted about how you had to remove a bannister when the stair lift was put in. Have you had to make any other changes to your home to accommodate the stair lift since we spoke last? Probe: Are you planning to make any changes? - Thinking about your typical day. Would you say that the stair lift still affects this? - Probe: What part of your day does the stair lift affect the most? - Have you tried anyone else's stair lift since the last time we spoke?

8. Thinking about the people you know - so family, friends.. - Has anyone else used the stair lift that hadn't used it before, since the last time we visited? Probe: who are they? - You mentioned before how your daughter had come round to visit more frequently to support you. Now that you've had the stair lift for 3 months, how do you think that having it had impacted how much support you are receiving from your extended family? - How do you feel about other people using the stair lift? Do you stay with them while they use it? - How do other people use the stairs when they visit you? Probe: grand-son. - Have they commented on what they think of the stair lift? Probe: Play. What kind of object do they see it as in your home? - Have you talked to anyone else outside your home about the stair lift, since our last visit? Probe: mother /granddaughter/medical professionals? - Has anyone you know commented on the costs associated with a stair lift?

8. Let's talk about when you're outside the house. - Talk us through how you would prepare for going outside now? Probe: Has this changed since you've had the stair lift? - What do you always take with you? - Who goes with you? Probe: Is it always the same person/people? - How do you plan for the future? Probe: ... For future activities inside/outside of the home?

9. Thinking back to before you had the stair lift installed again. - Why did you choose a local stair lift company over a national one? - What gave you the trust in the company you chose? - Tell us about how you learned to use the stair lift. Who taught you? - Talk us through how they taught you to use the lift? Probe: Was it all communicated verbally? Did they make you do anything?

Future

That's very helpful. Thank you for all your answers so far. For these next questions, we'd like you to do a bit of creative thinking for us, like before!

10. Let's imagine we're a year in the future. What do you think will be different about your home in the future? Is there anything you're planning to change?

B.1.7 Voice assistant households pre-install topic guide

Home and Multi-resident environment So these first questions are just to get an idea about your home and life at home.

21. Who lives in your home? - Has this changed at all whilst you've been living here? - Has anyone left or joined your home whilst you've been living here?

20. Firstly, how long have you lived in your current home? [If they've lived here a long time, don't ask about their previous homes.]

22. Does anyone else regularly come into your home from outside? - What do they do? - Are these family, friends, neighbours? - Is there anyone outside of these groups who comes in or comes to visit?

23. Do you change anything if people come into your home? So for me, I like to have a quick tidy round in my home. - Would you organise things differently, for example if one of your neighbours came over, instead of say, one of your children?

24. How often do you do things with other people in your home? [So for example, I regularly have board game nights with my housemates.] - Do these activities ever involve using technology?

Lifestyle and Routine

28. What's your favourite part of your home? - What is your spouse/child/other resident's favourite part of the home? - Do guests or visitors comment that they have a favourite part of your home?

29. Can you tell me about a typical day in your home? - What did you get up to yesterday [earlier time if they can't remember]? - Was this a normal day for you?

31. How do you get around outside of your home? - Do you use any technology to help you get around? [e.g. a car?] - How do you find using this?

26. How would you, as a household, decide if you wanted to get a new piece of technology? - Do you have to make this decision together?

25. Do you share any technology in your home? [We have a shared communal TV in our flat that we all watch, a games console, that sort of thing.]

27. Have you ever gone out of your way to get a piece of technology for someone in your home, say, in an emergency?

Health and Care Let's talk a little bit about the technology you use and your health and wellbeing in your home.

28. Do you currently use any technology to help manage your health? - Have you ever used any?

29. Would you consider using the Echo Show to manage your health? - Why/why not?

30. Would you use the Echo Show to discuss your health with anyone else? - Who would this be? - Would you involve a doctor/clinician/carer in this?

31. What conversations about your health (if any) would you be happy to discuss on this device?

32. How would you feel if a family member offered to support you through this device? - How would you feel about a carer supporting you through the device?

Technology Let's talk more generally about the technology you use in your home.

5. Let's talk some more about technology you use. We've already discussed this a bit earlier on. Apart from your [previously mentioned piece of technology], what other tech do you own? - How often do you use this? - Does anyone else use it with you?

6. What technology do you use with other people, inside or outside of your home?

8. Has it ever been important or urgent for you to get a piece of technology?

9. Have you ever had any apprehensions or concerns about getting new technology?

10. How easy do you find it to use TV, fridge, or kettle at the moment? - Did these things make sense to you when you first used them? - Do you use these appliances quite often?

11. Can you tell me what you know about the Echo Show device currently?

Echo Show/Expectations Let's talk a bit more about the Echo Show device you'll be getting.

11. With this in mind, Do you think the Echo Show will be easy to use for you, compared to say, your TV remote? - How often do you think you will use the Echo Show? - Would this be more or less than the other technology you own?

Customisation

12. Have you ever decorated any technology you own? [e.g. put something colourful on top of the fridge or the TV] - How did people in your home feel about this?

13. Do you think the Echo Show will aesthetically suit your home? [e.g. match the colour scheme?] - Do you have any expectations of what it will look like? - Do you think you will change its look or feel? [e.g. decorate it?]

Ownership

14. Will anyone else in your home be able to use it apart from you? - Will they be able to decorate it?

15. Where will you put the device when you get it? - Why do you want to put it there? - Would anyone else have access to it in this location?

TIPS

16. Do you have any other concerns about the device based on what you know about it? - Do you think this will change over time?

17. Do you have any expectations about the Echo Show?

18. Do you feel comfortable setting up the device yourself? - How do you feel about using an Amazon account?

19. How do you feel about storing data on the device? - How do you feel about other people storing data on there?

Closing

33. Let's imagine it's a year in the future. How do you think your home will be different than it is now?

B.1.8 Voice assistant households post-install topic guide

First Impressions

1. How long have you had your Echo Show for now? 2. What were your first impressions of it? 3. Does the device fit into your home? 4. Who used it first? 5. What are your feelings about using the device? 6. How confident do you feel using it? Probe: Ease/difficulty of use 7. Has the device

had any impact on your daily routine(s)? 8. Have you had any issues with the device so far? 9. Does the Echo Show remind you of any other technology you use? e.g. mobile phone.

Out of Box Experience

9. Did you do anything to prepare for getting the Echo Show? 10. Can you talk me through your first time using the Echo Show? 11. How did you find the setup of the device? 12. How long did it take you to set up the device? 13. Did anyone else help you set the device up? Probe: What do they think of it? 14. How did you know how to use the device? Probe: Did you use any resources e.g. online videos/books to help you? 15. How do you feel about using the device going forward?

Learning and Skills

16. Does the Echo Show interest you? Probe: Does it keep your attention? For how long? 17. Do you feel you understand how to use the device? Probe: How well? Fully understand/don't understand it? 18. Have you looked into getting the device to do things for you? Probe: - If Yes, what have you asked the device to do for you so far? - Have you found this easy or difficult? - Has anyone else in your household used the device for doing these types of tasks? 19. Does the device respond to you in the way you would expect? 20. Is there anything you would feel uncomfortable asking the device to do? Probe: Why? 21. Is the device doing everything it was promised to do for you?

Health and Wellbeing

22. Are you using the Echo Show to support your own health or care? 23. Would you ever consider using the Echo Show to help look after yourself? e.g. I use the voice assistant on my phone to help me track my calories and distance when running 23. Do you think this device is useful for someone who is self-isolating or shielding due to COVID-19? 23. Do you use any other devices apart from the Echo Show to support your health? 24. How would you feel about the device monitoring, for example, how much water you drink? Probe: Is this something you would ever consider letting the device track for you? 25. How do you currently schedule health-related appointments? e.g. doctor's appointments? Probe: Would you consider using the Echo Show to schedule these for you?

Cognitive Dissonance

26. Did you have any anxiety about getting the Echo Show? 27. Did you discuss getting the Echo Show with anyone else? Probe: Who were they? Do they live in your home? What did you discuss? 28. Can you talk us through your decision-making process about taking part in the study and getting the device? 29. Did you feel pressured at any time into getting the device? 30. Now that you have the device, do you think you will use it much? 31. Do you think you will still be using the device a year from now? 32. Is anything different about you or your home now that you have the device?

B.1.9 Voice assistant households 3-month topic guide

3-Month Use Let's start by talking a bit in general about your use of the Echo Show device after 3 months using it.

1. How are you getting on with the device now that you've had it for nearly 3 months? Probe: Have you used it for this whole period? - How frequently would you say you're using it? 2. Can you describe your current feelings towards the Echo Show? - How would you compare your feelings now with your first few days using it?

3. Have you downloaded or used the Alexa app on a smartphone? - [IF RELEVANT] What were your thoughts of the app? - [IF RELEVANT] Can you describe how you found the layout of the app? - [IF RELEVANT] How did you find accessing information about Alexa on the app?

4. Have you tried or downloaded any skills from the Amazon skills store online? - [IF RELEVANT] Did you know about the Amazon skills store? - [IF RELEVANT] Why did you select these? - [IF RELEVANT] How did you find them? - Have you used any skills that weren't suggested to you?

5. Have you used any other add-ons for Alexa at all? e.g. smart lightbulbs, blinds? - [IF NOT USED] Would you ever consider using these? - What type of add-on to Alexa, do you think would most suit your home lifestyle?

Integration into the Home/Multi-Resident Let's talk more about the Echo Show device itself again within the context of you and the other people in your home.

8. Has the use of the device been as you expected it? 9. Do you think the device fits into your home now? 10. Has anyone else used the device since we last spoke? - Have other members of the household commented on how they understand the device? - Are they a member of the household? - What did they use it for? 11. Can you describe for me, how you have used the device as a household? - [IF RELEVANT] How has the device impacted your life/lives? 12. Are you using the device for anything now, that you weren't before? 13. What types of activities are you typically using the device for now? 14. In your conversations with the device, how do you feel about talking to Alexa now? 15. How would you compare the Echo Show with using Careline now? 16. Is there a feature of the Echo Show that is most useful to you, as a household?

[ONLY IF NOT ALREADY DISCUSSED] Technical Questions

15. How well do you feel you know how the device works? 16. Does the device work as you expected? 17. Is the device doing everything it was promised to do for you? 18. How much would you say you're using the device now compared to the other devices you own e.g. phone, laptop etc.?

Health and Wellbeing Let's talk a bit more about the device in relation to your health and other people's health in your home. Now that you have been using the device for 3 months:

19. Thinking about your physical health. - Would you still consider using Alexa to support your physical health? - You mentioned it's important to you to be physically active. Do you think the device is supporting you in being more physically active? - Are there any new physical

activities you're doing now that you didn't do before you had the device? 20. And thinking about your mental wellbeing. - Would you still consider using Alexa to support your mental wellbeing? - You've mentioned previously that you do daily activities to keep yourself mentally fit. Has you used Alexa to support these mental activities in any way? - Are there any new mental exercises you're doing now that you didn't do before you had the device? 21. Let's talk about feeling connected to people you know. Who do you feel most connected to at the moment e.g. family/friends/neighbours? - Why? - How connected do you feel to the people around you? - Has this changed due to using the device? - Has the device supported you staying connected with others? 22. How would you feel about using Alexa to stay in touch with your doctor now? - How would you feel about using it in place of going to the doctors? 23. Has your opinion on sharing personal or health information on the device changed? - Have you used Alexa to stay in contact with any clinicians e.g. doctors/OTs/dentists etc.? 24. Do you feel the device has supported you during COVID? Probe: lockdown. 25. How comfortable would you feel planning your own care through the device e.g. scheduling appointments? - How about planning someone else's care?

Other

26. If there were no limits on what you could do, what would you change about the device itself? (e.g. mentioned linking to TVs/linking to stair lifts) - How would you design it differently? 27. Thinking about your Careline device, is there anything that this system does, that the Echo Show does not do? - Would you want to make the things that Careline provides you, available to you through the Echo Show? - Can you talk me through how you would see this working? 28. Do you anticipate you'll do anything different with the device over the next six months? - Next year? 29. What do you anticipate will change in your home over the next six months? - Next year?

B.1.10 Sensor study pre-install topic guide

Lifestyle and Routine

6. What's your favourite part of your home? - What is your spouse/child/other resident's favourite part of the home? - Do guests or visitors comment that they have a favourite part of your home?

7. Can you tell me about a typical day in your home? - What did you get up to yesterday [earlier time if they can't remember]? - Was this a normal day for you?

8. How do you get around outside of your home? - Do you use anything to help you get around? [e.g. a car?] - How do you find using this? / Do you experience any challenges getting around?

Home and Multi-resident environment So these first questions are just to get an idea about your home and life at home.

1. Can you tell me who you live with? - Has this changed at all whilst you've been living here? - Has anyone left or joined your home whilst you've been living here?

2. How long have you lived in your current home? [If they've lived here a long time, don't ask about their previous homes.]

3. Does anyone else regularly come into your home from outside? - What do they do? - Are these family, friends, neighbours? - Is there anyone outside of these groups who comes in or comes to visit?

4. Do you change anything if people come into your home? So for me, I like to have a quick tidy round in my home. - Would you organise things differently, for example if one of your neighbours came over, instead of say, one of your children?

5. How often do you do things with other people in your home? [So for example, I regularly have board game nights with my housemates.] - Do these activities ever involve using technology?

9. Can you describe for me what devices you own? - What's your favourite? - Why is this?

10. Do you share any technology in your home? [We have a shared communal TV in our flat that we all watch, a games console, that sort of thing.]

9. How do you, as a household, decide if you want to get a new piece of technology? - How have you decided in the past e.g. buying a new TV/tablet/laptop? - Do you have to make this decision together?

11. Have you ever received a piece of technology from someone in your home, say, a family member, for you to use? e.g. a fall alarm or pendant?

Health and Care Let's talk a little bit about the technology you use, your health and wellbeing in your home and a bit about the MiiCube.

12. Do you currently use any technology to help manage your health and wellbeing? - e.g. medical or consumer health - Have you ever used any?

13. What are your thoughts on MiiCube currently? - Would you consider using MiiCube? - Why/why not?

14. Miicube has an app that allows someone you know to store health data. Would you use MiiCube to discuss your health with anyone else? - Who would this be? - Would you involve a doctor/clinician/carer or researcher in this?

15. What conversations about your health (if any) would you be happy to discuss on this device?

16. How would you feel talking to your family members and friends using MiiCube? e.g. to offer you check-up calls or support - How would you feel about talking with your carer using MiiCube?

Technology Let's talk more generally about the technology you use in your home.

17. Let's talk some more about technology you use. We've already discussed this a bit earlier on. Apart from your [previously mentioned piece of technology], what other tech do you own? - Can you tell me any more about your experience using it? - How often do you use this? - Does anyone else use it with you?

20. Have you ever had any concerns about getting new technology?

21. What is your favourite household appliance? e.g. TV, fridge, or kettle? - Can you tell me about your experience using it? - Is there any household appliance or technology in your home

that you avoid using?

23. With this in mind, do you think the MiiCube will be easy for you to use, compared to say, your TV remote?

Customisation

24. Have you ever decorated any technology you own? [e.g. put something colourful on top of the fridge or the TV] - How did people in your home feel about this?

25. Based on what you've seen, do you think the MiiCube will aesthetically [look/feel] suit your home? [e.g. match the colour scheme?] - Do you have any expectations of what it will look like? - Based on what you've seen, would you like to change its look or feel? [e.g. decorate it?] - If so, how?

Ownership

26. Will anyone else in your home be able to use the MiiCube apart from you? - How would you feel if someone in your home changed MiiCube's appearance?

27. Where will you put the MiiCube when you get it? - Why do you want to put it there? - Would anyone else have access to it in this location?

TIPS 28. Do you have any other concerns about the device based on what you know about it?

30. In order to setup MiiCube and the app you need to plug it in and connect it to the internet by following Monica (the voice assistant's) instructions on setting up the device and the sensors for it. Do you feel comfortable setting up the device yourself?

31. MiiCube stores data on the cube by collecting this information such as the amount of water you're drinking and your heart rate and keeps this safe on the device. How do you feel about MiiCube recording this type of data? - How do you feel about MiiCube recording this much data? - How do you feel about MiiCube recording data about other people who come into your home?

32. MiiCare app supports you in collecting data and documenting your health by storing your health data on the MiiCare app, which you can access and see to get an understanding of your health over time. It also allows you to track and monitor your health via the app. How do you feel about using the Miicare app to track your health and wellbeing? - How would you feel about others in your household using the app? - How do you feel about someone else in your household seeing your data?

Closing

33. Let's imagine it's a year in the future. What do you think you will be different for you then as a result of using the MiiCube in your home?

B.1.11 Sensor study post-install topic guide

First Impressions

1. How long have you had your MiiCube for now? 2. What were your first impressions of it? 3. Does the device fit into your home? 4. Who in your household used it first? 5. What are your

feelings about using the device? 6. How confident do you feel using it? Probe: Ease/difficulty of use 7. Has the device had any impact on your daily routine(s)? 8. Have you had any issues with the device so far? 9. Does the MiiCube remind you of any other technology you use? e.g. mobile phone.

Out of Box Experience

9. Did you do anything to your household prepare for getting the MiiCube? 10. Can you talk me through your first time using the MiiCube? 11. How did you find the setup of the device? 12. How long did it take you to set up the device? 13. Did anyone else help you set the device up? Probe: What do they think of it? Have they used the app yet? 15. How do you feel about using the device going forward?

Learning and Skills 14. How did you know how to use the device? Probe: Did you use any resources e.g. online videos/books to help you? 17. Do you feel you understand how to use the device? Probe: How well? Fully understand/don't understand it? 18. Have you looked into getting the device to do things for you? Probe: - If Yes, what have you asked the device to do for you so far? - Have you found this easy or difficult? - Has anyone else in your household used the device for doing these types of tasks? 19. Does the MiiCube respond to you in the way you would expect? 16. Does the MiiCube interest you? Probe: Does it keep your attention? For how long? 20. Is there anything you would feel uncomfortable asking the device to do? Probe: Why? 21. Is the MiiCube and app doing everything it was promised to do for you?

Health and Wellbeing

22. How are you using the MiiCube to support your own health or care? 23. Would you ever consider using the MiiCube to help look after yourself? e.g. I use my phone to help me track my calories and distance when running - Do you use any other devices apart from the MiiCube to support your health? - Would you suggest using the device to support someone else's health or care? 24. How would you feel about the device monitoring, for example, how much water you drink? Probe: Is this something you would ever consider letting the device track for you? 25. How do you currently schedule health-related appointments? e.g. doctor's appointments? Probe: Would you consider using the MiiCube to schedule these for you?

Cognitive Dissonance

26. Did you have any anxiety about getting the MiiCube? 27. Did you discuss getting the MiiCube with anyone else? Probe: Who were they? Do they live in your home? What did you discuss? 28. Can you talk us through your decision-making process about taking part in the study and getting the device? 29. Did you feel pressured at any time into getting the device? 30. Now that you have the device, do you think you will use it much? 31. Do you think you will still be using the device a year from now? 32. Is anything different about you or your home now that you have the device?

B.1.12 Sensor study 3-month topic guide

3-Month Use Let's start by talking a bit in general about your use of the MiiCube device after 3 months using it.

1. How are you getting on with the device now that you've had it for nearly 3 months? Probe: Have you used it for this whole period? - How frequently would you say you're using it? 2. Can you describe your current feelings towards the MiiCube? - How would you compare your feelings now with your first few days using it?

App

3. So moving onto talking about the MiiCube app. We gave you some things that you could try on the app, so it would be good to hear your thoughts on the following things:

o What are your general thoughts on the app? o Could you describe how you have used some of the features of the app? o Do you have a favourite feature of the app? o How do you feel about how information is presented to you? o Do you understand what you are shown? o How would you design the app differently? - Or is there anything you would design differently

Integration into the Home/Multi-Resident Let's talk more about the MiiCube device itself again and about you and the other people in your household.

8. Now that you've used the MiiCube, has using it been as you expected? 9. Do you think the device fits into your home now? 10. Has anyone else used the device since we last spoke? - Have other members of the household commented on how they understand the device? - Are they a member of the household? - What did they use it for? 11. How have you experienced the device as a household? - [IF RELEVANT] How has the device impacted your life? 12. Are you using the device for anything now, that you weren't before? 13. What types of activities are you typically using the device for now? 14. In your conversations with the device, how do you feel about talking to Monica now? - How does the voice make you feel? - Does it answer all the questions you ask it? - What do you think of its responses? - Have you used any other devices that you can speak to? - OPTIONAL: How does Monica compare to those devices?

[ONLY IF NOT ALREADY DISCUSSED] Technical Questions

15. How well do you feel you know how the device works? 16. Does the device work as you expected? 17. Is the device doing everything it was promised to do for you? 18. How much would you say you're using the device now compared to the other devices you own e.g. phone, laptop etc.?

Health and Wellbeing Let's talk a bit more about the device in relation to your health and other people's health in your home. Now that you have been using the device for 3 months:

19. Thinking about your physical health. - Would you still consider using the MiiCube to support your physical health? - Do you think the device is supporting you in being more physically active? - Are there any new physical activities you're doing now that you didn't do before you had the device? 20. And thinking about your mental wellbeing. - Would you still consider using the MiiCube to support your mental wellbeing? - Has using the MiiCube helped to support any

mental exercise you might do? e.g. brain training, mindfulness, meditation, etc.? - Are there any new mental exercises you're doing now that you didn't do before you had the device?

Social 21. Let's talk about feeling connected to people you know. Who do you feel most connected to at the moment e.g. family/friends/neighbours? - Why? - How connected do you feel to the people around you? - Has this changed due to using the device? - Has the device supported you staying connected with others? 22. Thinking about the care you receive from health professionals now for example. How would you feel about using the MiiCube to stay in touch with your doctor now? - How would you feel about using it in place of going to the doctors? 23. Has your opinion on sharing personal or health information on the device changed? - Have you used the MiiCube to stay in contact with any clinicians e.g. doctors/OTs/dentists etc.? 24. Do you feel the device has supported you to stay socially connected with people you have less contact with? 25. How comfortable would you feel planning your own care through the device e.g. scheduling appointments? - How about planning someone else's care?

Other

26. If there were no limits on what you could do, what would you change about the device itself? (e.g. mentioned linking to TVs/linking to stair lifts) - How would you design it differently? 27. Thinking about the environment of your home; is there anything that you think the MiiCube could do to better support your residence? e.g. if you had unlimited use of wi-fi lightbulbs for example, would this kind of technology be useful to you, to use with MiiCube? 28. Do you anticipate you'll do anything different with the device over the next six months? - Next year? 29. What do you anticipate will change in your home over the next six months? - Next year?

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