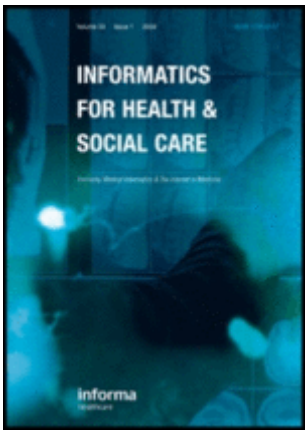
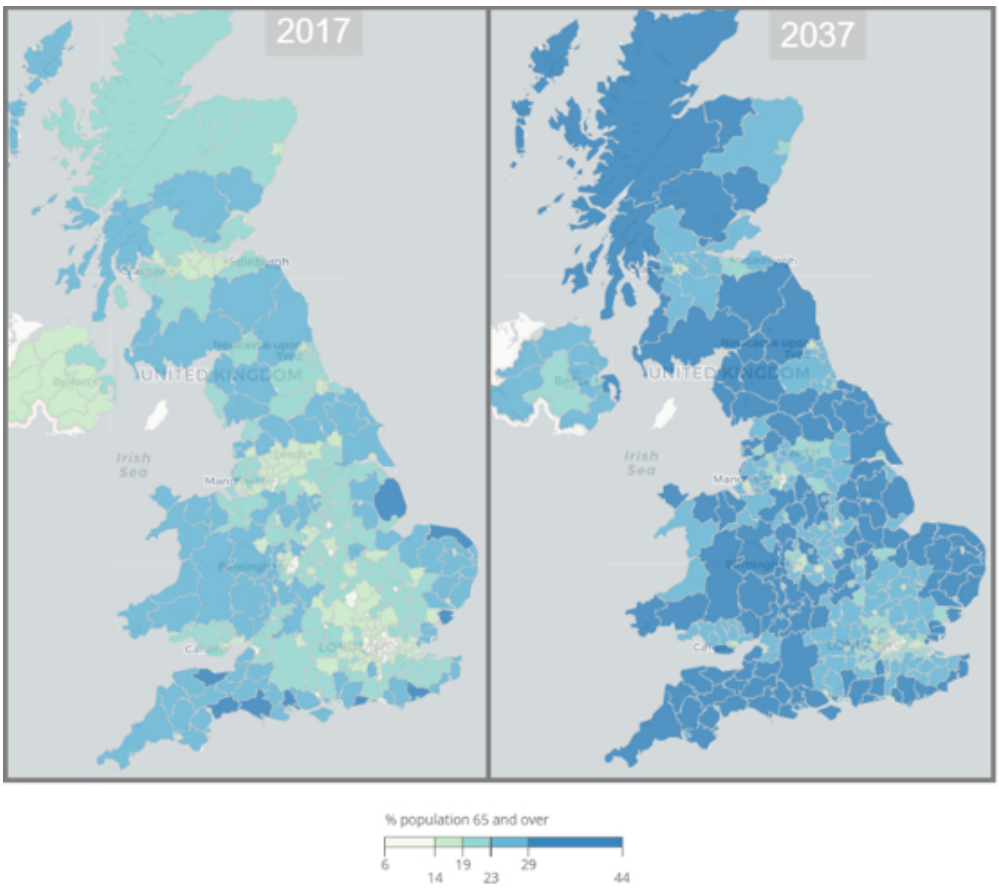


Ethics and Acceptance of Smart Homes for the Elderly

Journal:	*Informatics for Health and Social Care*
Manuscript ID	IHSC-2021-0009
Manuscript Type:	Review
Date Submitted by the Author:	12-Jan-2021
Complete List of Authors:	Pirzada, Pireh; University of St Andrews, Computer Science Wilde, Adriana; University of Winchester, Digital Technologies; University of Southampton Faculty of Physical Sciences and Engineering, Electronics and Computer Science Doherty, Gayle; University of St Andrews, Psychology and Neuroscience Harris-Birtill, David; University of St Andrews, Computer Science
Keywords:	Smart Home, Ethics, Ambient assisted living, Assistive technology, Ethical aspects
Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online.	
main.tex references.bib	



Population variance of 2017 and 2037 forecast [2]

Ethics and Acceptance of Smart Homes for the Elderly

Pireh Pirzada [a], Adriana Wilde [b,c], Gayle Helane Doherty [d] and David Harris-Birtill [a]

[a]School of Computer Science, University of St Andrews, St Andrews, UK;
[b]Centre for Health Technologies, University of Southampton, Southampton, UK;
[c]Department of Digital Technologies, University of Winchester, Winchester, UK;
[d]School of Psychology and Neuroscience, University of St Andrews, St Andrews, UK;

Abstract

Societal challenges associated with caring for the physical and mental health of the elderly worldwide have grown at an unprecedented pace, increasing demand for healthcare services and technologies [1]. Despite the development of several assistive systems tailored to the elderly, the rate of adoption of health technologies is low [2, 3]. This review discusses the ethical and acceptability challenges resulting in low adoption of health technologies specifically focused on smart homes for the elderly. The findings have been structured in two categories: Ethical Considerations (Privacy, Social Support, Autonomy) and Technology Aspects (User Context, Usability, Training). The findings conclude that the elderly community is more likely to adopt assistive systems when four key criteria are met. The technology should: be personalized towards their needs, protect their dignity and independence, provide user control, and not be isolating. Finally, we recommend researchers and developers working on assistive systems to: (1) Provide interfaces via smart devices to control and configure the monitoring system with feedback for the user, (2) Include various sensors/devices to architect a smart home solution in a way that is easy to integrate in daily life and (3) Define policies about data ownership.

Keywords— Ethics, Smart Home, Ambient assisted living, Assistive technology, Ethical aspects

1 Introduction

In the UK mid-2017 census, the age group 65 and above was 18.2% of the total population and this was then estimated to grow to 20.7% by 2027 , with projections for a further increase to 26.5% by 2040 [1, 4]. Population in this age bracket (65+) for 2017 and forecast for 2037 is shown in Figure 1 illustrating variation within the UK [1, 4]. This demographic shift towards an aging population increases health challenges giving rise to a need for health care technologies targeted to help the elderly population. There is an increase in people living with complex chronic illnesses. The percentage of people with dementia is forecast to increase by 40% over the next 12 years and 56% over 38 years [5], with significant costs to health services. In the UK, dementia costs £26.3 billion GBP per year averaging at £32,250 per patient per year including health and social care (public and private funded). In addition, between £22.1 and £40.3 million per year is spent on police costs for missing people with dementia [5, 6]. More recently, due to COVID-19, additional healthcare challenges have arisen for the elderly. In the UK, the number of deaths was highest among older adults, specifically those who were aged 80 or above. According to ONS, the death rate was higher in males over the majority of age groups[7]. The significant increase in at home deaths triggered by the pandemic highlights the need for better healthcare monitoring with remote communication features to be able to connect the elderly with family members or emergency services in the time of need.

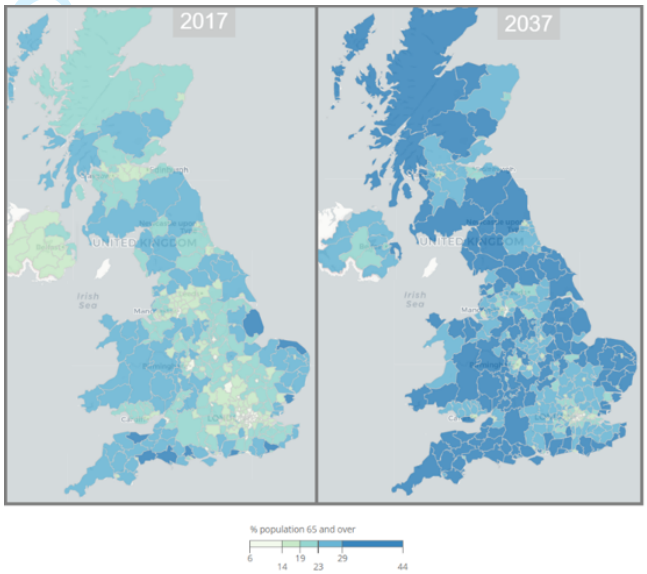


Figure 1: Population variance of 2017 and 2037 forecast [2]

To reduce this pressure, assistive technologies are being researched and developed for elderly people to enable them to lead their daily lives independently without compromising their health and safety. Advanced technologies benefit families and care takers offering affordable options to monitor, care and provide safety to their loved ones remotely.

In other words, the purpose of these technologies is to assist the elderly in their daily lives to achieve a good quality of life (QoL). QoL is characterized by various factors such as social contacts, activities, health and family relations [8], and therefore the World Health Organization (WHO) characterizes QoL as physiological, social and mental well-being[1], as illustrated in Figure 2.

Within this paper we define a *smart home* as a home with a system consisting of one or several assistive technologies. We are focusing on the use of these technologies to improve QoL for the elderly community, for example: using assistive technologies to ease the activities of daily life, health monitoring and self-management systems to help with recording physiological details, fitness related technologies to be physically active and track emergency situations such as falls. Figure 3 illustrates the functionalities of a smart home to provide various benefits to the elderly community. There is continuous research and development on functionalities of smart homes [9, 10, 11, 12, 13]. One of the main concerns is the adoption and acceptance of these technologies. The number of studies conducted for the acceptance and adoption for smart home technologies for healthcare targeting the elderly are surprisingly low. In this paper, we present a literature review about the acceptability and ethical issues surrounding smart home technologies for the elderly community, addressing the possible issues and challenges.

[1]World Health Organization, WHOQOL: Measuring Quality of Life. `https://www.who.int/healthinfo/survey/whoqol-qualityoflife/en/`.

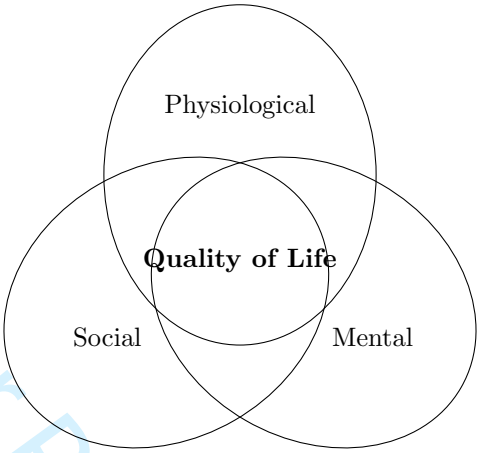


Figure 2: Conceptual design of characteristics of QoL[1]

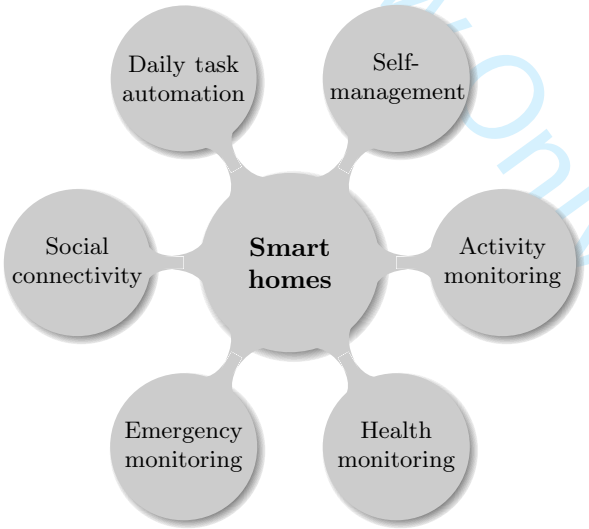


Figure 3: Functionalities of a Smart Home

2 Motivation and Goals

Smart home technologies provide several benefits for the elderly population endeavouring to support a good QoL. Despite the continuous research and development and the availability of several products in the market, questions arise regarding the technology acceptance, adoption, and interaction. This could be due to several reasons such as age, gender, health status, physiological and cognitive abilities all of which can heavily impact the acceptance and adoption of assistive technologies [14]. Another reason for low adoption could be related to the system design not adapting to ethical concerns, user experience, user interaction, awareness about technology, or catering for individual user requirements and/or personalization.

Whilst researching, there was no recent data available to identify the rate of adoption of assistive technologies, but it can be concluded that there is little work done in this area. For example, the only identifiable study that could be found was in 2005 where Lau studied adoption rate of personal emergency response services (PERS) in various countries [15]. They stated that despite the availability of these technologies for some time in the market, only a fraction of the population adopted these technologies with less than 5% of elderly Americans adopting PERS. In the UK, adoption rate was only 15 percent and below 20% in other countries [15]. Another reason for this could be simply due to the lack of smart home assistive technologies readily available. Liu et al. found that readiness for smart home and health monitoring technologies is still low. Around 56% of the studies regarding smart homes and home health monitoring technologies were carried out or tested in lab environments and were proof of concepts. Currently, there is no evidence that these technologies help address cognitive decline, QoL,or heart conditions for elderly people with complex needs [16]. Many research studies focus on using models available to investigate the acceptance of assistive technology among elderly people but it is still unclear the reasons for low adoption of these technologies [17].

Intelligent assistive technologies for dementia patients were found to be developed in the absence of ethical considerations which results in low prevalence [18]. While a further assistive technology study (BRAVEHEALTH) shows that participants had a positive attitude towards the technology but were still resistant to adopt the system due to concerns over reliability, security, privacy, and trust. For example, some preferred to engage personally with physicians rather than use videoconferencing [19]. Studies show that video conferencing is perceived useful with benefits such as convenience, time and cost efficiency [20, 21, 22]. It was found that most people had experience of using video conferencing for personal or work reasons but less than half people used it for health and rehabilitation reasons [21]. In another study doctors and patients were willing to use videoconferencing, although they preferred face-to-face contact, subject to the nature of the complaint meaning VC is not a solution for all illness and clinical needs but more suitable for short visits with non-chronic conditions or in an urgent care setting [22]. In light of the recent COVID-19 pandemic it is possible that attitudes around videoconferencing have further changed, especially as it has become a more normal activity in everyday life.

Hence, it is important to gain an understanding of the acceptability and adoption rate of the health care technologies especially for smart homes. The main goal of our research is to identify the reasons for this low adoption by conducting this literature review and find the methods by which adoption and acceptance can be increased. In the end we offer some recommendations that may help shape the future assistive technologies to make them more acceptable.

3 Methodology

To understand more about the low acceptance and adoption of the smart home technologies among the elderly, we conducted a literature review. We searched in Google Scholar using the following keywords: ("acceptance", "adoption", "perception", "awareness") and ("elderly", "elderly population") and ("assistive technology", "intelligent environment", "smart home", "medical technology", "health technology"). We refined our search through the development of stringent inclusion and exclusion criteria (Table 1).

4 Acceptance Models

Research studies have used models to investigate adoption and acceptance of a technology, one of which is named "The Technology Adoption Model/Technology Acceptance Model (TAM)". This model is based on perceived usefulness (PU) and perceived ease of use (PEU) where PU means the person perceiving the technology under investigation as useful and PEU refers to a person perceiving the technology is not complex to operate and therefore easy to use without a lot of effort [23]. In 2000, this model was extended as TAM2 which included two more factors which impact the acceptability of a technology. Social influence means a persons perception towards a technology formed by family, friends or social status. While the latter means a person's assessment of a technology based on how relevant it is for the goals, results and its level of quality along with its ease of use [24]. In 2003, The Unified Theory of Acceptance and Use of Technology was presented (UTAUT). This model merged contributions of various adoption theories and models of technology use [25, 26, 23, 27, 28, 29, 30, 31]. This model was further extended to UTAUT2 to further include a user's perspective considering cost, motivation and habits for example [32]. Other models which talk about factors affecting adoption include Technology to

Table 1: Criteria for work to be included in this review

Inclusion Criteria	Exclusion Criteria
Focused on elderly audience where certain studies also included younger age groups	Studies conducted using robots as assistive technology
Technologies related to smart homes	Smart homes not consisting of elderly participants
Assistive technologies for self-management, easily integrable in daily life to promote independence	Assistive technologies involved in hospitals or rehabilitation centres
Elderly living independently	Research focusing on other aspects such as robots, sound, speech detection and security aspects of smart homes.
Studies were published in English	Articles that did not fit the inclusion criteria
Studies about perception of smart home technology focusing on acceptance or adoption by the elderly	

Performance Chain Model (TPC) and Model of Acceptance of Technology in Households (MATH) [33, 34, 35]. Many researches have used these models which include [36, 37, 38, 39, 40, 41, 42, 43, 44]. Capability Approach Framework (CA) is designed to describe an individual's use of resources to improve their daily life [45]. However, this model was used by Nikou et al., to investigate the adoption of digital health care technology among older adults [46]. The Expectation Confirmation Model (ECM) was used by Marikyan et al, to study smart home users' technology adoption [47].

5 Commercialised Assistive Technologies

Assistive technologies can support elderly people to lead an independent, safe and secure life within the comforts of their own home. Different types of assistive technologies such as remote health monitoring via video, sensors and other smart objects, fall detectors, door monitors, bed sensors and Smart HVAC (Heating, Ventilation, Air conditioning) which can support the elderly community, have been previously defined by Miskelly [48]. Table 2 lists various examples of commercially available assistive technologies fitting within these categories and more.

Several studies show that elderly people generally have a positive attitude towards the technologies mentioned in Table 2 [19, 49, 50, 51, 52, 53] but they raise ethical and technical concerns, such as: privacy [8, 18, 40, 54, 55, 56, 57, 58, 59, 60], autonomy [18, 54, 55, 60], beneficence [18, 55, 60], loss of social contact [18, 55, 57, 61], ease of use [8, 61], control over technology [55, 57, 62], support [55], training or ability to learn [8, 55, 61, 63], lack of awareness [61, 64], personalisation [65] and reliability [19, 56, 60].

There are many more early-stage research ideas being conceived than there are commercial products available for consumer use within the smart home technology space. Some examples of commercially available products are shown in Table 3. It could be argued that the steps involved in the commercialisation of assistive technologies are slow or not able to meet consumer demands. Coughlin et al. discuss translation of invention to innovation stating that although assistive technologies have been available for some time, government and major corporations have only recently given priority to the implementation of technology for the elderly community. Therefore, availability of these assistive technologies may be limited due to the lack of the policies required to successfully convert them to commercial opportunity [56].

[2]Tiny Logics, https://pillbox.tinylogics.com
[3]Arlo, https://www.arlo.com/uk/use-cases/assisted-living/
[4]Fibaro, https://www.fibaro.com/en/smart-home-in-use/smart-hvac
[5]Lifeline , https://www.lifeline24.co.uk/
[6]Medical Guardian, https://www.medicalguardian.com/freedom/?aid=3900
[7]MedicalFitbit, https://healthsolutions.fitbit.com/
[8]Garmin, https://www.garmin.com/en-GB/
[9]Red Panic Button, https://itunes.apple.com/us/app/red-panic-button/id422029296
[10]Blood Pressure Monitor, https://apps.apple.com/us/app/blood-pressure-monitor/id430133691
[11]Pillboxie, https://apps.apple.com/us/app/pillboxie/id417367089
[12]PPP Taking Care, https://www.ppptakingcare.co.uk/
[13]Lively, http://www.getmylively.com/

Table 2: Commercial Products Categorised

Categories	Description
Smart Objects[2]	Objects connected via smart phones or laptops such as smart pillbox, door or smart locks. Also, for auto detecting presence such as for turning on lights.
Monitoring via Cameras[3]	Elderly home security and activity monitoring
Smart HVAC[4]	Smart heating, ventilation, and air conditioning for temperature control. Saving energy as well as providing control via smartphone
Personal Emergency Response Systems[5]	Personal health monitoring system which can be used to call help in case of an emergency such as wearable push button necklace, watch, belts.
Smart Watch[6,7,8]	Monitoring multiple measurements such as movement, falls, heart rate and SpO_2.
Smart Phone Applications [9,10,11]	Reminders, step counts, data sharing with family members.
Sensors[12]	Monitoring activities and monitoring environment such as humidity sensor, smoke alarm etc. Monitoring activities such as placed on the fridge, shower, pillbox, or any object to monitor that activity.

Table 3: Current assistive technology products and services

Commercial Products	Description
Lively[13]	Lively provides a watch that includes a push button for calling help in case of fall emergency. It also gives reminders for medication, counts steps and shares this with family members.
HomeCare[14]	Develco provides home monitoring sensors under the HomeCare umbrella, e.g. Gateway, Window sensor, Smart Plug, Light bulb, Flood alarm, Smoke alarm, Humidity sensor, Motion sensor for fall detection and preventing fire or any emergency. This is built for developers to design the solution.
Just checking[15]	Just checking is a home monitoring system to monitor movement of the elderly by sensors attached to walls and various objects in the house. It is also for door monitoring and activity monitoring
CanaryCare[16]	Monitors movements, bathroom visits, tracks sleep, temperature and reminds medication
MariCare[17]	Smart floor and activity sensing for monitoring activities and falls
Smart Life in Fife[18]	Smart Life in Fife is a visual tool to aid people to manage their ageing progress with expert advice.

[14]HomeCare, https://www.develcoproducts.com/business-areas/home-care/
[15]Just checking, https://justchecking.co.uk/
[16]CanaryCare, https://www.canarycare.co.uk/
[17]MariCare, https://maricare.com/en
[18]SmartLifeinFife, https://www.smartlifeinfife.org/

6 Findings

We organise our findings under two categories: (1) Ethical Considerations and (2) Technology Aspects. A summary of the findings from the surveyed studies is shown in Table 4.

6.1 *Ethical Considerations*

Ethics play an important role when developing any technology involving humans. This can heavily affect the adoption and acceptance of the technology if not considered. This gives rise to ethical and legal concerns despite the benefits that can be attained from various assistive technologies [18, 66].

We have identified five themes related to ethical considerations including privacy, perceived benefits, autonomy, cost, and support of social and natural environments.

6.1.1 *Privacy*

Privacy is one of the major concerns voiced by participants in various studies [56], [67], [68], [19], [17], [58], [40]. In a focus group study about commercially available assistive technology products, participants raised a concern about the technologies monitoring them 24/7 [56]. They considered it as a loss of dignity in their own home, even though they acknowledged that the purpose of the technology was to ensure their safety and security [56]. In a further study, elderly participants stated that sharing details about them was very interfering and privacy intrusive [67]. They showed negative responses to image capturing technology which made them feel uncomfortable. However, a recent study in the US found that the elderly people with internet experience and a positive attitude towards emerging technology were willing to use Internet-connected cameras for home monitoring. Approximately 48% of participants were willing to use cameras for home monitoring compared to other technologies [69].

They also mentioned that it was important for them to control information sharing, as not all the participants were willing to share their data with their families, staff and health care providers [67]. Elderly participants in another study by Steele et al. stressed that they wanted systems to be unobtrusive [70]. Camera monitoring was found to be a useful method to provide complete activity monitoring and fall detection surveillance for the elderly, but it was felt to be the most intrusive form of surveillance which made users feel more reluctant to adopt the system [71, 72]. Interstingly, Birchley et al. mention that users consider unobtrusiveness as an assurance of data privacy, suggesting that unobtrusive technologies could help alleviate some privacy concerns [73].

Nonetheless, Demiris et al. found that elderly participants evaluated the smart home "Tiger Place" at the University of Missouri (in Table 4) to be an unobtrusive environment but raised concerns about the data shared with third parties [57]. In addition to data privacy concerns it is also important to consider data protection. Sanchez et al. raise concerns regarding identity theft from a smart home. Since the smart home data contains details about a user's behaviour and daily routine, it becomes very crucial for this data to be protected [74].

It was also found that privacy concerns seemed to be more important for younger people than elderly people. This may be due to the lack of knowledge within elderly community about the data transmission and other technical details involved in a system [65]. Studies show that compared to those in poor health, healthy people also hold more value to data protection, its connection with third parties, its storing process, and policies. People with poor health were more focused on how the technology can benefit them [75, 76].

Privacy being one of the main concerns among the participants could be overridden by a better understanding of the significant need for technology.

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Demiris et al. (2006) [57]	Focus Groups: 3 Male: 5 Female: 9 Total: 14 aged 65 and above Session Duration: 1 hour	Tiger place (Intelligent Ambient Living/Smart Home) which provides activity recognition data	Concerns related to privacy of data, social isolation, and lack of control over the technology were raised by participants, but they confirmed that the system was an independent unobtrusive way of living.
Demiris et al. (2006) [57]	Focus Group: 1 Gerontology Nurses: 4 Social Worker: 1	Tiger place (Intelligent Ambient Living/Smart Home) which provides activity recognition data	Visualisation of large activity recognition data sets such as summaries and overall trends were thought to be more useful. Suggestions for designing the application to have consistent interfaces, allow communication with health care providers and interoperability with other applications for record keeping.
Rahimpour et al. (2008) [77]	Focus Groups: 10 Interviews with patients (congestive heart failure and/or chronic obstructive pulmonary disease) Location: Sydney Background: 7 different ethnic groups	Video and prototype demonstration of the a Home Telecare Management System (HTMS) by MedCare Systems Pty. Ltd. (Sydney, NSW, Australia)	The participants agreed that the technology could benefit their health, but concerns were raised regarding cost, usability, clinical support, inability to self-operate and anxiety issues relating to operating the system.
Coughlin et al. (2007) [56]	Focus Groups: 30 leaders in aging advocacy and aging services from 10 north-eastern states. Location: United States and Washington, DC	Commercially available and still under development technologies ranging from telemedicine systems, smart scales, health kiosk systems, personal advice systems to guide diet, home monitoring	Concerns regarding usability, privacy, reliability, and cost were identified, although participants acknowledged benefits of the technologies.
Courtney (2008) [67] Courtney et al. (2008) [26]	Focus Groups: 4 with 11 participants and 3 additional interviews Elderly aged 65 and above Location: Mid-western U.S. residential care facilities	Smart Home technologies containing various sensor technologies such as bed sensor, kitchen sensor, motion sensor and fall detection sensor	The study found that privacy was the major concern which caused low adoption. But the need for these technologies could potentially override their privacy concern.
Dhukaram et al. (2011) [19]	Focus Groups: 5 Participants: 34 Location: West Midlands and Cheshire areas in England	BRAVE HEALTH System combining a wearable vital signs measurement system with telemedicine	Participants showed a positive attitude towards the benefits of the technology but were not willing to adopt the system due to current privacy, trust, reliability and security issues

Continues on next page

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Chernbumroong et al. (2010) [78]	Participants: 14 participants aged 26 to over 80 years old Location: Local hospitals, nursing homes and general population	A survey conducted to understand the perception of smart home technologies for assisting the elderly people	The participants showed positive attitude towards the six smart home technologies under review (cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm, automatic lighting system, video monitoring system and activity monitoring system). However, willingness to adopt these technologies was uncertain among the participants. This could be due to factors such as difficult User Interface design, learning difficulties, privacy concerns, cost and lack of human responders.
Ziefle et al. (2010) [14]	Participants = 82 aged between 40 and 92 years. 53% male and 47% female 39 / 82 participants stated to have a chronic disease.	Questionnaire for smart technologies including smart homes, smart phones and smart clothing.	The study found no interrelation between age, gender or health status and willingness to adopt technology. Therefore, diversity (age groups, gender, health states) do not impact the acceptance of technology. The study also shows that smart homes were most critically evaluated compared to mobile devices or smart clothing. Also, participants gave less importance to the design and aesthetic of the technology and more towards its beneficence.
Wilkowska et al. (2011) [75], Wilkowska et al. (2012) [76]	Questionnaire Participants: 104 Qualitative data evaluation Focus Groups: 1) n=7 aged 24 – 29 2) n=6 aged 60 – 68 3) n=6 aged 67 – 73 Quantitative data evaluation Focus Groups: 1) n=25 aged 21 – 29 2) n=15 aged 30 – 39 3) n=21 aged 40 – 49 4) n=16 aged 50 – 59 5) n=16 aged 60 – 69 6) n=11 aged 70+	E-Health technologies e.g., blood pressure meter, blood sugar meter, insulin pump	The participants of all ages in this study perceive data protection and health and safety as highly important. Men tend to perceive greater advantages of health control using medical devices more than women. However, this is marginal difference only. Men also pay less attention to anonymous and intimate ways of using the technology, but other aspects of privacy seem to be similar in all gender groups. The study also shows that healthy people hold more importance for data protection, its storage and transfer for e-health usage than people with poor health. People with poor health tend to be less concerned about the permanent surveillance unlike healthy people.

Continues on next page

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Guo et al. (2016) [65]	Participants: 650 293 participants aged between 18 and 26 198 participants aged between 27 and 49 159 participants aged 50 and above Location: China	A survey of 650 participants with different age groups in China was conducted. This survey was conducted to study trust, privacy concerns and adoption intention for Mobile Health Services.	The study found that privacy concerns are associated with trust and intention of adopting the technology. While personalisation is proportional to consumer trust and willingness to adopt. It also found that privacy is unlikely to be a problem for the elderly which could be due to the lack of awareness about technology compared to young people.
Hoque, R. et al. (2017) [79]	Participants: 300 participants aged 60 years or above	The study conducted a face-to-face structured questionnaire survey to determine factors impacting intention to adopt and use mHealth service technologies among the elderly people.	The findings show that social influence, performance expectation, anxiety related to using technology, and resistance to change had a significant impact on the elderly persons intention to use and adopt mHealth services.
Etemad-Sajadi, R. et al. (2019) [80]	Participants: 605 elderly people who use health technologies.	The research focuses on the elderly people's acceptance of healthcare technologies within their home.	The findings show that the usefulness of the healthcare technologies impacts elderly persons intentions positively and hence they agree to use them. Along with that, the social presence from using health care technology positively influences one's decision to use it.
Reeder et al. (2020) [81]	Participants: 10 female participants aged 60 or above.	The research studies perceptions of smart home and wearable technologies among older women. Technologies included fitness trackers, accelerator sensors, residential sensors such as bed sensors, activity sensors and video sensors.	Participants perceived sensors as acceptable for data collection of personal activities. Participants generally perceived wearable sensors more useful than smart home sensors as they mostly had activities outside their homes. While home sensors were considered most useful for those who spent their time mostly at home. Privacy concerns related to break-ins or unwanted disclosure of activity levels and overall had few concerns about data sharing.
Ashraf et al. (2020) [82]	Participants: Participants aged 55 year and above Location: Pakistan	Interviews covered perception of smart home technology among the Pakistani elderly community.	About 91.5 percentage of the participants perceived smart technology as useful and convenient. However, it was found that excessive pressure from relatives and friends can easily hinder the elderly persons from adopting technology. Issues with accuracy of technology can also negatively affect their adoption.

Continues on next page

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Shirani, F. et al. (2020) [83]	Participants: 24 residents aged between 20 to 70 years old Participants were interviewed once a year over a successive three year period Location: Caerau, South Wales Valleys	Interviews covered perception and experience of smart technology of low income house holders amongst vulnerable consumers.	Participants considered smart technology for vulnerable energy consumers to be beneficial for example remote controlled energy assistance for those with mobility impairments. Participants either showed interest in the new technology or found it wasteful. Participants under 40s considered it as 'cool' technology and perceived benefits of increased control while many of the older participants were less interested in it. This could be due to participants finding smart technology to be complex and unusable.
Pal, D. et al. (2020) [41]	Participants: 315 and 1945 participants in two phases Age range varied from 20s to 50s and above. Location: Thailand	Two surveys were conducted to study the adoption intention of the voice based smart home system.	Findings state that the senior people with high income and smart home appliances were most likey to use voice based smart home systems within an year. Participants with low intention of adoption perceived the technology to be less useful.
Marikyan, D. et al. (2020) [47]	Participants: 387 smart home technology users Age range varied from 18 to 65 and above.	A survey conducted to gather input about negative emotions and difficulties faced, from 387 smart technology users (for example smart security system, smart kitchen, visual assistant and many other technologies)	The findings state that people who experience negative emotions caused by a technology performance might cope by giving up the use of smart home technology.
Mashal, I. et al. (2020) [36]	Participants: 258 household Location: Jordan	This study investigates the reasons that influence people in Jordan regarding acceptance and usage of smart home services.	The findings show that trust, perceived usefulness, ease of use, enjoyment and personalisation influence intention to use and technology adoption. Also, cost was found to be an insignificant factor to influence intention to use.
Nikou, S., Agahari et al. (2020) [46]	Participants: Interviews (N=59) and Focus group (N=12) sessions Electronic survey collected from elderly people in Netherlands Followup interviews (N=7)	This research develops and tests a theoretical model to explain intention to use health technology's by older adults by considering how the digital health technologies enhance their ability to live independently.	Findings state elderly people were positive about independent living and were against living in care settings. Participants mentioned difficulties faced by them to find the correct health care technology and service for them-self to live independently. The elderly people base their intentions to use health care technology by assessing the capability of the products and service which enhance independent living.

Continues on next page

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Robinson, E. L. et al. (2020) [58]	Participants: Four Focus Groups of 23 participants aged 60 and above One Focus Groups of 5 participants with family members Five 90 Minutes Focus Groups	Focus groups were conducted to gather input from the elderly people and family members about adapting and using the home sensor technology	The findings state that family members were more eager to adopt the technology then elderly people. Family members also expressed that they would want to have access to their elderly relatives health information while the older adults did not want to obsess about their health. Participants of both groups did prefer using their cell phones to receives messages and alerts about health. Older participants expressed concerns about privacy related to video monitoring.
Schlomann, A. et al. (2020) [84]	Participants: 1863 participants aged 80 to 103 years old Location: North Rhine-Westphalia, Germany.	The research studies about the adoption of assitive technologies among the elderly people in private homes and care facilities and analyses the environment and characteristics in both settings.	Mobile phones were most common among elderly people living in private homes who did not receive any care. Assitive technology was found to be less common in private homes than in long term care. Information communication technology users were found to be younger, have higher level of functional health and were more interested in technology while users of assitive technology were older and had poor health comparatively.
Kadylak, T. et al. (2020) [69]	Participants: 1148 respondents aged 65 years and above Location: United States, America.	An online survey conducted through Qualtrics to assess willingness to adopt various emerging technologies including smart home technologies.	The findings show that the older adults were most willing to use digital home assistants, smart technologies and Internet-connected cameras.
Guhr, N. et al. (2020) [40]	Participants: 187 respondents 100 males and 79 females and 8 unknown gender	The study explores and addresses information privacy concerns that affect usage intention of smart homes	The research found that privacy negatively impacts intention of use for smart home technology.
Weck, M. et al. (2020) [85]	Participants: Participants aged 55 years and above Location: 3 Finnish cities, Finland	Focus groups interviews were conducted to understand use of digital technology among ageing people. The research presents findings on the basis of trust towards technology functionality, institution such as healthcare authorities in Finland and costs related to technology.	Findings suggest that generally, participants trusted digital assistive technology to work well but the healthcare service providers or authorities integrity and competence needs to be taken into account. Cost issues were also raised and that technology should be available for everyone equally.

Continues on next page

Table 4: Key Findings from Assistive Technology studies (spans over 7 pages)

Author	Sample	Technology	Key Findings
Zou, P. et al. (2020) [86]	Participants: Participants aged 65 and above Chinese Immigrant Community in Canada Two groups controlled trail with a sample size of 60 participants Participants with high blood pressure Location: Ontario, Canada	A pilot study to design and test smart phone based dietary app for Chinese Canadian seniors to help with a health diet and hypertension control.	The research is in progress and aims to test the usability and feasibility of the dietary application to support Chinese Canadian seniors with a healthy diet and hypertension control. The research hypothesises that this app will help decrease blood pressure and improve quality of life of seniors with elevated blood pressure.
Lin, T. et al. (2020) [87]	Participants:35 Participants aged between 58 and 82 years old Majority of participants were diagnosed with hypercholesterolemia and hypertension Location: Singapore	Semi structured Interviews were conducted regarding ownership of mobile phones and its usage for healthcare to understand the willingness of adoption . Videos of mHealth applications were also shown to participants.	Participants considered mobile phones as a personal device and a way to access healthcare via calls and messages. It was identified that the elderly people face technology anxiety causing resistance towards adoption of mHealth applications. It was suggested that training can help reduce this anxiety and increase adoption of mHealth services and applications.

The need for the technology may lead people to adopt smart homes or assistive technologies if they fulfil their intended beneficial purpose. As mentioned above, people in poor health were more focused about the benefits of technology rather than privacy concerns [76]. We can conclude that the need for technology outweighs privacy concerns to some extent provided the expected or intended benefit is met by the assistive technology [67, 68, 74]. Despite this trade off, elderly people still require technology to be reliable and trustworthy. Guo et al. [65], found that privacy concerns are associated with trust, and they impact the intention of adopting the technology. For example, users not familiar with a given service provider are not willing to disclose their personal data for fear it will be misused, which in turn impacts the acceptance of service or technology. However, personalisation and familiarisation of the technology towards the user may positively impact users' trust in technology and therefore its acceptance.

A study conducted by Wilkowska et al. [75, 76] found a gender difference when looking at various ethical aspects, including privacy. In this study, all age groups irrespective of health condition deemed privacy to be of high importance. Only by a small marginal difference was noted; men seemed to be less concerned about the anonymous and intimate way of using technology while women were more concerned about the security and required more security features. Women are reported to prefer to use assistive technology in an anonymous way.

To summarize, the main factors influencing views around privacy that these papers highlight are: obtrusiveness, camera surveillance, age, gender and personalization to improve trust. All age groups and genders are concerned about continuous surveillance and data privacy issues which creates doubts about adopting technology. Therefore, it is important to develop technology considering the privacy aspect as it may heavily impact the acceptance and adoption of technology.

6.1.2 *Perceived Benefits*

Technology benefits are more evident to the caregivers [88] than to the elderly people for whom the technology is designed. They feel they can do well without it, and therefore lack perceived benefit [88]. If the perceived benefit by the users is high, then they are more willing to adopt technology. Accordingly, elderly people with high perceived benefit consider technology beneficial in supporting them for aging in a place and believe that technology will not only increase independence but also reduce burden on family and caregivers. This positive attitude towards the perceived benefits of technology helps in acceptability of the technology [89]. Therefore, it is important that the expectation of the users matched the benefits provided by the technology.

Systems should aim to deliver the benefits and functionality that users consider as desirable and avoid those which are not adequate or unnecessary [48], [90]. For example, the basic need of the users expected from assistive technologies is to promote their QoL. In other words, users see a benefit in technologies that can support them to achieve daily tasks, maintain their health, provide safety, and enable independence. This can be achieved by

designing systems which monitor health in an unobtrusive manner and alert contacts in case of emergency. These systems when connected to other e-health services can prove to be even more beneficial where doctors or GPs can be in touch with the user and monitor their health records [91].

For assistive technologies to play an important role in supporting the elderly they must be reliable. One of the elderly participants in a study reported failing to continue to use a blood pressure monitoring device as they felt readings were inaccurate [77]. Other functionality issues such as batteries running out, or malfunctioning of the features, cause the elderly to distrust the devices making technology less appealing [55]. These occurrences take away the trust from the users, making it difficult for the systems to be adaptive.

There is some debate surrounding the factors affecting the adoption of technology. Wilkowska et al, found that men perceived the advantages of health control using medical technologies as more valuable than women did [75, 76]. However, the difference is only marginal and perhaps this could be due to some women not perceiving the health technology beneficial for themselves due to no health conditions or perhaps lack of knowledge or simply marginal difference. It was found that males were more aware of IoT and the term "smart home" than females [64]. And, Ziefle et al, found that there was no relationship between diversity (age, gender or health status) and willingness to adopt technology [14]. Also, participants gave very little importance to the aesthetic of the technology and were focused on the perceived benefits [14].

Assistive technologies need to be designed with the expectations and requirements of users in mind. The system does not need to be highly complex to provide benefits otherwise it will make it difficult for users to operate and accept assistive technologies. For example, a remote health monitoring system should not require a complex set of commands to start up or interrupts activities of daily life (ADL), which makes it inconvenient for the user.

6.1.3 *Autonomy*

Elderly people may consider themselves as vulnerable due to their age-related health conditions. This does not imply that they do not have pride, self-respect, and dignity [66]. Studies show that some of the elderly people think they will do well without assistive technologies as they feel ashamed and insulted [55]. They were not willing to wear devices to monitor their health as it would make them feel frail or needing special assistance [55]. Elderly people also prefer to live independently in the comfort of their own homes as long as possible [88]. Autonomy refers to this independence and control over one's life [92].

Assistive technologies which restrict and restrain elderly people may be even more difficult to be acceptable. For example, smart homes monitoring activities of individuals need to be adaptive of their habits and behaviours (daily routines) [11]. Elderly people find it difficult to change their daily routine, learn new patterns and interactions for using the systems. Products should be designed to suit the living patterns of the elderly rather than enforcing new patterns [88]. Technologies that do not offer users control, or limited control, over the influence on their lives are not readily adopted by the elderly. For example, participants agreed that the sensors in the smart home (Tiger Place) were not intrusive but there was a lack of control, such as duration of monitoring, which made participants hesitate to adopt such technology [67]. Control over technology provides a sense of independence, making the user feel less conscious of being under surveillance as they can turn it off when they prefer [62]. The perception of control over a system made the elderly people feel they also had control over their well-being and therefore, impacted their intention positively for using such a system [93].

6.1.4 *Cost*

Studies show that cost is a reason why elderly people are reluctant to buy a technology [77, 56, 17] and it can also be difficult in rural areas, developing countries or countries with low economic development and low incomes [94]. Many business facilities have transformed to automated systems but very few households incorporate smart home technologies due to high cost [95]. Smart homes contain a collection of several sensors and technologies making them costly. As elderly people are often on a restricted pension income, cost is an important concern, as shown in a study by Steele et al.[70] which highlighted that cost was a frequently discussed subject in the focus group.

They also found that elderly people were more likely to accept the technology if the implementation and maintenance cost was covered by their children or the government [70]. Since these technologies may indeed be costly, the concern about who will pay for these technologies becomes crucial. In case of care services, people with health insurance may have these costs reimbursed. But if people have to pay for assistive technologies then the question of whether or how this will be available to people with low income is something that certainly should be considered. Health is an important basic need for every individual. Services and technologies could either be made less expensive or at a subsidised cost for a more inclusive society, where not only the rich have access to these technologies. For example, government bodies could initiate methods to provide support to the elderly community by making assistive technologies more inclusive through the improvement of their affordability and their integration with existing services.

6.1.5 *Support of Social and natural environments*

Socializing is an important part of every person's life and depriving people from social needs can cause mental and physical health problems. Social support is a crucial environmental part which helps in improving health. Loneliness plays a role in increasing functional disability among the elderly people [96, 97]. It is important to include social interaction using smart home technologies to help avoid loneliness [98, 99], [59]. Yeh et al. found a relationship between dependence on activities of daily life (ADL) and people who experience loneliness. Meaning people who were socially isolated or feeling lonely were more dependent on using instruments or assistance for completing daily activities of life. [100]. A study by Chen and Chan found that factors specifically relating to cognitive decline, social isolation and fear of illness were largely overlooked in studies relating to technology for older people [101]. It has been found that elderly people perceive that smart homes restrict them from social interactions, which leads to loneliness. For example, the technology may give them a feeling of being safe only when within their house [57]. If technologies do not provide comfort, and support maintenance of social interactions this can lead to difficulties familiarizing with and learning to operate the technologies. This is itself can be a source of anxiety for the elderly [55]. In the light of COVID pandemic, the elderly people and vulnerable groups have been enforced into social isolation. This isolation increases the risk of health decline, which creates a necessity for healthcare monitoring with features to allow communication with family and friends and call emergency services in case of severe health decline.

6.1.6 *Stigma, Social Pressure, Awareness and Other Issues*

There are several other reasons which cause low adoption assistive technologies [17]. Elderly participants in a study were not very keen on using smart home sensors as they did not want to obsess over their health. However, their family members thought the opposite and expressed interest in monitoring and accessing health information, even if the elderly relative did not want to worry about it [58]. Another reason is the pressure from family and friends which can hinder their need to adopt technology by creating negative emotions [82], [59]. When this motivation from friends and family is positive, it can lead to adoption of technology by elderly people or their own need is higher then the pressure from others. However, if social and learning support is not available from the relatives for example a persons children refusing to help could lead discouragement, embarrassment or impatience [82].

Stigma can also lead to hesitation in adopting technology. Another term for this could be Ageism which is a form of discrimination and discourages people from adopting technologies, if they are told that this is specifically for frail, vulnerable and old aged people [102].

Awareness, experience or low interaction with technology, ownership of devices (early adoption) and personality can also impact adoption of technology [82], [64]. It was found that male were more aware of IoT and the term "smart home" then females. [64].

There is some debate around gender and adoption of assistive technology. Some studies show that the elderly women seem to perceive technology as less beneficial than elderly men. This could be due to several reasons, one of which could be due to fewer female participants in the study or simply due to a marginal difference or a small sample [75, 76]. Another reason for the gender gap in technology adoption could be simply due to societal influence. The current elderly female generation had much lower access to employment and education than their male counterparts. STEM was less accessible to women in the past than it is today[103].

A study was conducted in 2018 on smart phone acceptance and their usefulness among male and female in Jordan and UAE. Generally, there was no difference in terms of how both genders think about the significance of the ease of using smart phones. It was found that Jordanian females who were less exposed to smart phones perceived them to be less useful[104]. It shows that gender gap varies due to cultural or social influence where women have less female role models to look up to, face sexism in education and at workplace or simply have had less opportunities.

Prior research was gender biased, it historically led researchers to carry out their observations on males, in biomedical, social or behavioural research. This has resulted in a death of information focused on females ranging from organisms, well-being, governments or polices[103]. This discrimination is no longer acceptable, and researchers recruit both genders to test and validate their developments. However, the older female generation may still be unaware of the technology and its benefits that the younger generation enjoys today.

This stigma and unawareness can be avoided by approaching the elderly people through media which is mostly used by them for example newspapers. Training's or help portals and services can be provided to the elderly people, this will also give a sense of independence to them. Research shows that smart phones and watches seem to be more acceptable among elderly people [81, 38] while some elderly also accept camera based systems if privacy is taken in consideration [69]. This could be used to advertise service and technologies to assist them in their daily lives. Workshops, seminars and general awareness can be spread among people with the help of cell phones which will also help remove stigma if advertised appropriately.

6.2 *Technology Aspects*

Technology needs to be specially designed for use by the elderly as they are more likely to suffer from various health conditions. Elderly people can be less patient, have difficulties in learning new tasks, or have physical or cognitive problems. In a study by Steele et al. [70], elderly participants expressed their concern about interacting with wireless sensor network technologies due to not being able to utilise all functionalities of the system. Participants emphasised that systems can be difficult to understand due to their age. Hence, technology needs to be designed in a way which does not induce anxiety and discomfort and that it can be easily adaptable.

We have identified three themes related to technological aspects including user context and requirements, learning and training, and design and usability.

6.2.1 *User Context and Requirements*

Despite the availability of various assistive technologies as shown in Table II, the rate of adoption is low. One of the reasons for this could be not understanding or stereotyping the users' needs and expectations [105] or simply not catering for the users' context and requirements. This makes the product less beneficial to the users and results in low acceptability and adoption. For example, some products are designed to be cost efficient for caregivers, instead of promoting the QoL of the elderly [88]. It has been found that products currently available are not focused on the user's context and therefore do not consider the behaviour, environment, or activities of the user. Systems need to provide information about the user's situation and environment to enable efficient remote monitoring and provide maximal benefit to the user [88], whilst ensuring ease of operation for the elderly user.

Understanding and catering for user requirements within this demographic are essential. For example, designing smart homes or intelligent environments where users have to alter their activities in accordance with the system, rather their own preferred way, should be avoided. Individual habits vary and forcing everyone to follow the same standards may lead to irritation, since every individual is different. Therefore, it is important to design a system which adapts to individual needs [11].

When designing a system for a specific audience, it must involve characteristics specialized to that user group. For example, some elderly people might have issues with reading small text on the screen, hence enhancing the font size, and creating interactive visualizations which are easily understandable is important. Overall, it is important to understand the audience at which the product is targeted, so it is more personalized and provides the perceived benefit, making it adoptable and acceptable.

6.2.2 *Learning and training*

Elderly people may have difficulty learning the new skills needed to interact with technologies due to their age and health conditions. This can result in difficulties when trying to accomplish regular activities of daily life. Hence expecting them to learn and operate complex interfaces or configurations is not appropriate. Studies show that participants did not want to train or learn new technologies [77, 56]. This causes fear, discomfort and anxiety issues when trying to use such assistive technologies [55, 17]. The elderly community often regards technology as difficult to operate. Generally, they consider that they are not capable enough to learn new products [88]. Mostly, they agree that modern technology provides many benefits but because they consider themselves to be incapable of operating technology, they are hesitant to use and therefore benefit from it [101].

Compared to young people, elderly people have more difficulty in learning to use new products. However, this could be improved by making products with simple interfaces which are easy to use, and understandable to the elderly community [101].

6.2.3 *Design and Usability*

Usability and design contribute to user experience, which indicates the level of ease of use, simplicity, and joy that a user can experience from interacting with the technology or product. It has been found that ease of use, interaction with the device and controllability were the most important characteristics of a system among the middle-aged and elderly participants [62, 14]. It is often assumed that a completely automated system might be easy to operate and interact with. Studies show that elderly participants when given choice between an automated and manual system, chose manual as it gives the feeling of having control over the system [43]. Systems may also create fear and irritation when a user is unable to control the system or interact with it [62]. Birchley et al suggest that providing improper focus on choices to end users puts burden on individuals [73]. It was found that mobile health applications designed for people with dementia lacked some features which impacted the user experience and its usage [106].

There is some debate around the level of importance of design. Gamberini et al. found that 50% of the problems reported in technology by users were due to usability. This could be resolved by adjusting the design or providing training. [107] In contrast, Ziefle et al. found that participants were less concerned about the design

of the technology. They were more focused on the benefits that the technology could provide [14]. Aesthetic design of the technology is another perspective for designers and researchers to keep in mind when designing and developing assistive technology [81], [108]. For example, Older women in a study considered device aesthetics as one of the barriers to wearable sensors and it was also found the wearable sensors which are prominent was not acceptable [81]. Technology can be designed in a way which is familiar to the older generation, this enhances its sense of identity and belonging to the home environment of the person [108].

Multimodal Interaction has also been found to be a positively evaluated technique for interacting with technology. This can include various interaction approaches such as voice, keyboard, touch screens [109], gestures [110], or facial expression [111] recognized by a system [109].

Designing systems in a user friendly and interactive manner is important. Elderly users need to interact with systems that are easier to operate and provide appropriate feedback [58], making them easier for users to comprehend. Careful design is crucial as bombarding users with too many unnecessary options or heavy designs can complicate the system and negatively impact user perception of the technology.

6.2.4 *Design and Data Bias*

Smart assistive technologies are being developed with latest artificial intelligence (AI) to help their users achieve full benefits of the technology. AI or machine learning uses training and test data to train and evaluate the systems. However the data used to train the systems can be based on data sets which are non-representative of the general case or the targeted audience. This creates bias which means the result is unjust for the audience which it is targeted towards [112, 113, 114].

A study was conducted for face recognition algorithms with influence of factors such as race, age and gender. It was found that accuracy of the system was lower for females, people with darker skin color and varied among age groups as well [115]. Many studies mentioned in Table 4 include various age and genders but there is a difference in number of recruited participants for age and gender. This variation can also lead to biased results for example a technology just reviewed and tested by males may not necessarily work for females or technology designed for older adults but tested by younger audience may also impact acceptance of technologies as they will not provide benefits as expected by the elderly people. A smart home study was conducted in a living environment where the residents were students and living at the the Missouri University of Science and Technology Solar Village. The purpose of the study was to study about the use and interest in adopting smart home technology [116]. The research is a great way to understand perspective of residents regarding smart home technology. However, the same study needs to be conducted with residents who are aged 65+ to understand their perspective for research aimed specifically for the elderly people. Another example is results achieved on gender difference. For example, there is some debate around difference in perception about smart home technology between genders. However this could be either statistically insignificant (only marginal difference) or perhaps differences in sample sizes. There may be a difference in need between the genders or differential financial constraints or awareness.

Data sets are a crucial part of AI applications. They need be large and aligned to the population they are designed for [102]. Data set accountability is also essential when determining what is going to be used in an application [63]. Another example is of patients with dementia where providing care varies on individual basis. This variation requires to be aware of the persons condition to be able to provide a comprehensive care. A behavior pattern based on a incomplete data set or on average values may not produce expected results and undermine the care [102]. Data can be collected from real environments and shared with hospitals and researchers over years to collect real data and experiment research on that [102].

7 Recommendations

Having surveyed the state of the art in assistive technology for smart homes, we are able to recommend that researchers and developers keep both the user needs and user experience in mind when designing an assistive system through: (1) Providing interfaces to control and configure the monitoring system with feedback for the user, (2) Designing a system which can easily integrate in daily life without creating any constraint or difficulties for the user, and (3) Defining clear and concise policies about data ownership enabling transparency and increasing trust.

Privacy seems to be one of the major concerns which initiates fear of technology leading to lack of trust. The elderly community appear to prefer assistive technologies which are unobtrusive and designed to protect their dignity and independence. Privacy concerns can lead users to opt-out of using technologies, despite the benefits they offer to them. Hence, assistive technologies must ensure independence, dignity, choice of control over technology and information sharing. Data ownership policies need to be introduced, this will include in Europe the General Data Protection Regulation (GDPR) or equivalent policies that may protect and help people understand about the data transmission, storage and sharing with third parties. Data protection is also crucial for data obtained from smart homes as risk of identity theft is high [74], and thus poorly secured smart home systems may be vulnerable to such attacks. Therefore, excellent security protocol measures must be followed.

Personalisation is an important factor which helps in earning users trust. Deriving the system around user's behaviour and activities may enable the technology to be more adaptive to the elderly's needs [65]. It is crucial to design technology in a way that provides informative visualisation of data and with simple interfaces which boosts ease of use and ease of comprehension. It is assumed that intelligent environments are easier to use and control. However, a fully automated system may take away the control from the user making them feel vulnerable to the system [62].

Hence providing users with a configuration panel to control the technology with appropriate feedback is necessary [93]. It can help improve the system if customer satisfaction feedback is taken continuously to improve the needs of the aged demographic. Study shows that the elderly people are reluctant to adopting technology which associates themselves as frail, vulnerable or has negative image of being too old attached to it. Therefore self image should be taken into consideration when designing or marketing an assistive technology [117].

Products available are often standalone and are made independently from one another. Therefore, the integration or connectivity for exchanging information is limited [88]. For example, products defined in Table II and Table III cannot be connected to exchange information. Hence, benefit is limited to each technology. Smart homes need to have devices which can communicate and exchange information, to provide meaningful data about the user and their environment. For this purpose, hybrid solutions need to be designed that contain a combination of various sensors and devices that communicate with each other. Systems need to be designed so that they comprise of multiple functionalities to provide a solution under one platform. For example, giving users reminders in a visually friendly calendar, summarized data, trends, alerts, information about the environment [11]. Making technologies integrable so they become part of the user's daily life rather than forcing people to change their routine.

8 Conclusion and Future Work

Smart homes consisting of several assistive technologies provide a variety of benefits for elderly people who want to live independently in the comfort of their own home and improve their QoL.

The elderly population is often stereotyped as dependent and resistant to change. However, the elderly people are demanding users who seek an independent and socially connected life. Studies show that people are willing to use these technologies, but factors such as privacy, perceived benefit, autonomy, cost, support for social environment and technology aspects (user context, user requirements, design, usability, learning and training) as highlighted in the findings of the extensively surveyed literature listed in Table 4 must be catered for when designing such systems. Customer satisfaction feedback can be utilized to help minimize these problems. This would help in improving the system design in accordance with user-specific needs, hence making it more adoptable. Trust needs to be gained by personalization and focusing on the needs of the user while incorporating ethical and technical aspects.

Finally, the key themes we have identified that smart home technologies need to consider are: (1) Provide intended or expected benefit, (2) Data ownership policies and data security, (3) Personalized systems to gain trust, (3) High reliability, (4) Cost effectiveness, (5) Promotion of autonomy (independence and control over technology), and (6) Caters for user requirements and enhances user experience.

Most importantly elderly people should be involved in the evaluation of these products as end users. If elderly people are not aware of, or satisfied with the products, then it is highly unlikely that they will be willing to accept and adopt these technologies. We would therefore recommend that future research includes investigating the perception of the elderly community on currently available commercial products and getting early feedback on state-of-the-art research.

There is a need to study the current rate of adoption and acceptability of assistive technology among the elderly people in the UK. Understanding the perception of available assistive technologies among the elderly people, as illustrated in Table 2 and Table 3, is essential. It is crucial to evaluate what the elderly are expecting from smart homes and assistive technologies. This data could help design future technologies to maximize the perceived benefits, acceptability, and adoption among the elderly community.

9 Conflict of Interest

The authors report no conflict of interest.

10 Funding

P. Pirzada is funded by the School of Computer Science and by St Leonard's Postgraduate College Doctoral Scholarship, both at the University of St Andrews.

References

[1] ONS. Overview of the UK Population: November 2018; 2018. Available from: http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/mid-2014/sty---overview-of-the-uk-population.html.

[2] Yu L, Chan WM, Zhao Y, Tsui K. Personalized Health Monitoring System of Elderly Wellness at the Community Level in Hong Kong. IEEE Access. 2018;6:35558–35567.

[3] Shahrestani S. Internet of Things and Smart Environments: Assistive Technologies for Disability, Dementia, and Aging. Springer; 2018.

[4] Organisation WH. Global Health and Aging; 2011. https://www.who.int/ageing/publications/global_health.pdf. Available from: https://www.who.int/ageing/publications/global_health.pdf.

[5] org uk A. Dementia UK; 2014. https://www.alzheimers.org.uk/sites/default/files/migrate/downloads/dementia_uk_update.pdf. Available from: https://www.alzheimers.org.uk/sites/default/files/migrate/downloads/dementia_uk_update.pdf.

[6] org uk A. Dementia UK; 2014. https://www.alzheimers.org.uk/sites/default/files/migrate/downloads/dementia_uk_update.pdf. Available from: https://www.alzheimers.org.uk/sites/default/files/migrate/downloads/dementia_uk_update.pdf.

[7] Caul S. Deaths registered weekly in England and Wales, provisional: week ending 25 September 2020. Office for National Statistics; 2020. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsregisteredweeklyinenglandandwalesprovisional/latest#deaths-registered-by-age-group.

[8] Rashidi P, Mihailidis A. A Survey on Ambient-Assisted Living Tools for Older Adults. IEEE Journal of Biomedical and Health Informatics. 2013;17(3):579–590.

[9] Bruegger P, Wilde A, Guibert L. On the Development of a Resident Monitoring System: Usability, Privacy and Security aspects. 2020:1–6.

[10] Cesta A, Cortellessa G, Fracasso F, Orlandini A, Turno M. User needs and preferences on AAL systems that support older adults and their carers. Journal of Ambient Intelligence and Smart Environments. 2018 Jan;10(1):49–70. Available from: https://doi.org/10.3233/AIS-170471.

[11] Pirzada P, White N, Wilde A. Sensors in Smart Homes for Independent Living of the Elderly. In: 2018 5th International Multi-Topic ICT Conference (IMTIC); 2018. p. 1–8.

[12] Almeida A, Mulero R, Rametta P, Urošević V, Andrić M, Patrono L. A critical analysis of an IoT—aware AAL system for elderly monitoring. Future Generation Computer Systems. 2019;97:598 – 619. Available from: http://www.sciencedirect.com/science/article/pii/S0167739X18321769.

[13] Ghayvat H, Mukhopadhyay S, Shenjie B, Chouhan A, Chen W. Smart home based ambient assisted living: Recognition of anomaly in the activity of daily living for an elderly living alone. In: 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC); 2018. p. 1–5.

[14] Ziefle M, Röcker C. Acceptance of Pervasive Healthcare Systems: A Comparison of Different Implementation Concepts. 4th ICST Conference on Pervasive Computing Technologies for Healthcare 2010. 2010 04.

[15] Lau J. Building a national technology and innovation infrastructure for an aging society; 2005. Available from: https://dspace.mit.edu/handle/1721.1/38566.

[16] Liu L, Stroulia E, Nikolaidis I, Cruz A, Ríos-Rincón AM. Smart homes and home health monitoring technologies for older adults: A systematic review. International Journal of Medical Informatics. 2016 04;91.

[17] Kavandi H, Jaana M. Factors that affect health information technology adoption by seniors: A systematic review. Health & Social Care in the Community. 2020;28(6):1827–1842. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/hsc.13011.

[18] Ienca M, Wangmo T, Jotterand F, Kressig R, Elger B. Ethical Design of Intelligent Assistive Technologies for Dementia: A Descriptive Review; 2017. Available from: https://dspace.mit.edu/handle/1721.1/38566.

[19] Dhukaram AV, Baber C, Elloumi L, van Beijnum B, De Stefanis P. End-User perception towards pervasive cardiac healthcare services: Benefits, acceptance, adoption, risks, security, privacy and trust. In: 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops; 2011. p. 478–484.

[20] Fischer AJ, Dart EH, Leblanc H, Hartman KL, Steeves RO, Gresham FM. AN INVESTIGATION OF THE ACCEPTABILITY OF VIDEOCONFERENCING WITHIN A SCHOOL-BASED BEHAVIORAL CONSULTATION FRAMEWORK. Psychology in the Schools. 2016;53(3):240–252. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/pits.21900.

[21] Ownsworth T, Theodoros D, Cahill L, Vaezipour A, Quinn R, Kendall M, et al. Perceived usability and acceptability of videoconferencing for delivering community-based rehabilitation to individuals with acquired brain injury: A qualitative investigation. Journal of the International Neuropsychological Society. 2020;26(1):47–57.

[22] Stahl JE, Dixon RF. Acceptability and willingness to pay for primary care videoconferencing: a randomized controlled trial. Journal of telemedicine and telecare. 2010;16(3):147–151.

[23] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly. 1989:319–340.

[24] Venkatesh V, Davis FD. A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science. 2000;46(2):186–204.

[25] Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: Toward a unified view. MIS quarterly. 2003:425–478.

[26] Fishbein M, Ajzen I. Belief, attitude, intention, and behavior: An introduction to theory and research. Addisson-Wesley; 1977.

[27] Davis FD, Bagozzi RP, Warshaw PR. Extrinsic and intrinsic motivation to use computers in the workplace 1. Journal of applied social psychology. 1992;22(14):1111–1132.

[28] Ajzen I, et al. The theory of planned behavior. Organizational behavior and human decision processes. 1991;50(2):179–211.

[29] of Western Ontario National Centre for Management Research U, Development. Personal Computing: Towards a Conceptual Model of Utilization. [London, Ont.]: National Centre for Management Research and Development . . . ; 1989.

[30] Orr G. Diffusion of innovations, by Everett Rogers (1995). Retrieved January. 2003;21:2005.

[31] Bandura A. Social foundations of thought and action. Englewood Cliffs, NJ. 1986;1986:23–28.

[32] Venkatesh V, Thong JY, Xu X. Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS quarterly. 2012:157–178.

[33] Goodhue DL, Thompson RL. Task-technology fit and individual performance. MIS quarterly. 1995:213–236.

[34] Brown SA, Venkatesh V. Model of adoption of technology in households: A baseline model test and extension incorporating household life cycle. MIS quarterly. 2005:399–426.

[35] Venkatesh V, Brown SA. A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges. MIS quarterly. 2001:71–102.

[36] Mashal I, Shuhaiber A, Daoud M. Factors influencing the acceptance of smart homes in Jordan. International Journal of Electronic Marketing and Retailing. 2020;11(2):113–142.

[37] Angioni M, Musso F. New perspectives from technology adoption in senior cohousing facilities. The TQM Journal. 2020.

[38] Conci M, Pianesi F, Zancanaro M. Useful, social and enjoyable: Mobile phone adoption by older people. In: IFIP Conference on Human-Computer Interaction. Springer; 2009. p. 63–76.

[39] McCloskey DW. The importance of ease of use, usefulness, and trust to online consumers: An examination of the technology acceptance model with older customers. Journal of Organizational and End User Computing (JOEUC). 2006;18(3):47–65.

[40] Guhr N, Werth O, Blacha PPH, Breitner MH. Privacy concerns in the smart home context. SN Applied Sciences. 2020;2(2):247.

[41] Pal D, Arpnikanondt C, Funilkul S, Razzaque MA. Analyzing the adoption and diffusion of voice-enabled smart-home systems: empirical evidence from Thailand. Universal Access in the Information Society. 2020:1–19.

[42] Hong A, Nam C, Kim S. What will be the possible barriers to consumers' adoption of smart home services? Telecommunications Policy. 2020;44(2):101867.

[43] Shareef MA, Kumar V, Dwivedi YK, Kumar U, Akram MS, Raman R. A new health care system enabled by machine intelligence: Elderly people's trust or losing self control. Technological Forecasting and Social Change. 2021;162:120334. Available from: https://doi.org/10.1016/j.techfore.2020.120334.

[44] Zhou J, Zhang B, Tan R, Tseng ML, Zhang Y. Exploring the Systematic Attributes Influencing Gerontechnology Adoption for Elderly Users Using a Meta-Analysis. Sustainability. 2020;12(7):2864.

[45] Sen A. Inequality reexamined. Oxford University Press; 1992.

[46] Nikou S, Agahari W, Keijzer-Broers W, de Reuver M. Digital healthcare technology adoption by elderly people: A capability approach model. Telematics and Informatics. 2020;53:101315.

[47] Marikyan D, Papagiannidis S, Alamanos E. Cognitive Dissonance in Technology Adoption: A Study of Smart Home Users. Information Systems Frontiers. 2020:1–23.

[48] Miskelly FG. Assistive technology in elderly care. Age and ageing. 2001;30(6):455–458.

[49] van Hoof J, Kort HSM, Rutten PGS, Duijnstee MSH. Ageing-in-place with the use of ambient intelligence technology: perspectives of older users. International journal of medical informatics. 2011 May;80(5):310—331. Available from: https://doi.org/10.1016/j.ijmedinf.2011.02.010.

[50] BAILEY C, FORAN TG, NI SCANAILL C, DROMEY B. Older adults, falls and technologies for independent living: a life space approach. Ageing and Society. 2011;31(5):829–848.

[51] Chou HK, Yan SH, Lin IC, Tsai MT, Chen CC, Woung LC, et al. A pilot study of the telecare medical support system as an intervention in dementia care: the views and experiences of primary caregivers. Journal of Nursing Research. 2012;20(3):169–180.

[52] Doyle J, Bailey C, Dromey B, Scanaill CN. BASE - An interactive technology solution to deliver balance and strength exercises to older adults. In: 2010 4th International Conference on Pervasive Computing Technologies for Healthcare; 2010. p. 1–5.

[53] Uzor S, Baillie L, Skelton D. Senior Designers: Empowering Seniors to Design Enjoyable Falls Rehabilitation Tools. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. CHI '12. New York, NY, USA: Association for Computing Machinery; 2012. p. 1179–1188. Available from: https://doi.org/10.1145/2207676.2208568.

[54] Al-Shaqi R, Mourshed M, Rezgui Y. Progress in ambient assisted systems for independent living by the elderly. SpringerPlus. 2016;5(1):624.

[55] Vassli LT, Farshchian BA. Acceptance of Health-Related ICT among Elderly People Living in the Community: A Systematic Review of Qualitative Evidence. International Journal of Human–Computer Interaction. 2018;34(2):99–116. Available from: https://doi.org/10.1080/10447318.2017.1328024.

[56] Coughlin JF, D'Ambrosio LA, Reimer B, Pratt MR. Older adult perceptions of smart home technologies: implications for research, policy & market innovations in healthcare. In: 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE; 2007. p. 1810–1815.

[57] Demiris G, Skubic M, Rantz M, Keller J, Aud M, Hensel B, et al. Smart Home Sensors for the Elderly: A Model for Participatory Formative Evaluation. Human-Computer Interaction. 2006 01;6.

[58] Robinson EL, Park G, Lane K, Skubic M, Rantz M. Technology for healthy independent living: Creating a tailored in-home sensor system for older adults and family caregivers. Journal of Gerontological Nursing. 2020;46(7):35–40.

[59] Lee C, Coughlin JF. PERSPECTIVE: Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers. Journal of Product Innovation Management. 2015;32(5):747–759. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/jpim.12176.

[60] Panico F, Cordasco G, Vogel C, Trojano L, Esposito A. Ethical issues in assistive ambient living technologies for ageing well. Multimedia Tools and Applications. 2020 Jul. Available from: http://dx.doi.org/10.1007/s11042-020-09313-7.

[61] Maan C, Gunawardana U. Barriers in acceptance of Ambient Assisted Living technologies among older Australians. In: 2017 IEEE Life Sciences Conference (LSC); 2017. p. 222–225.

[62] Kaasinen E, Kymäläinen T, Niemelä M, Olsson T, Kanerva M, Ikonen V. A User-Centric View of Intelligent Environments: User Expectations, User Experience and User Role in Building Intelligent Environments. Computers. 2012 12;2:1–33.

[63] Sovacool BK, Del Rio DDF. Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. Renewable and Sustainable Energy Reviews. 2020;120:109663.

[64] Cannizzaro S, Procter R, Ma S, Maple C. Trust in the smart home: Findings from a nationally representative survey in the UK. Plos one. 2020;15(5):e0231615.

[65] Guo X, Zhang X, Sun Y. The Privacy-Personalization Paradox in MHealth Services Acceptance of Different Age Groups. Electron Commer Rec Appl. 2016 Mar;16(C):55–65. Available from: https://doi.org/10.1016/j.elerap.2015.11.001.

[66] Remmers H. Environments for ageing, assistive technology and self-determination: ethical perspectives. Informatics for Health and Social Care. 2010;35(3-4):200–210.

[67] Courtney K. Privacy and Senior Willingness to Adopt Smart Home Information Technology in Residential Care Facilities. Methods of information in medicine. 2008 02;47:76–81.

[68] Courtney KL, Demeris G, Rantz M, Skubic M. Needing smart home technologies: the perspectives of older adults in continuing care retirement communities. Informatics in Primary Care. 2008;16:195—201.

[69] Kadylak T, Cotten S. United States older adults' willingness to use emerging technologies. Information, Communication & Society. 2020 01;23:1–15.

[70] Steele R, Lo A, Secombe C, Wong YK. Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare. International journal of medical informatics. 2009;78(12):788–801.

[71] Mulvenna M, Boger J, Bond R. Ethical by Design: A Manifesto. In: Proceedings of the European Conference on Cognitive Ergonomics 2017. ECCE 2017. New York, NY, USA: Association for Computing Machinery; 2017. p. 51–54. Available from: https://doi.org/10.1145/3121283.3121300.

[72] Portet F, Vacher M, Golanski C, Roux C, Meillon B. Design and evaluation of a smart home voice interface for the elderly — Acceptability and objection aspects. Personal and Ubiquitous Computing. 2012 01;17:1–18.

[73] Birchley G, Huxtable R, Murtagh M, Meulen R, Flach P, Gooberman-Hill R. Smart homes, private homes? An empirical study of technology researchers' perceptions of ethical issues in developing smart-home health technologies. BMC Medical Ethics. 2017 12;18.

[74] Sánchez VG, Taylor I, Bing-Jonsson PC. ETHICS OF SMART HOUSE WELFARE TECHNOLOGY FOR OLDER ADULTS: A SYSTEMATIC LITERATURE REVIEW. International Journal of Technology Assessment in Health Care. 2017;33(6):691–699.

[75] Wilkowska W, Ziefle M. Perception of privacy and security for acceptance of E-health technologies: Exploratory analysis for diverse user groups. In: 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops. IEEE; 2011. p. 593–600.

[76] Wilkowska W, Ziefle M. Privacy and data security in E-health: Requirements from the user's perspective. Health informatics journal. 2012 09;18:191–201.

[77] Rahimpour M, Lovell NH, Celler BG, McCormick J. Patients' perceptions of a home telecare system. International journal of medical informatics. 2008;77(7):486–498.

[78] Chernbumroong S, ATKINS A, Yu H. Perception of smart home technologies to assist elderly people. In: 4th International Conference on Software, Knowledge, Information Management and Applications. 4th International Conference on Software, Knowledge, Information Management . . . ; 2010. p. 90–97.

[79] Hoque R, Sorwar G. Understanding factors influencing the adoption of mHealth by the elderly: An extension of the UTAUT model. International journal of medical informatics. 2017;101:75–84.

[80] Etemad-Sajadi R, Santos GGD. Senior citizens' acceptance of connected health technologies in their homes. International Journal of Health Care Quality Assurance. 2019 Oct;32(8):1162–1174. Available from: https://doi.org/10.1108/ijhcqa-10-2018-0240.

[81] Reeder B, Chung J, Lyden K, Winters J, Jankowski CM. Older women's perceptions of wearable and smart home activity sensors. Informatics for Health and Social Care. 2020;45(1):96–109.

[82] Ashraf A, Liu JH, Rauf Q. Aging Population Perception and Post Adoption Behavior About the Usability of Smart Home Technology of Pakistani Culture. In: Proceedings of 2020 the 6th International Conference on Computing and Data Engineering; 2020. p. 179–188.

[83] Shirani F, Groves C, Henwood K, Pidgeon N, Roberts E. 'I'm the smart meter': Perceptions of smart technology amongst vulnerable consumers. Energy Policy. 2020;144:111637.

[84] Schlomann A, Seifert A, Zank S, Rietz C. Assistive Technology and Mobile ICT Usage Among Oldest-Old Cohorts: Comparison of the Oldest-Old in Private Homes and in Long-Term Care Facilities. Research on Aging. 2020;42(5-6):163–173.

[85] Weck M, Afanassieva M. AGEING PEOPLE'S TRUST IN DIGITAL ASSISTIVE TECHNOLOGY: INITIAL TRUST FORMATION; 2020.

[86] Zou P, Stinson J, Parry M, Dennis CL, Yang Y, Lu Z. A Smartphone App (mDASHNa-CC) to Support Healthy Diet and Hypertension Control for Chinese Canadian Seniors: Protocol for Design, Usability and Feasibility Testing. JMIR Research Protocols. 2020 Apr;9(4):e15545. Available from: http://dx.doi.org/10.2196/15545.

[87] Lin TTC, Bautista JR, Core R. Seniors and mobiles: A qualitative inquiry of mHealth adoption among Singapore seniors. Informatics for Health and Social Care. 2020;45(4):360–373. PMID: 32484720. Available from: https://doi.org/10.1080/17538157.2020.1755974.

[88] Vastenburg MH, Visser T, Vermaas M, Keyson DV. Designing Acceptable Assisted Living Services for Elderly Users. In: Aarts E, Crowley JL, de Ruyter B, Gerhäuser H, Pflaum A, Schmidt J, et al., editors. Ambient Intelligence. Berlin, Heidelberg: Springer Berlin Heidelberg; 2008. p. 1–12.

[89] Peek ST, Wouters EJ, Van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJ. Factors influencing acceptance of technology for aging in place: a systematic review. International journal of medical informatics. 2014;83(4):235–248.

[90] Calvaresi D, Cesarini D, Sernani P, Marinoni M, Dragoni AF, Sturm A. Exploring the ambient assisted living domain: a systematic review. Journal of Ambient Intelligence and Humanized Computing. 2016 May;8(2):239–257. Available from: http://dx.doi.org/10.1007/s12652-016-0374-3.

[91] Sun N, Rau PLP. The acceptance of personal health devices among patients with chronic conditions. International journal of medical informatics. 2015;84(4):288–297.

[92] Perry J, Beyer S, Holm S. Assistive technology, telecare and people with intellectual disabilities: ethical considerations. Journal of Medical Ethics. 2009;35(2):81–86.

[93] Zaad L, Allouch SB. The influence of control on the acceptance of ambient intelligence by elderly people: An explorative study. In: European Conference on Ambient Intelligence. Springer; 2008. p. 58–74.

[94] Tetteh N, Amponsah O. Sustainable Adoption of Smart Homes from the Sub-Saharan African Perspective. Sustainable Cities and Society. 2020:102434.

[95] Baraka K, Ghobril M, Malek S, Kanj R, Kayssi A. Low Cost Arduino/Android-Based Energy-Efficient Home Automation System with Smart Task Scheduling. In: 2013 Fifth International Conference on Computational Intelligence, Communication Systems and Networks; 2013. p. 296–301.

[96] Andersson L. Loneliness and perceived responsibility and control in elderly community residents. Journal of Social Behavior and Personality. 1992;7(3):431.

[97] Holmén K, Ericsson K, Andersson L, Winblad B. Loneliness among elderly people living in Stockholm: a population study. Journal of Advanced Nursing. 1992;17(1):43–51. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2648.1992.tb01817.x.

[98] Embarak F, Ismail NA, Othman S. A systematic literature review: the role of assistive technology in supporting elderly social interaction with their online community. Journal of Ambient Intelligence and Humanized Computing. 2020:1–14.

[99] Lindberg RS, De Troyer O. Towards a Reference Model of Guidelines for the Elderly Based on Technology Adoption Factors. In: Proceedings of the 6th EAI International Conference on Smart Objects and Technologies for Social Good; 2020. p. 30–35.

[100] Yeh SC, Lo S. Living alone, social support, and feeling lonely among the elderly. Social Behavior and Personality: an international journal. 2004 01;32:129–138.

[101] Chen K, Chan AH. A review of technology acceptance by older adults. Gerontechnology. 2011.

[102] Rubeis G. The disruptive power of Artificial Intelligence. Ethical aspects of gerontechnology in elderly care. Archives of Gerontology and Geriatrics. 2020;91:104186. Available from: http://www.sciencedirect.com/science/article/pii/S0167494320301801.

[103] Upchurch M. 7. In: Gender Bias in Research. John Wiley & Sons, Ltd; 2020. p. 139–154. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119315063.ch7.

[104] Ameen N, Willis R, Hussain Shah M. An examination of the gender gap in smartphone adoption and use in Arab countries: A cross-national study. Computers in Human Behavior. 2018;89:148 – 162. Available from: http://www.sciencedirect.com/science/article/pii/S0747563218303753.

[105] Eisma R, Dickinson A, Goodman J, Syme A, Tiwari L, Newell AF. Early user involvement in the development of information technology-related products for older people. Universal Access in the Information Society. 2004;3(2):131–140.

[106] Brown A, O'Connor S. Mobile health applications for people with dementia: a systematic review and synthesis of qualitative studies. Informatics for Health and Social Care. 2020;45(4):343–359. PMID: 32237937. Available from: https://doi.org/10.1080/17538157.2020.1728536.

[107] Gamberini L, Alcañiz Raya M, Barresi G, Fabregat M, Ibanez F, Gonçalves F, et al. Cognition, technology and games for the elderly: An introduction to ELDERGAMES Project. PSYCHOLOGY JOURNAL. 2006 01;4:285–.

[108] Leikas J. In: Aesthetic Well-Being and Ethical Design of Technology. Cham: Springer International Publishing; 2020. p. 155–166. Available from: https://doi.org/10.1007/978-3-030-53483-7_10.

[109] Blumendorf M, Feuerstack S, Albayrak S. Multimodal user interfaces for smart environments; 2008.

[110] Wan Q, Li Y, Li C, Pal R. Gesture recognition for smart home applications using portable radar sensors. In: 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2014. p. 6414–6417.

[111] Fei Zuo, de With PHN. Real-time face recognition for smart home applications. In: 2005 Digest of Technical Papers. International Conference on Consumer Electronics, 2005. ICCE.; 2005. p. 35–36.

[112] Lloyd K. Bias amplification in artificial intelligence systems. arXiv preprint arXiv:180907842. 2018.

[113] Buolamwini J, Gebru T. Gender shades: Intersectional accuracy disparities in commercial gender classification. In: Conference on fairness, accountability and transparency; 2018. p. 77–91.

[114] Wang L, Wong A. Implications of computer vision driven assistive technologies towards individuals with visual impairment. arXiv preprint arXiv:190507844. 2019.

[115] Klare BF, Burge MJ, Klontz JC, Bruegge RWV, Jain AK. Face recognition performance: Role of demographic information. IEEE Transactions on Information Forensics and Security. 2012;7(6):1789–1801.

[116] Wright D, Shank DB. Smart Home Technology Diffusion in a Living Laboratory. Journal of Technical Writing and Communication. 2020;50(1):56–90.

[117] Astell AJ, McGrath C, Dove E. "That's for old so and so's!": does identity influence older adults' technology adoption decisions? Ageing & Society. 2020;40(7):1550–1576.

word count

Counts of words

```
File: main.tex
Encoding: utf8
Sum count: 9608
Words in text: 9486
Words in headers: 66
Words outside text (captions, etc.): 56
Number of headers: 24
Number of floats/tables/figures: 6
Number of math inlines: 0
Number of math displayed: 0
Subcounts:
  text+headers+captions (#headers/#floats/#inlines/#displayed)
  200+10+0 (2/0/0/0) _top_
  531+1+28 (1/3/0/0) Section: Introduction
  591+3+0 (1/0/0/0) Section: Motivation and Goals
  64+1+9 (1/1/0/0) Section: Methodology
  279+2+0 (1/0/0/0) Section: Acceptance Models
  248+3+9 (1/2/0/0) Section: Commercialised Assistive Technologies
  27+1+0 (1/0/0/0) Section: Findings
  5131+20+10 (7/0/0/0) Subsection: \emph{Ethical Considerations}
  1455+16+0 (5/0/0/0) Subsection: \emph{Technology Aspects}
  556+1+0 (1/0/0/0) Section: Recommendations
  371+4+0 (1/0/0/0) Section: Conclusion and Future Work
  7+3+0 (1/0/0/0) Section: Conflict of Interest
  26+1+0 (1/0/0/0) Section: Funding
```