Designing Digital Technologies and Safeguards for Improving Activities and Well-Being for Aging in Place

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Abstract. Older adults (65+) are becoming primary users of technologies, including IoTs, wearables and emerging smart systems, especially for aging in place and in daily living activities related to better health and wellness. Research demonstrates some critical features in home health care and wearable technology adoption by older adults such as wearability, device appearance, display and interaction, the modeling and technical aspects of data measurement and presentation, with more sophisticated, personalized interaction systems and data analysis expected over time. The design and development of home health care technologies are often led by the requirements of their social and caregiving environments rather than the needs and preferences of older adult users. The mismatch between functionalities, intrinsic motivations and expected benefits has a detrimental impact on user acceptance. User acceptance is critical for technology to be integrated within daily living especially in areas such as IoTs and wearables. Cybersecurity is an essential part of a safe, effective and reliable healthcare delivery system. Security and privacy challenges can be overcome by implementing best practices to safeguard systems and devices. There are significant privacy risks associated with wearables and home IoTs. The literature review has identified emerging issues that underscore the need to develop a set of guidelines for conducting HCI and human factors research based on an understanding of older adults' perceptions and preferences about data privacy and security. Additionally, directions for current and future research are discussed in the paper, including late breaking research on virtual care and support vulnerable seniors during the COVID 19 pandemic.

Keywords: Human computer interaction · Human factors · IoT · Wearables · Privacy · Aging in place

1 Introduction

Older adults (65+) are becoming primary users of technologies, including IoTs, wearables and emerging smart systems, especially for aging in place, in daily living activities

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related to better health and wellness [1–3]. However, such technologies are often not designed for older users and can pose serious privacy and security concerns due to their novelty, complexity, and propensity to collect vast amounts of sensitive information [4–7].

Research indicates that isolation from significant relationships and support services is one of the most significant factors undermining the quality of life and longevity of seniors [8, 9]. The COVID-19 pandemic is causing untold fear and suffering for older people across the world [10]. The literature also points out that with the right tools, seniors of all ages can create unique solutions to enhance the quality of their life and stay connected. For example, many older adults use wearables, such as electronic monitoring devices, that enable them to track and monitor their health-related physical fitness metrics including steps taken, level of activity, walking distance, heart rate, and sleep patterns to improve their health and wellbeing. These devices are also used for treatment to collect certain information (e.g., steps, heart rate, and sleep) to better manage functional status assessment and provide support in the clinical setting and for aging at home. Wearables have potential as an intervention tool to increase activity levels for older adults through self-monitoring in the short term, however there is a need to evaluate the long-term impacts of these devices [1]. Wearables are useful for motivating older adults through personal goal setting, self-monitoring and for social connectivity. Both wearables and IoTs are critical parts of the Personal Informatics (PI) systems, "those that help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" [12].

Research demonstrates some critical features in wearable technology adoption by older adults such as wearability, device appearance, display and interaction, the modeling and technical aspects of data measurement and presentation, with more sophisticated, personalized interaction systems and data analysis expected over time [11]. Users over age 50 with chronic illnesses and older adults would benefit from cheaper and more compatible devices, and user acceptance may be improved by addressing barriers during deployment, such as by providing tutorials on challenging features and communicating the device's usefulness. There are, however, some privacy risks associated with wearables and IoTs. In contrast to medical health wearables and IoTs, where electronic records are created and managed by healthcare providers, users of consumer health wearables and IoTs create and manage their own personal health information without the help of a physician [13]. While data collected by healthcare wearables and IoT devices are subject to various legal protections [14], the same protections are not provided for in consumer wearables. Researchers [15] have identified a number of privacy risks for consumer wearables including user context privacy, bystander privacy during data collection, and external data sharing privacy.

The current pandemic has created challenges for healthcare in both hospital and in home care settings with an increased need for virtual care and online consultations for vulnerable populations; seniors living alone and in fair or poor health are considered vulnerable and at-risk for health-related complications. Dr. Paul Hebert, Special Advisor to the Canadian Red Cross expressed that "these are not new challenges for isolated older adults, especially those with chronic health concerns. The pandemic simply underscores them" [16]. The pandemic has also increased the proliferation of technological solutions

around digital health. Older adults in particular could be the main benefactors from this shift, and, as a result, become primary users of technologies for aging in place, including IoTs, wearables and emerging smart systems, for daily living activities related to better health and wellness. The next section will look at the emerging issues from the literature on HCI and health technologies related to technology acceptance, privacy and security challenges for aging in place.

2 Literature Review

Recent HCI research addresses the major societal concern of an aging population in the developed world. Currently most websites, apps, and digital devices are used by diverse populations, thus they should not be design with a 'one size fits all' approach [17]. The 50+ age group is the fastest growing demographic online and according to Home Care Magazine, 46% of baby boomers use a cell phone, 65% are active on social media, and a whopping 75% are digital buyers [18]. Research has shown that ability and motivation to use new technologies are strongly determined by work experience and education, and the difficulties people experience around the use of technology are related to past performance rather than age-related factors [19].

The rapid development of digital proficiency in an aging population has accelerated research and development in areas of gerontechnolgy, which merges the study of aging with the study of technology, and includes the following five aspects: enhancement, prevention, compensation, care and research [20]. With over 10,000 people turning 65 every day in America, this is a market about to explode, and building technology for an aging population is at a critical tipping point [18].

The HCI literature points to important issues related to user acceptance factors in health applications aimed at an aging population [3]. Researchers argue that the purpose and functionalities of gerontechnologies are often led by the requirements of their social and caregiving environments [21] rather than the needs and preferences of older adult users resulting in a mismatch between functionalities, basic motivations and expected benefits which in turn has a negative impact on user acceptance [21], which is critical for technologies to be integrated as part of daily living [22].

The literature around technology acceptance highlights the connection between technologies that support self-determination as having a positive impact on acceptance. That is, older adults are 'intrinsically motivated' by technology that promotes autonomy [23]. Acceptance and perceptions around assistive technologies can also be influenced by individual factors such as gender, previous experience, attitude towards technology, and education. Environmental factors such as accessibility and the availability of assistance, support and guidance from immediate family or their social network can either positively or negatively affect acceptance and perceptions around assistive technologies and their integration as part of daily living [23]. Age-related factors such as biological age, perceived age and attitudes towards aging are considered relevant parameters for technology acceptance [24], and part of the ever changing demographics to consider in an aging population. Capturing the daily life of older adults has become a major task for researchers and service providers alike. A thorough understanding of the expectations of

older adults, their likes and dislikes, and the nature of their social relationships is essential in designing meaningful tools and devices they will actually accept and integrate as part of their daily living.

One type of health technology for use in the home is wearable technology, which refers to any electronic device with sensors, typically worn on the body, that is used to collect and deliver information about health and fitness related activities. Wearable devices (such as smart watch, smart ring, smart band, smart clothing, etc.) are used widely by the general population to track exercise and health [25]. Originally designed to support medical needs, modern consumer wearables have sensors that monitor and record not only sensitive patient health information (such as heart rate, respiratory rate, oxygen saturation, blood pressure, temperature, ECG, etc.), but also record physical activity (e.g., steps taken, distance traveled, sleep patterns, exercise activity, falls, etc.). Consumer wearables also serve a function of ancillary healthcare, when medical attention is triggered by a wearable device that detects a life threatening event (heart attack, stroke, fall, etc.). Widespread use of wearables has allowed researchers [26] to use data from wearables for tracking influenza-like illness in real time using temperature, heart rate and activity data, including location. In other studies of activity trackers, comfort issues related to continuous wearing, design comparability considering older adult's mental and physical constraints, and utility of historical activity data were identified as major usability issues [27]. Historical data without any interpretation display in the tracker or associated apps may not be useful for older adults. The data needs to be more informative and deliver more meaningful and empowering directions for long-term use [27].

Cybersecurity is an essential part of a safe, effective and reliable healthcare delivery system [28]. Researchers note that privacy and security challenges can be overcome by implementing best practices to safeguard systems and devices [29]. The context of use is also important: devices operating in the home, such as wearable technology are more exposed to unauthorized access than those in more controlled environments, such as nursing homes and hospitals [30]. Despite the widespread proliferation of wearables, there are many privacy issues and risks associated with consumer wearables that have yet to be resolved by industry and law makers [13]. In contrast to medical health wearables for professional usage, where electronic records are created and managed by healthcare providers, users of consumer health wearables create and manage their own personal health information without the help of physicians [14]. While data collected by healthcare wearables are subject to various legal protections [15], the same protections are not available for consumer wearables.

Data generated by consumer wearables are extremely personal and considered to be even more sensitive and vulnerable than user's financial data. If accessed by a hacker, health data and activity data from a wearable (including location data) could easily be used against the individual. Researchers [13] have identified a number of privacy risks for consumer wearables including user context privacy, bystander privacy during data collection, and external data sharing privacy, and proposed technology solutions to mitigate the risks. Typically, wearable data is stored on the server of a company-provider, therefore, the user's data is never immune to a breach by hackers and there is no guarantee of permanent data deletion even if the user wants to delete their own account data [13]. The literature indicates that users are frequently not aware of the

degree of anonymization of their data on the provider's server, they have concerns about the improper access to their data, and have concerns about the privacy complacency of companies in particular [31]. Thus, along with privacy by design technology solutions for wearables, privacy laws and regulations need to be updated to include wearables, and new ways to improve clear notice and consent from users need to be developed.

The concept of privacy by design by Dr. Ann Cavoukian states that the principles of Fair Information Practice (FIPs) need to be built into systems [21]. Home healthcare technologies need to be built with cybersecurity in mind; however, such systems also have to consider human needs and perceptions of security in order to ensure successful use [31]. Research has shown that older populations are very aware of privacy issues [33, 34] and that privacy considerations are key factors in the adoption of assistive technologies. Privacy seems to be more of an issue for technologies designed for aging in place, especially as older populations with health issues must learn to manage their personal health data [35]. Older people are faced with having to navigate a complex relationship between loss of privacy and increased freedom for users and caregivers to collect data and opening up the home environment to calls, checks, and visits.

Additionally, systems perceived as intrusive can impact user acceptance – a fact that many researchers overlook [33]. Applications of technological solutions still suffer from sociocultural misunderstandings of group differences, and poor acceptability of technology for patients and caregivers [33]. Researchers emphasize that older adult users should be included in the design of remote home monitoring technologies and in gathering privacy requirements for such technologies [34, 36]. Care technologies in the home environment require different contextual considerations whereby privacy issues are key. From a data privacy perspective, devices operating in the home are more exposed to unauthorized access than those in more controlled environments, such as nursing homes and hospitals [30]. Additionally, devices in the home also invade the personal space of the user, and their friends and family.

The literature points to barriers such as the concern for privacy, followed by issues of trust when adopting technologies for use by older adults [32]; however there is a willingness to give up some privacy for the benefit of staying in their home [37]. Older adults view personal data as only one important dimension of privacy concerning home healthcare technologies: they also have other privacy concerns related to aspects of personal privacy such as intrusiveness and feelings of surveillance—this has an impact on technology acceptance [38, 39]. Technological solutions for home healthcare still suffer from sociocultural misunderstanding of group differences, and poor acceptability of technology from patients, caregivers and clinicians [38]. Researchers emphasize that older adults as end-users should be included in the design process as well as in gathering privacy requirements for such technologies [34, 36]. Privacy concerns should be considered when designing health technologies for in home use, and not just the privacy of personal data [34]. All levels of users should be consulted, including the end user (older adults), secondary users (caregivers) and tertiary users (clinicians). An overarching theme that warrants further exploration is the trade-off between privacy (data and information privacy), the sense of surveillance and the invasion of personal space and the freedom of safely living independently at home [39, 40]. End-user perspectives and

the need for autonomy and control must be balanced with privacy, security and trust in systems and devices [40].

2.1 User Acceptance and Satisfaction

While there is a large swath of literature on heath related IoTs and wearables for older adults, most current publications on technological solutions for aging in place do not report on user acceptance and satisfaction [29]. Research demonstrates that the following conditions are necessary for persuasive technology to promote a behavior: motivation, physical ability, and an effective trigger [41]. Additionally, persuasive fitness technologies are attractive because they "automate" behavior change [42]. Persuasive technologies should offer convenient data collection, analysis, and storage over long periods of time with immediate automated feedback. There are few studies of user needs and user acceptance of wearables and IoTs by older adults. For example, as shown by face-to-face interviews with senior citizens [43], older people see the future of wearable devices in the healthcare sector by indicating the need for stakeholders to get involved in promoting physical activity trackers to patients as a possible way to improve their health. In fact, most of the interviewed older adults wished the devices were available in pharmacies, and that they could learn about the devices from someone in health care, such as pharmacists, similarly to what is done with other health-monitoring systems (e.g., blood glucose meters, blood pressure meters), with the standard health-related tax exemptions or credits [43]. Older adults who were interviewed also indicated that they were also interested in doctors or other health care professionals potentially taking advantage of the data provided by the devices [43]. The functionality of IoT/wearables data sharing with health professionals would be particularly useful in a pandemic lock out situation.

Older adults often feel that modern consumer wearables are "not built with us in mind," that they are created "for someone younger," and that devices needed a more "tech-savvy" user. The design and development of home healthcare technologies are often led by the requirements of their social and caregiving environments rather than the needs and preferences of older adult users resulting in a mismatch between functionalities, intrinsic motivations and expected benefits which in turn has a detrimental impact on user acceptance [21]. User acceptance is critical for technology to be integrated within daily living [22] especially in areas such as IoTs and wearables. Another issue brought up was that there were no instruction manuals, which prevent them from feeling comfortable with the various devices [43]. Long-term use was significantly associated with wearing the device every day, being female, exercising more frequently, having higher education, not engaging in step count competition, and not having chronic conditions [44]. Older adults may not always accept and use wearables, even if they have initially accepted the technology. Acceptance of this technology may be improved by addressing barriers during deployment, such as providing tutorials on challenging features and communicating the device's usefulness. Users over age 50 with chronic illnesses would benefit from cheaper and more compatible devices, and more comprehensive set-up assistance.

Wearable activity trackers (WAT) are electronic monitoring devices that enable users to track and monitor their health-related physical fitness metrics including steps taken, level of activity, walking distance, heart rate, sleep patterns, etc. [11]. WAT are useful for motivating patients through personal goal setting, self- monitoring and the devices' social connectivity enhancements. Users have mixed feelings after having disengaged with their device, ranging from relief and freedom to feelings of frustration and guilt about having abandoned it. The most commonly cited deterrent to smart wearables is privacy concerns. According research, privacy and security are the foremost concerns of consumers regarding the use of smart wearables [45]. Research on consumer abandonment of smart wearable devices revealed privacy considerations as the most prevalent reason for desertion [46]. The study found that 45.2% of the time privacy concerns were cited as driving consumer decisions to abandon smart wearables. The concerns were multi-faceted, including users being uncomfortable with location tracking that revealed their movements to others and objected to selling their information to third parties for advertising purposes. In recent years, advancements in smart wearables have allowed the integration of biotechnology to collect consumer health data. "In the age of the Fitbit, strapping technology onto your body to track and monitor yourself is not only doable, but desirable. Bio-sensing wearables meld together passive and active data collection, often offering round the clock and personal self-surveillance, knowledge, and control. In other words, wearable technologies that have come into fashion are making the line between creepy vs. cool much fuzzier." [47]. Without adequate assurances and practices in place to protect highly personal biotechnology data and information, consumers will remain hesitant to participate in the ecosystem of IoT. Robust privacy legislation is a necessary ingredient for an effective ecosystem of IoT and wearables. While it is users who opt into data sharing, how the data will be shared is deeply affected by designers, "who have the power to enable and constrain certain action possibilities through their design choices" [48].

Currently, the lack of standards around user privacy and security issues can be a potential regulatory hurdle for adoption of wearables and IoTs by older adults, as well as data sharing issues due to low integration between public and private healthcare systems [49].

2.2 Design Guidelines

The current literature review has identified emerging issues that underscore the need to develop a set of guidelines for conducting HCI and human factors research that builds an in-depth understanding of older adults' perceptions and preferences about data privacy and security for these technologies. Research studies on older adults' use of wearable trackers demonstrate that the successful design of an all-purpose, universal device is unreasonable and that design concepts and data models should align with the personal preferences of various groups of users [11]. More research needs to be carried out to fully understand the best practices for designing wearables for older adults. Current recommendations and suggestions include the following (see Table 1):

Table 1. Design and user experience recommendations for wearable trackers for older adults.

Recommendations and suggestions for wearable trackers for older adults	References
Make devices available in pharmacies, with the standard health-related tax exemptions or credits	[43]
Provide an option to learn about the devices from someone in health care, such as pharmacists, similarly to what is done with other health-monitoring systems (e.g., blood glucose meters, blood pressure meters)	[43]
Include a simple paper-based instruction manual that clearly addresses set up, how to use the device, and basic problem solving	[43]
Allowing access to device on both a computer and a mobile app would allow older adults to access data in a more familiar way, in terms of comfort with technology and by allowing them to view results on a bigger screen	[43]
Displays for wearables should consider using large, high-contrast text with large light-on-dark letters and numbers to allow for easier viewing	[43]
Waterproof design decreases worry about the fragility of the device if it is forgotten, and accidentally damaged by doing dishes or the laundry, and also allows older adults to use it in the water-based activities that are commonly recommended by health care providers as part of a low-impact way to increase physical activity	[43]
Older adults use wearable trackers longer if they use a wider variety of functions to track health and activity levels (calories burned, distance, heart rate, mood, sleep time, steps, blood oxygen saturation, etc.)	[44]
Wearable trackers targeting patients with chronic illness should focus on mHealth, integrating programs that designed for specific patient populations, using a customized regimen and specific levels of physical activities	[11]
Users over age 50 with chronic illnesses would benefit from cheaper and more compatible devices, and more comprehensive set-up assistance	[11]
Critical features for adoption include wearability, device appearance, display and interaction, as well as the modeling and technical aspects of data measurement and presentation	[11]
To stay engaged with the device, users expect a more sophisticated, personalized interaction system and data analysis over time	[11]
Technology providers should increase the reliability of their products, by limiting technology errors, malfunctioning devices, improving connectivity, and enhancing the analytics for better healthcare delivery and treatments	[49]
There is an ethical issue around the inclusion that needs to be resolved, especially in insurance-defined wearable-based new products, of people with specific conditions (e.g., subjects in a wheelchair), which, in programs based solely on physical activity evaluation, may be disadvantaged by earning a lower amount of points/discounts compared to normal subjects owing to their conditions	[49]

There is also the need to implement cybersecurity safeguards with design considerations for enhancing privacy and security for sharing health information, including designing interfaces not only for single users but with the ability to add others as medical conditions change; either temporarily, during times of surgery or illness recovery or more permanently, during cognitive decline. An in-depth case study of adults with mild cognitive impairments and their caregivers highlighted the importance of shared decision making-user interfaces to improve joint decision making practices [50]. A study of residents in senior care facilities identified the design implications to support communication for older adult related to privacy and sharing of health information. The design consideration presented in Table 2 are based on privacy and health information sharing concerns derived from semi-structured interviews with a dozen residents from senior care facilities [51].

Table 2. Design consideration for privacy and health information sharing

Category of decision making	Recommendation
Choosing recipients	Should be based on information relevance
Levels of communication	Should be based on urgency, relevance and individual attitudes
Content and information	Should be based on information relevance and characteristics of recipient
Choice of delivery method	Should be based on urgency and established communication style

The literature on mHealth and new technologies for home care highlights the importance of autonomy, self-management and control as part of the efforts around aging in place, along with the need for user centered, collaborative, interdisciplinary research and development [52]. The next section highlights research and development efforts currently underway as part of the National Research Council of Canada pandemic challenge program with vulnerable seniors.

3 Current Research and Development

Work is underway to advance the design and implementation of an early prototype help system for tablet devices to support older adults as they interact with unfamiliar interfaces and new technologies for aging in place. This work will explore the design of contextual support for vulnerable seniors as many current interfaces such as mobile (i.e., tablet) devices often do not incorporate elements that align with older adults' models of use: explicit help menus, user manuals, and navigational cues and affordances.

The current pandemic will require remote usability testing with end-users from their home, using online tools that help to identify navigational and usability issues. Usability testing will help to identify important elements of interface and navigational cues to manage health information, including preferences for digital or tactile help buttons, and which elements would be more effective in supporting older adults as they interact with

new interfaces in the context of managing their own health and wellness, particularly for a range of seniors who are no longer absolute novices. This work aims to provide useful recommendations for designers of mobile interfaces, who seek to implement effective help and support systems for vulnerable seniors.

A survey on home health care services is also being launched across the USA and Canada. This project will use convenience sampling to collect primary data through online surveys. The online surveys will target persons who are concerned about the well-being and care of aging adults and personnel who work in a clinical or administrative capacity in home health care services. The end-user survey will be distributed widely across the USA and Canada using internet sites like Quora, LinkedIn, Reddit, or other panels of interested people. Publicly available information and lists provided by industry associations will be used along with an e-mail invitation to professionals with the request to fill out an online survey. A targeted sample size of 300 respondents is expected. The knowledge from survey results will help to identify opportunities to improve adoption experiences for innovative health services for vulnerable seniors. This research is especially important in the face of the current pandemic where seniors would have benefited greatly from remote care technology when face-to-face interaction was restricted. There are currently gaps in knowledge around the level of technology use and integration in home health care services as well as senior's level of technology adoption and acceptance for managing their health and wellness. It is expected that the survey data will provide insights into the current state of home health care services and help to inform future phases of the research on assistive technologies for aging in place.

4 Conclusions and Discussion

A review of the literature in the area of HCI and human factors has pointed out important issues related to user acceptance factors in health applications and important challenges related to privacy, security, trust, and technology acceptance among older adult users. The protection of personal data is an area of concerned expressed by older adults, along with concerns about the improper access and use of their data, and especially concerns about the privacy complacency of companies. It is important to consider privacy concerns when designing health technologies for in home use especially. More research needs to be carried out to fully understand the best practices for designing wearables for older adults, along with robust privacy legislation as a necessary ingredient for an effective ecosystem of IoT and wearables. While it is users who opt into data sharing, how the data will be shared is deeply affected by designers, "who have the power to enable and constrain certain action possibilities through their design choices". Currently, the lack of standards around user privacy and security issues can be a potential regulatory hurdle for the adoption of wearables and IoTs by older adults. Older adults should be included as co-creators in the research and development of technologies that meet their needs and support them in living a quality of life now and in the long-term. Future research directions will focus on user friendly and secure technologies for home healthcare, including wearables for self-monitoring, and technologies for caregivers and home healthcare professionals. Further research is required to improve the design of new technologies for health and wellbeing, while empowering older adults to make informed decisions, to

maintain their dignity and control over their personal data through HCI and more transparent safety and security mechanisms. Ongoing research is needed to address societal changes of an aging population and to advance research and development in digital technologies in the context of aging in place.

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