

Aging in Smart Environments for Independence

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Abstract—This paper highlights current technological limitations and offers recommendations for scientists and engineers when designing devices to support aging in place. Existing technology for older adults to support independent living is examined as well as the implications of contextual factors, namely, location, on how people live and age based on the location in which they reside. This is the first review to investigate how challenges of aging change relative to location of residence and, subsequently, how such variation may inform technological solutions. To date, few devices consider the environment in which older individuals age. Places examined include aging: at home; assisted living facilities; nursing homes; and family housing. Challenges found in common across these locations were financial strain and isolation. In addition, each setting was found to have its own unique hurdles. Understanding these barriers is essential to developing technology that enables older adults to successfully age in place.

Index Terms—aging in place, gerontechnology, smart home, robotics, older adults, seniors

I. INTRODUCTION

The objective of this paper is to understand how locations where people age—specifically, homes, assisted living facilities, nursing homes, and family housing—contribute to the aging process in unique and overlapping ways. By addressing this knowledge gap, our work aims to galvanize interest and attention in gerontechnology limitations and potential solutions.

In 2019, CNN reported that in 2018, the fertility rate in the United States hit another record low with younger generations having children later in life or not at all [1]. Additionally, advancements in medicine are enabling longer life spans. These factors are contributing to a population shift: by 2050, Earth will be home to an estimated 9.3 billion people; of which 20%, or 2 billion, are predicted to be 65 or older [2]. Changing demographics will affect all aspects of life and introduce novel challenges. One such challenge will be even larger shortages of healthcare workers. For example, a shortage of nearly 2 million healthcare workers was estimated by the year 2020 [2]. It is easy to imagine such shortages exacerbated by the aforementioned variations in the makeup of the U.S. population.

Research in smart health and living is investigating new technologies for deployment in homes to address the shortcomings of healthcare systems and support the aging

population. Examples include: sensors to alert occupants when the stove is left on too long; robotic vacuums for automated cleaning; and digital assistants to support routine tasks. Such devices have the potential for enabling the elderly population to continue to live inside their homes while aging.

Gerontechnology is an interdisciplinary field of research at the confluence of technology and gerontology, focusing on the development of technological solutions for older adults by considering their needs, desires, attitudes, opinions, and behaviors [3]. The field coalesced through the activities of the 1991 first international congress on gerontechnology in Eindhoven, the Netherlands, and launched thereafter through the compiled proceedings by Bouma and Graafmans in their volume on *Gerontechnology* [3]. Some examples of gerontechnology include: sensor- and internet-of-things enabled smart homes to detect, analyze, and visualize daily living patterns; robots to assist with cognitive tasks; and exergames to encourage fitness.

SeniorLiving.org defines Aging in Place as a person making the decision to age in the living residence of his or her choice [4]. Successful aging in place is dependent upon the person; however, many older adults prefer to age inside their own home and only move to care facilities when it is necessary. Aging is a natural and inevitable aspect of human life, yet many barriers to this process remain. Challenges are encountered in a variety of places, from in the home, to nursing homes, to communities more broadly. There is a pronounced need for Aging in Place (AIP) to ensure future older generations stay independent longer without reduced quality of life.

Connecting advances in gerontechnology with various manifestations of AIP offers two important implications. First, an improved match between assistive devices and their care and environmental setting will help to maximize efficacy and effectiveness of the technologies developed. Second, greater inclusion in the design process of the target population will likely enhance usability, improve user experience, and lead to greater adoption among older adults, hopefully leading to better care outcomes.

II. METHODOLOGY

This paper serves as an extensive literature review assessing technology for older adults and the different locations in which they choose to age. By understanding the challenges associated with each location and how they are unique or different, scientists and technologists can build technology

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that can be utilized in multiple locations and customize solutions where needed. It is estimated that by 2029, 14.4 million seniors will belong to the middle-class bracket meaning they do not qualify for Medicare assistance while also not having the financial abilities to cover long-term care [5]. Pearson et al. report 80% of seniors in the middle-class bracket will need assistance; however, 54% will be unable to afford care [5]. Knowing this, scientists and technologists should take extraordinary efforts to develop low-cost, universally accessible technology.

The remaining paper is laid out as follows: III. Technology for Older Adults presents technological solutions that have been proposed; IV. Aging in Place: How Place Affects Aging will present the different locations a person can choose to age along with the challenges in each location; V. Discussion summarizes the common challenges found in locations a person can age and critiques the technology from section III; VI. Recommendations of the Field focuses on how to address the common challenges found in each location a person can age; VII. Conclusion summarizes the findings; VIII. Next Steps is our recommendations for scientists and technologists to follow as they develop technology for older adults.

III. TECHNOLOGY FOR OLDER ADULTS

Regardless of where people age in place, a variety of technologies have been proposed to augment care for older adults. Below we review findings from numerous gerontechnology studies showcasing applications of robotic, internet-of-things enabled, and wearable devices designed to improve quality of life and enhance care for older adults.

A. Robotics and Automation

Robotics in healthcare is an emerging use-inspired field at the confluence of engineering and computer science. Robots have been investigated for utility across a variety of purposes and conditions, elaborated below, from dementia care, to neurorehabilitation, to companionship. Each paragraph below will present a solution which we critique in the Discussion.

Cruz-Sandoval and Favela used a robot, Eva, for dementia care. They report that Eva is the first autonomous robot to guide therapy sessions via verbal communication. Eva is being used for music therapy by being tasked with leading a group of people living with dementia in singing songs. Patients are able to make requests for songs he or she wishes to hear; Eva encourages the person to participate and sing along and provides praise for singing ability. Cruz-Sandoval and Favela have also explored robots for patient-care through storytelling, dancing, and problem-solving [6]–[8].

Cruz-Sandoval and Favela used Eva in a study with twelve people aging from 71-90 over twenty-three sessions, lasting thirty-five minutes each, however, only five participants completed all sessions. All subjects—members of the same geriatric care center—reported that participants enjoyed interacting with the robot beyond the music therapy sessions [6]. Eva was tested using a fully autonomous mode and a Wizard-of-Oz approach. In [8], Cruz-Sandoval and Favela used Eva in fully autonomous mode with five people living with dementia, and documented better outcomes compared to the Wizard-of-Oz study in [7].

Martin et al. [9] used NAO, a small, commercially available humanoid robot, to lead therapy sessions for older adults living with dementia. These sessions included music therapy (singing and dancing); physiotherapy (mimicking exercises); storytelling; and logic-language (problem prompts only). Thirteen people participated in thirty to forty-five-minute sessions two days a week for a month. Most of the participants had moderate to severe dementia with ages ranging from 74-91 years old; 92% of the participants were women. They report that people living with dementia reacted positively to the robot.

Robots have been proposed to promote physical activity for older adults through dancing; leading exercises; or physical therapy. Chen et al. [10] assessed older adults acceptance of a robot dance partner to promote healthy aging through dance-based exercise. The study team recruited sixteen participants and found that older adults would go out of their way to use this robot if it taught them new dances.

Robots are also being used for companionship. Breazeal et al. [11] found that older adults were more likely to accept a physical robot as a social companion than a digital assistant due to feeling more engaged with the former compared to the latter. They also found that older adults were more likely to be open to social robots than younger generations. Breazeal et al. report that older adults did not like when the robot told them what to do such as “eat something” or “take a nap” but did appreciate suggestions such as “call home.”

Paro is a small robotic pet designed in the likeness of a seal that has been investigated for its utility in promoting companionship. Robotic pets may be preferred when it is no longer possible, or difficult, for an older adult to care for a live animal. Marti et al. [12] conducted a study with Paro allowing therapists to decide when to use the pet with nine participants living in long-term care. Paro was found to stimulate feelings such as affection and caretaking in older adults.

Una et al. [13] conducted a follow-up study with Paro. Eighteen participants in long-term care were recruited; however, some of the data were lost during the trial. The authors reported that Paro demonstrated promising results for a companion robot finding many older adults talking lovingly to it, taking care of it as if it were real, including petting it.

Iwabuchi et al. [14] did similar work at a group home with a robot called Sota. This robot greets owners at the beginning of a conversation, offers topics to discuss, offers conversations to evoke emotions, plays Japanese word games, and includes a touch feature. Iwabuchi et al. reported promising results, as well, although the number of patients involved in testing was not included.

B. Internet of Things

The concept of the internet of things (IoT) is driven by a vision of smart homes with embedded sensors and other technologies, connected in such a way that older adults may be assisted on demand, no matter where they live. These IoT-enabled devices provide insight into daily routines, track activity through the day, monitor sleep, and track how much a person is eating [15].

Demir et al. [16] proposed an Ambient Assisted Living system to make life at home more comfortable. Sensors were embedded throughout the house to detect human activities such as sitting or lying down. Sensors were also deployed to detect

the status of the house, for example indicating an open window or running shower. The purpose of detecting such behaviors or house status was to help older adults and their caregivers recognize half-completed tasks. The devices were designed such that user's caregivers or doctors would be automatically alerted when a task began, and again later upon completion.

Similarly, Enshaeifar et al. [17] deployed sensors throughout homes in addition to sensors for heart rate, blood pressure, temperature, and patients' pill boxes. This system was designed to keep a medical staff in the loop for timely intervention when patients might require support. Data were collected from twelve people over three-month periods. A novel approach was introduced to understand daily patterns for people living with dementia; 72% accuracy was reported for classifying agitation, irritation, and aggression.

Basu et al. [18] augmented participants' homes with sensors to understand trends of people's daily lives. Sensors were placed on electrical appliances to detect use and to ensure data collection transmitted from correct locations. To protect privacy, microphones, and cameras were not used. The goal of the work was to analyze collected data for deviations from normalcy to detect incipient signs of dementia.

Dawadi et al. [19] equipped the Washington State University smart home test-bed with sensors to detect indicators of dementia. Sensors were placed on doors, cabinetry, ceilings, and throughout the kitchen. Temperature sensors were used in each room along with sensors to monitor water, electricity, and the stovetop. Dawadi et al. recruited 145 participants who completed multitasking objectives around the home. If a participant was unable to complete a certain number of parallel tasks, his or her performance was classified as possibly a nascent stage of dementia. The paper reports that this is one of the first experiments to use a smart home to automate assessments for a group of this size.

Rantz et al. [20] worked toward developing an in-home system for the University of Missouri's Home Place Aging in Place Care Center to communicate with medical staff due to there being no commercial system to integrate health and sensor data. Sensors were embedded in the stovetop, bed, and chairs. The bed sensor detected three levels of activity by measuring pulse and respiration. Rantz et al. included motion sensors, pulse-Doppler Radar, and a Microsoft Kinect to distinguish between multiple people inside the home. These were used to detect early signs of an illness and to track activity levels to relay information to health care professionals. Rantz et al. had monitored 49 people for data. There was no report on how participants felt about the technology throughout the house.

C. Wearable Technologies

Researchers have investigated wearable technologies for older adults to track fitness levels or detect wandering in people living with dementia. Steinert et al. [21] explored the effect of different wearable fitness tracking devices on physical activity levels for older adults. They recruited 20 adults aged 60 or older to test different fitness trackers such as Nike FuelBand, Jawbone Up, Fitbit Flex, the Garmin vivofit, and the Sony SmartBand. The paper brought attention to the marketing around these devices, in particular, how they are not targeted for older adults and when technology is developed for older adults, the marketing presents frail, unhealthy older adults.

Steinert et al. found that the acceptability of these products was positive; however, price was a concern especially for low-income older adults. Their work also revealed that older adults desired fitness trackers that are more comfortable to wear and have additional capabilities, such as measuring blood sugar. Additional issues were gleaned: screens were too small to read; buttons were too small even for health adults without impaired motor skills; instructions on how the tracking is done were missing; and placing pins in the correct holes was difficult due to the size.

Attard et al. [22] developed a tool to assist caregivers with individuals wandering as a consequence of living with dementia. The application ran on smart mobile devices. Preliminary results showed promise for caregivers in assisting their patients. The system was developed in two phases: during phase one, a workshop with caregivers was held to provide a channel for participants to share their perspectives and explain what assistance was needed. As part of the second phase, a pilot usability study was conducted with people who live with dementia. Machine learning algorithms were employed to learn daily patterns, such as the person's location, travel patterns, temperature, and activity level for detection of abnormal behaviors that may require the attention of a caregiver.

IV. AGING IN PLACE: HOW PLACE AFFECTS AGING

To complement our review of gerontechnology, we explored the multiple venues in which older adults age. Understanding how differences in place affect aging will enable further refinement of technologies and associated care service for older adults and caregivers. In the sections below, we report on challenges of ageing in the home, in assisted living facilities, in nursing homes, and in family housing. While each of these settings brings its own unique constraints, we also explore two challenges found across places of aging: financial strain and isolation.

A. The Home

One of the main reasons people desire to stay and age in their own home is its association with memories [23]. In addition, people remain inside their home when they feel they are healthy enough to stay and have made the necessary accommodations to continue to live in their house. Accommodations may range from a bedroom on the first floor, to grab bars in the bathroom, to nonslip flooring [24]. Such universal design features can provide important safety mechanisms to keep older adults safe in their homes. Safety is paramount for those wishing to remain independent and with more autonomy when living alone or with another aged individual. A high degree of safety can also reduce stress among family members when they feel confident their loved one is safe living alone.

Tang et al. [25] found older adults are more at risk when they require assistance with personal hygiene; transfer, e.g., lifting oneself; finances; and medication. To address the aforementioned challenges, homes have been remodeled to include accessible features for those desiring independence [26], [27], [28]. Common renovations include adjustments to floors to ensure they are level; installation of grab bars, especially in bathrooms; and stretching carpet to ensure no areas are loose [27]. Szanton et al. found that these upgrades

made a positive impact for 93% of their study participants. However, older adults who are unable to afford these changes and do not have a community willing to assist with costs, are left to age in a potentially unsafe home.

B. Assisted Living

Moving into an assisted living facility often represents only a short-term solution for older adults [29]. These facilities are not designed or intended to replace nursing homes, and rather serve as a steppingstone, resulting in an average stay of around 18 months [30]. When looking into these options, one problem older adults encounter is understanding how long they will be allowed to stay at these facilities and if they will receive adequate care.

There are multiple factors, beyond finances (covered below), determining whether a person may be able to move into an assisted living facility. One consideration is whether the individual would get along with other residents [30]. This is even more difficult for those who use a wheelchair; only 15% of this population are admitted into nursing homes [29]. Other exclusion criteria include being constrained to a bed, living with bed sores, or requiring a feeding tube [31].

Assisted living facilities have strict requirements. For example, a person should not require too much help when moving into the residence. Assisted living facilities require maintenance of this level of independence during a person's stay, which often is not obtainable with age. An outcome of this rule is that as older adults need more help with simple tasks, they are reluctant to ask for fear that they will be removed from the home [29]. Other common reasons adults are dismissed from assisted living include: two-person transfers; individuals can no longer afford care; and becoming bowel incontinent [32].

C. Nursing Home

Once a person reaches a stage where he or she requires assistance with at least three activities of daily living, or needs more care above what an assisted living facility is willing to provide, the resident is moved into a nursing home [29]. Due to declining health, residents are often too cognitively impaired to make a decision to move. Therefore, this decision is frequently left to family, and can further affect older adults' mental health [32].

People seek to avoid nursing homes. Ball et al. [30] found that even when people were unhappy with their assisted living facility, it was preferred compared to a nursing home. One resident in an assisted living facility said they hope to die before having to be moved into a nursing home [30]. Chapin et al. [32] found that placing older adults into nursing homes puts them at risk of becoming depressed, and eventually suicidal with increased weight loss.

When older adults move into a nursing home, they must limit what they can bring into the residence due to limited personal space [32]. Chapin et al. [32] discussed the emotional turmoil this can have on older adults through forcing removal of their identity. When older individuals are forced to sell most of their personal belongings prior to moving into a nursing home, they lose ownership as well as the ability to participate in past activities requiring those previously owned items.

D. Family Housing

When an older adult cannot remain inside their home due to compromised safety, or is unable to transfer to a care facility, e.g., due to financial strains, the individual may move in with his or her family. While this may seem a financially sound decision at the time, it often has the opposite effect on the greater family.

These situations are taxing on loved ones, both physically and mentally, creating feelings of becoming a permanent caregiver for a father or mother. This can lead to depression for younger generations as they must be consistently available and attentive as well as simultaneously be able to manage their own responsibilities. Johnson et al. [33] found that key stakeholders that need to be accounted for during the design process of family housing are adult children, usually daughters, and that these caregivers experience physical, emotional, and financial burdens.

Family caregivers often feel that they need to surrender their social life because their elder loved one may be unable to independently perform basic tasks such as bathing, cooking, or eating. Reducing or eliminating a young person's social life can cause social isolation and depression. The younger adult's friends may distance themselves, knowing that he or she will be too occupied to allocate time for social events. Even in situations where there is time for socialization, many young caregivers will avoid such events to alleviate guilt associated with leaving their dependent mother or father alone at home.

Cornwell et al. [34] point out that social isolation among caregivers is detrimental to physical and mental well-being. Caregivers may also endure physical strain from transfer tasks including lifting, assisting, and supporting their elder while bathing, rising, and changing clothes.

The mental and physical exhaustion of caregiving can carry over into the rest of the younger adult's life. If younger caregivers are not sleeping enough from having to take care of their elder and children during the night, sleep deprivation could lead to decreased performance at work. Consider another scenario: the caregiver is married, and the couple decides it is easier for one of them to quit their job to attend to their elder. The couple then loses a source of income while increasing the amount of resources they require in the house such as electricity, water, and food. Such a strain can cause financial challenges, which can lead to arguments, increased stress, and mental health issues.

V. DISCUSSION

This section summarizes different issues associated with aging in locations and proposed technological interventions for older adults.

A. Locations to Age in Place

Once a person moves out of his or her house, he or she is faced with different options pertaining to where to transfer, from assisted living facilities to nursing homes. People often choose to transition into assisted living for a number of reasons: access to a larger social community; no housekeeping chores; nursing home-level care is not required; and/or the individual prefers not to live alone [31].

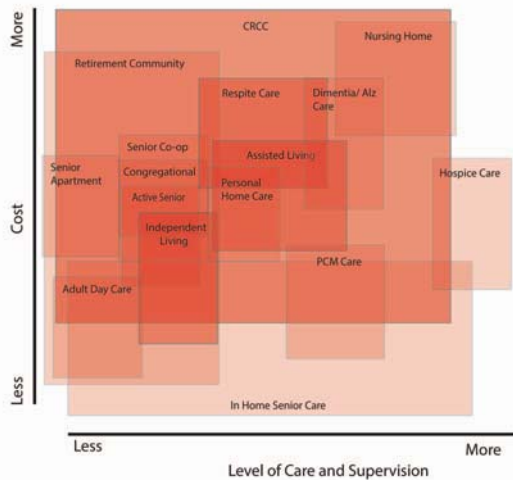


Figure 1: Diagram to Compare Cost to Level of Care
 Alz: Alzheimer's; CCRC: Continuing Care Retirement
 Communities; PCM: Personal Care Homes

Assisted living facilities are not long-term solutions for older adults. Eligibility requirements are strict for new residents and are often challenging to maintain over time for existing residents. Therefore, older adults frequently avoid asking for additional help when crucially needed.

Among aged adults, it is often said that nursing homes are feared more than death. Nursing homes are associated with a complete loss of independence and depression. Offered services are expensive, causing affordability barriers for older adults.

Family housing may seem ideal in the beginning when loved ones discuss ideas on where an elder family member can move; however, it leads to many negative consequences: depression among family members; not enough space in the home; declining physical health of the caregivers; and financial strain on younger adults.

B. Technology

Studies have shown that the majority of older adults do not like to feel monitored and tracked by sensor and video surveillance technologies inside their home. Older adults are often unwilling or hesitant to use such devices given that these systems create a focus on the disability [35]. It is important to note that the solutions described thus far are not designed for healthy older adults [36]—an important point to keep in mind for designers and engineers building technologies for older adults more generally.

When designing for older adults, it is important to create technology that performs multiple functions [15]. Another important consideration is ease of adoption and learnability; older adults are likely to be slower to adopt and learn new technologies due to learning curves [37]. Learning experiences that are easy, straightforward, enjoyable, and non-degrading are critical to successful adoption and long-term use. Frequent required software updates often causes skepticism, confusion, and frustration, and therefore, should be avoided when possible [38].

Larger participant sample sizes are needed for usability

studies and experiments. Small samples sizes have stymied the transfer of these technologies from the laboratory to medical practice [39]. Evaluating technologies against medical standards, however, often entails an arduous, lengthy process, potentially rendering a technology obsolete by the end of the trial [39].

Lastly, older adults may not adopt technology due to cost [38]. Many health insurance companies do not cover these devices, so people are unwilling to purchase them out-of-pocket.

C. Finances

Beyond affording technologies, the majority of older adults face financial problems across potential places of aging. Figure 1 depicts how care changes with cost in different settings.

While the issues encountered vary by situation, a commonality across settings is insufficient funds for the level and quality of care desired. Being aware that older adults struggle with finances when choosing to age in place is paramount for technologists to understand so that they may seek solutions that solve actual needs and bring about the greatest impact.

Crary [23] reports on the situation of a woman who was unable to move due to the value of her home dropping. Many older adults may be living in outdated homes and cannot afford to upgrade them. Some of these outdated styles include inaccessible features such as narrow doorways and tall kitchen cupboards as well as potentially dangerous bathrooms. Being unable to afford to upgrade their home to sell, the elderly are often forced to remain inside an environment that does not accommodate them now that they are aged.

Tang et al. [25] found that older adults living below the poverty line were more vulnerable to the vagaries of aging and associated financial challenges.”

Home care does not require older adults to move out of their homes, but still allows them to receive necessary care. The cost of home care depends on the kind of assistance a person chooses; in 2019, the average monthly cost was \$4,385 [40]. Johnson et al. [33] discuss how those most likely to need these services are unable to afford them, finding only 22% of adults with long-term care needs could afford a moderate amount of care and only 7% could afford extensive care.

In 2019, in the United States, assisted living cost an average of \$4,051 a month [40]. For adults who did not prepare to move into a facility before it became a concern, cost was a barrier to access. Ball et al. [30] report money as a significant factor in how long residents are able to stay in these facilities. Mitty et al. [29] discuss how assisted living is targeted as a less expensive alternative to nursing homes for older adults who need personal assistance, but is not a long term solution because they do not support end of life services. Additionally, assisted living may not support an older adult who is already less abled due to the person needing an extra level of support and care. It is common for residents to refuse to accept increasing care due to lack of money and these residents were subject to be discharged [30].

In 2019, the average monthly cost of using nursing home facilities was \$7,513 to \$8,517 [40]. Johnson et al. [33] found that only 14% of the 9,966 adults they interviewed could afford

a nursing home. Johnson et al. also reported adults with significant needs for long-term service and support were unable to afford nursing homes and only 6% could afford a nursing home on income alone. One quarter of the seniors who move into a long-term nursing home stay for more than four years. Johnson et al. found these people could afford nursing homes if they liquidated their homes but doing so only extended assisted living care by 106 months or nursing home care by 34 months. Liquidating all other assets on average would cover about one year of nursing home care.

VI. RECOMMENDATIONS FOR THE FIELD

Special consideration should be given to ensure scientists and engineers are doing all they can to assist older adults through design more attentive to places of aging. While the robotic, internet-of-things, wearable, and other technical solutions described above hold promise, they often do not account for the specific challenges of aging differently in different places. This section evaluates these overlapping challenges to allow designers to adapt the way they develop technology to make the largest positive impact on Aging in Place. The goal is to understand these barriers and ways technologies, in particular, may contribute to addressing them.

A. Finances

Finances are an important issue for older adults who are hoping to Age in Place. Most proposed solutions are expensive and do not disclose costs, and therefore, are unobtainable for much of the elderly population. Challenges include being unable to remodel the home to make it safer; not making enough money once selling the home to move into an assisted living facility; not having a sufficient income to cover assisted living or nursing homes expenses; or being unable to afford adult day care or home care services.

Proposing solutions to financial burdens is out of the scope of this paper, however it represents an issue that desperately needs to be addressed and affects the ability of older adults to access beneficial technology, as well. Ultimately, it is important to understand that when developing technological solutions for older adults, solutions should strive to be low-cost. Considering older adults who are unable to afford care are the ones most in need of help, special attention should be toward developing affordable, accessible solutions.

Another might be supporting early detection and prevention technologies related to sensors, to catch issues early and reduce the cost and need for certain types of care later in life.

B. Isolation

Isolation is often a result of the environment in which a person ages. Isolation can manifest in all situations of life, including when a person is around people. It is important to understand how isolation affects people's lives if one seeks to develop technological solutions which could assist those who feel isolated by either finding better ways to connect them with loved ones or providing emotional support through devices such as robotic pets. Joy for All sells such robotics pets for around \$100 that interact with the user instead of pretending to sleep. For example, Joy for All's robotic puppy will bark when

its interaction partner speaks, and has a heartbeat that can be felt while petting [41].

When an older person makes the decision to stay in their home alone, they can face social isolation. This is due to having decreasing motor skills leaving them unable to drive to social events they used to attend. Some people face isolation due to their family being unable to visit frequently. Older adults often struggle to use social media or other technology to keep connected to their friends, even if they own the necessary equipment. Isolation is detrimental to a person's health and has been compared to smoking cigarettes and obesity [34].

When an older adult is moved from an assisted living facility to a nursing home, there are social consequences. Older adults can lose the friends they made at the assisted living facility and they lose the relationship with the staff who knows their medical conditions and what they need. Chapin et al. [32] report how these social relationships can be affected with the staff and affect the care.

The utility of robotics for addressing isolation among older adults has shown promise. For example, there are many instances where proposed assistive robots have been shown to aid older adults. Moreover, older adults are generally receptive to these devices. However, many of the proposed research prototypes are still proofs-of-concept with much work remaining.

With the assistance of medical professionals, research could be augmented to measure the level of depression in older adults before and after therapy sessions involving technological interventions to determine how successful devices are in practice. Measuring levels of depression before and after using the technology could provide strong evidence that the technology assists the person by decreasing depression rather evidence being based on observation.

Robotic assistants should do more than one task benefitting multiple areas in need of assistance among older adults and their caregivers. Features that could be included are playing music, playing games, fall detection, or even leading exercises. These features will allow robots to engage with users on various tasks making users more likely to enjoying interacting with the robot. Additionally, these robots should avoid giving the older adults commands such as "eat something" and should try more collaborative suggestions for the person as would take place in real life such as "would you like to eat something".

VII. CONCLUSION

Technology has the potential to transform the lives of older adults and to enable many to age in place, especially those who cannot afford long-term care. The future smart home will alter the way people view aging enabling people to stay inside their home longer while maintaining independence and safety. For older adults who choose to age in place through family housing, smart homes have the potential to ease caregiver stress by adding additional safety features or by bringing assistance directly into the house.

Scientists and engineers have a greater potential to improve quality of life of older adults through technological interventions if steps are taken in a co-design process to understand not only the people who age, but also the environments in which they age, and the burdens of caregivers

and medical professionals. A more inclusive design process will increase the chance of such broader impact through greater adoption and use rates as well as more effective technology.

While introducing technology to assist older adults inside their homes and care facilities presents a unique set of ethical challenges that must be addressed, this topic is outside the scope of this paper. Relevant ethical questions, however, must be addressed if technologies are to be accepted by older generations. Additionally, some challenges presented may not necessitate technological solutions; however, it is outside the scope of this paper to identify alternative ways to solve these challenges.

VIII. NEXT STEPS

Few older adults are consulted when developing technology specifically for them. This causes older adults to be less willing to adopt the technology because they are unfamiliar with it, unwilling to learn it, or afraid of it. By including the intended users in the design process, more scientists and engineers might become aware that many older adults do not want surveillance technology inside their home due to the associated discomfort. A co-design process could ensure engineers are developing solutions that meet users' needs without sacrificing users' desires (such as not being monitored).

At the same time, there are studies that demonstrate how older adults may be more comfortable using certain technologies than originally thought. Participants in these studies were willing to learn and adopt a novel device if it offered the potential to help in daily life. However, for older adults to adopt these inventions, accessibility and safety considerations should be addressed during the earliest stages of design. As one example, screens and text should be large enough for readability, and buttons should be large and easily accessible. Additionally, easy-to-follow, step-by-step instructions should be created to assist people who are less familiar with technology.

Finally, as a key stakeholder, caregivers need to be included in the design process, as well. Caregivers may provide insights pertaining to what to be aware of when implementing certain features; how to measure success; the utility of a solution; and problems or situations designers may not have considered.

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