



## Practical Technological Solutions to Support Successful Aging

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### Abstract

**Background:** Rapid growth of older populations has created a need to provide support and innovative care for successful aging, especially for the many seniors who want to remain in their own homes and stay engaged in the community. With strained healthcare resources and a growing shortage of providers and caregivers, technological resources may become more critical for supporting older adults, social connectedness, and healthy aging later in life.

**Purpose:** The primary purpose of this commentary supported by a streamlined review of literature is to explore practical technological options to support successful aging among older adults. In this effort, we will suggest opportunities that may hold promise for older adults with varying needs and preferences.

**Methods:** Our primary interest was in specific categories of evidence-based technology that could be feasibly used with older adults. Thus we conducted a targeted review of relevant literature, rather than a broad systematic review of all technology topics, to meet our primary purpose in supporting this commentary. An online search was utilized to identify publications relevant to this purpose.

**Results:** Older adults are increasingly adopting technology although with prevalence and type of use varying by several characteristics. Younger, higher income, and higher educated seniors as well as those without disabilities are most likely to use common technologies, especially smart phones, internet/broadband connections, and social media. Newer innovative options such as smart watches, interactive home devices, and medical alert systems are also growing in popularity. However, unique challenges to widespread adoption exist, including cost concerns, training, accessibility, usability, design challenges, and privacy.

**Conclusion:** Research is developing, yet common technologies appear to hold promise for supporting successful aging. Consideration of the individual needs, preferences, and characteristics of seniors may help identify the most practical options for specific segments. However, unique challenges of technology adoption need to be addressed.

### Keywords

Aging in place; Successful aging; Older adults; Technology; Technological solutions

### Introduction

Rapid growth of the older population is predicted to continue through 2050 and beyond [1-3]. Consequently, the demands on healthcare services, home care, healthcare providers, and caregivers are worrisome, with a growing shortage of resources available for older adults, increasing strain on the healthcare system and communities [1-5]. Meanwhile, many caregivers, especially family members, are staying connected and/or providing care from a distance to help care recipients manage their health, often enabling them to live independently as they age. Approximately 90% of adults age 65+ prefer to remain living at home and/or within their communities later in life, while maintaining their usual routines in a familiar environment [1-4]. Aging in place or living independently is often considered by healthcare leaders as one potential solution for avoiding the high costs of long-term care and part of the answer to a shortage of caregivers [4]. Yet no systematic support from US government resources, such as Medicare or Medicaid, is currently available to older adults. Nevertheless, those who do transition to assisted living or another living situation also have needs as they age that may require significant caregiver and social support in some cases.

The adoption and use of technology among those age 65 and older has grown significantly in recent years with the aging of Baby Boomers [5]. Older adults have become more digitally “connected,” with internet use, broadband connection, and social media engagement increasing rapidly over the last decade [5]. Four in 10 adults age 65+ now own smart phones, an increase from just 18% ownership in 2013 [5]. Similarly, internet and broadband (high-speed) use have increased, with two-thirds of this group reporting internet use, three-quarters of those going online daily, and about half with a broadband connection at home [5]. Among those who go online, 86% use email, 34% use social networking/media websites, and 27% use the internet to search for health or medical information [1,5]. Research indicates that older adults often become just as engaged and active in online activities as younger adults [6]. However, compared to younger Americans overall, many older adults still remain digitally “disconnected” from emerging technological developments [6].

Technology use later in life varies substantially by several characteristics, primarily by age. Several common characteristics of those most likely to adopt technology emerge: younger (i.e., 65-69), higher educated, higher income, and healthier seniors tend to be the highest users [1,5-7]. Technology adoption drops off in the mid-70s, with age 75 (i.e., younger Baby Boomers) an approximate divider between higher and lower use [1,2,4,5,8,9], suggesting that different age segments may have differing technology needs and preferences. While less is known about other characteristics, some research indicates that Caucasian, male, and married older adults demonstrate a higher prevalence of technology use in comparison to other segments [1]. Meanwhile, older women often self-report they lack technological skills [2,8]. However, despite low self-efficacy with technology, older women are more likely to use the internet to search for health-related information than older men [2]. Finally, lower technology use is associated with greater disability, physical and memory limitations, and vision impairments [1]. Thus opportunities may exist to target segments of the population with different types

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of tools or interventions specifically designed for various needs and levels of support across the life span.

Despite the growing popularity of common technologies among seniors, unique challenges and barriers to broader adoption exist as compared to younger groups [3,4,6,9]. Attitudes and receptivity toward newer technologies vary, often influenced by social networks, sociodemographic characteristics, and backgrounds. Many older adults also have concerns regarding privacy and safety in the digital world, potentially compounded by a previous lack of experience with technology [3,4]. Furthermore, training and technological support needs, self-efficacy, and worries about burdening family members with requests for assistance are among the challenges within this population [3,4,9,10]. Finally, affordability and thus accessibility of advanced technologies to support successful aging remains a concern. As healthcare insurance providers and other payers have not broadly incorporated technology for this purpose into their payment systems, the question of who will pay for and enable access to technological options for older adults remains [3,4,10].

In our review of literature, we did not identify any published comprehensive reviews describing the use of common technologies with older adults for the specific purpose of supporting successful aging. Thus this paper adds to the literature on the role of technology later in life and may help to inform future directions for technological interventions.

## Statement of Purpose

Our primary purpose is to provide a commentary, supported by a targeted review of relevant literature, exploring practical technological tools and resources with the potential to support quality of life, health management, and successful aging later in life. Based on this review, we will provide a commentary to suggest opportunities that may hold promise for older adults.

## Methods

To begin our literature search, several common databases were considered, including PubMed and SCOPUS, along with more general search engines such as Google and Google Scholar. However, considering the limited results and limited access to publications through several of these databases and search engines, we made a decision to focus on the PubMed database and a broader Google search to identify publications describing our areas of interest. These were selected as our focus primarily due to their wide scope of research available, up-to-date publication status, access to full-text articles, as well as alignment with our usual research methods of successfully using these resources. In addition, these are widely accepted databases used in the scientific literature thus we streamlined our search and methodology while still allowing for a thorough review of literature related to our primary areas of interest and purpose of this manuscript.

The search terms used were determined primarily based on closely tailoring results for our specific purpose. Initially, a list of search terms was determined by considering our purpose, areas of interest, and common terms used frequently in these areas, as well as in research on older adult populations (Figure 1). In addition, from an initial broad yet informal search on emerging technologies, the terms that most often appeared were related to those topics used frequently in the literature as well as in mainstream news articles describing these technologies and their applications. These commonly used terms along with those topics related to older adults/aging were considered and selected as long as relevant to the purpose of our commentary. As

an example, we found that the terms “smart homes,” “smart phones,” and “social media” have become common, almost “household” terms used in both mainstream discussions of technological developments as well as in research areas. These terms and others selected apply to the needs of the growing population of older adults in the United States and as such were relevant to this commentary. The terms ultimately used in our searches are detailed in Tables 1-3.

Some terms returned a large number of results, many of which were outside the scope of this paper. However, these initial results provided an overview of technological solutions being considered or utilized with older populations. From there we determined several general categories of technology to further narrow our focus: smart phones/tablets/the internet; e-Health; exergaming/digital gaming/physical activity applications; and interactive home devices. Once these main categories were determined, publications describing alternative options outside of these areas were excluded. Notably, we also chose to narrow our results to these certain search terms in order to identify publications most closely related to viable solutions that could be generalizable and practical for broad older populations with varying needs. Furthermore, one significant challenge in this area of research is the lack of common or standard terminology to describe technological resources and emerging options as applied to the support of daily living.

Next, we used PubMed’s advanced search feature with the Medical Subject Headings (“MeSH”) terms filter to further narrow results. Because several search phrases still returned a very large number of results, we further utilized the MeSH Major Topic filter to identify more relevant publications for several topics. Titles and selected abstracts were reviewed to determine if each publication met our needs. Inclusion criteria included original research and review publications with titles and/or abstracts that fit our scope, as well as those focusing on older populations (i.e., primarily age 60+ but also from age 50+). Research focusing strictly on younger populations, employee populations, or other specific groups was typically excluded, as were publications detailing technologies or approaches unrelated to our purpose and scope. Studies published in languages other than English were also excluded, while several international publications providing relevant information were included as long as they were written in English. Table 1 displays the final search terms used in our initial literature search, as well as in all subsequent and streamlined searches. In addition, the results identified with the use of each search term/phrase are listed in this table. Table 2 shows the categories of final search terms created once searches were complete; similar and related terms were combined to show the final results obtained in each general category once final searches were complete.

## Results of Search

PubMed provided the majority of relevant published research. For brevity, only those results from PubMed searches are described here. Notably, we were unable to identify any comprehensive reviews of technological solutions within our chosen categories being utilized on a large scale specifically with older adults to support quality of life and/or successful aging. Thus our commentary adds to the literature on the role of technology later in life.

To narrow our initial search results (over 2,000) to identify those most closely aligned with our purpose, PubMed’s advanced search features were used as described. The results of this search appear in Table 1, placed at the end of this manuscript. Table 1 displays the number of articles identified with this strategy, grouped by broader

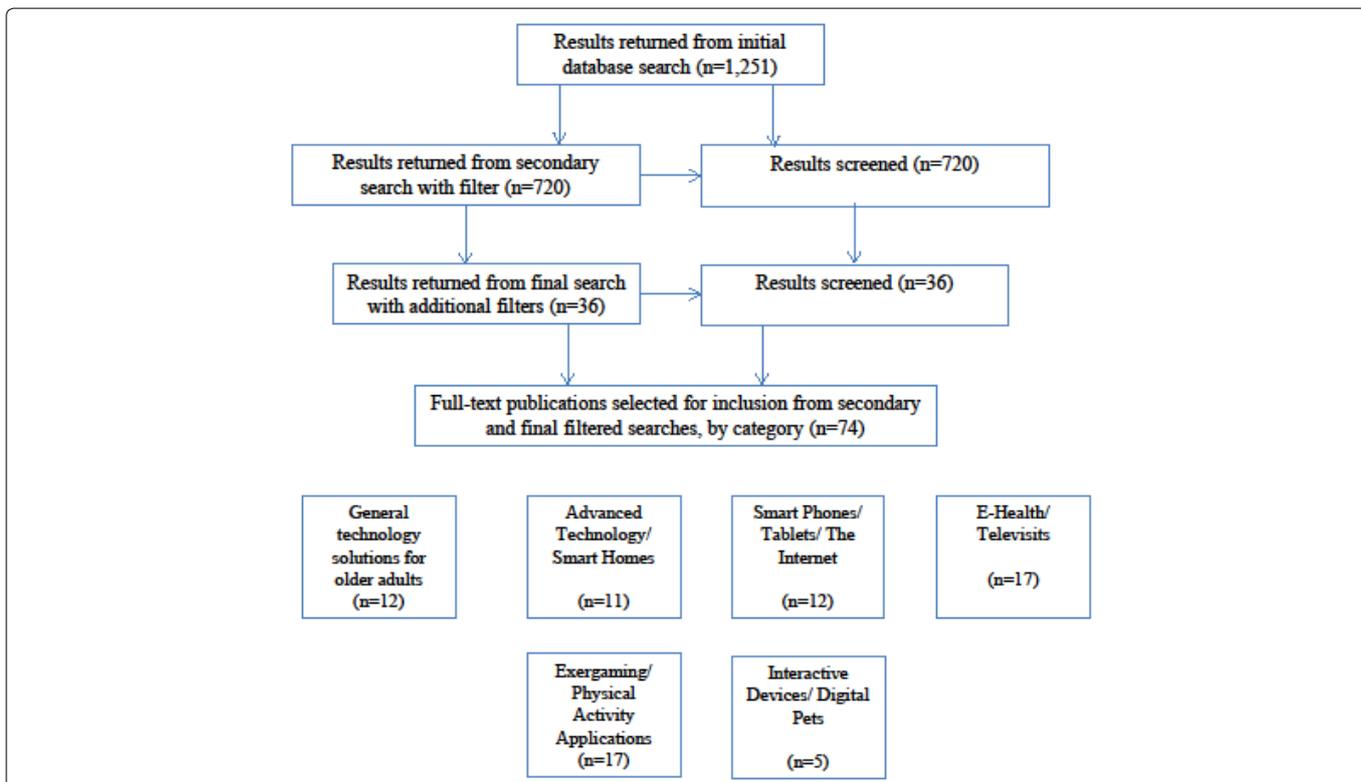


Figure 1: Diagram showing search methods and results.

Table 1: Number of results returned through all literature searches.

Search terms	Initial search	“MeSH terms” filter
Technology solutions older adults	103	70
Technological innovations older adults	23	NA
Gerontechnology	163	0
Smart homes for aging	39	NA
In-home technology older adults	93	74
Smart phone applications for older adults	26	NA
Social media use among older adults	393	323
Computer games for older adults	258	194
Medical alert devices for older adults	12	NA
Wearable fall detection monitors	58	0
Virtual reality interventions for older adults	17	10
Interactive devices older adults	58	49
Digital toys for older adults	8	NA
<b>TOTAL</b>	<b>1,251</b>	<b>720</b>

NA: Not applicable (MESH filters not used for these phrases)

Table 2: Number of final references selected for inclusion in the manuscript by major topic category.

Major topic category	Number of references selected
General technology solutions for older adults	12
Advanced technology/Smart homes	11
Smart phones/Tablets/The internet	12
E-Health/Televisits	17
Exergaming/Physical activity applications	17
Interactive devices/Digital pets	5
<b>TOTAL</b>	<b>74</b>

search term categories. Results for the additional filters used to streamline results are also shown (MeSH Terms and MeSH Major Topics).

After reviewing the titles and abstracts and applying exclusion criteria, we selected for inclusion the publications most relevant for our purpose. The final number of references ultimately included in this review totals 74. Articles were grouped based on their content and the search terms used to identify them. At the end of the manuscript, Table 2 is shown to list the final publications used as background information to support this commentary. More specifically, Table 2 details the distribution of final references selected for inclusion in each category, with similar or overlapping categories combined where appropriate.

### Summary of Findings

Our findings confirm that while a digital divide still exists, older adults are increasingly adopting and using various technologies in their daily lives [1,2,4,5,8,9]. For this literature search, we determined categories of technological development to explore for their accessibility, practicality, and potential to support quality of life, social connectedness, health management, and successful aging for older adults. Thus the areas of technology summarized will include: 1) Advanced smart home features; 2) Common technologies: smart phones, tablets, and device-based applications; 3) E-health tools and televisits; 4) Digital games and physical activity applications; and 5) Interactive home devices and digital pets.

### Advanced technology

**Smart homes:** As advanced technology has developed, the field of gerontechnology has emerged; described as a field blending gerontological research with technology, this domain links developing

**Table 3:** Summary of technological resources.

Advanced smart homes	Common technologies	E-Health tools/televisits	Exergaming/Digital gaming	Interactive devices/Pets
Remote tracking systems	Smart phones and tablets	Remote condition monitoring	Activity trackers/pedometers	Interactive home devices
Movement monitoring	Internet applications	Physician-patient communications	Exergaming	Smart speakers
Passive fall detection	Email and online shopping	Virtual televisits	Virtual reality gaming systems	Virtual assistants
Medication reminder systems	Information searches	Skype and FaceTime	Computer-guided group exercise	Robotic pets
Safety technology/automatic locks	Social media	Online monitoring tools	Physical activity applications	Digital toys
Bed occupancy sensing	Interventions and education	Email intervention	Online exercise programs/guides	
Assistive robotics and smart dressing	Condition/symptom management	Online treatments/therapies	Online activity interventions	
Ambient intelligence	Biometric data monitoring	Wearable devices/biometric scales	Digital gaming for cognition	

technology with aging needs [11,12]. Gerontechnology primarily focuses on advanced solutions to create smart homes and enable independent living for older adults, often designed for the challenges of individuals with dementia or disabilities who cannot live alone [2,11]. Smart home options include remote tracking systems for monitoring movements and behaviours; passive fall detection alerts; medication reminder systems; safety technologies (i.e., automatic door locks and video entry sensing); and other applications tailored for smart home living [2,12,13]. Additional options under development although not yet widely adopted include bed/chair occupancy sensing, assistive robotics (i.e., “smart dressing” systems), and ambient intelligence [2,12,13].

Smart home features have shown some potential in supporting independence for those with cognitive and/or functional disabilities, and may help replace the constant care that caregivers have provided yet is now less practical due to cost considerations and a shortage of care providers [12,13]. If equipped with the necessary features, smart homes can allow continuous, remote monitoring of an individual’s health, safety, and well-being while allowing independent living at a relatively lower cost than assisted living [13-15]. While research studies remain limited primarily with small sample sizes and the long-term benefits remain unclear, older adults in some cases demonstrate receptiveness to these technologies, although overall express serious concerns regarding cost, privacy, obtrusiveness, technological support, and training requirements, among other drawbacks [12,16,17]. One recent literature review describing smart home interventions and applications worldwide identified multiple concerns regarding feasibility and adoption within older populations, with further research recommended [12]. Similarly, other reviews report lacking evidence of improved health outcomes related to the use of smart homes; significant technical and ethical challenges; and consistently low levels of readiness and acceptance among older adults [18,19].

**Common technologies**

**Smart phones, tablets, and the internet:** Commonly used technologies, including smart phones, tablets, and their internet-accessible applications (“apps”), have begun to show as much potential to support successful aging as more advanced technologies [9,11]. Consequently, older adults are already adopting them, with some, especially age 75 and younger, using them daily [1,5,6]. Younger Baby Boomers are increasingly using devices (i.e., smart phones, tablets) to access the internet and engage in online activities, including email, shopping, information searches, and social media interaction [1,5].

In fact, research suggests online engagement may serve as part of a solution to address loneliness through computer-based programs, trainings, and websites [20-25].

Social media websites targeting both general and older audiences are gaining popularity among seniors as well. Over 60% of individuals age 50-64 and half of those age 65+ reportedly use Facebook on a regular basis [5,26]. These websites aim to create social connections and networks based on common interests or activities, regardless of location. Those who use social media tend to search for information, share, and connect with others [5]. Older (age 55+) social media users report privacy and inappropriate content as their primary concerns with use, along with a perceived lack of purpose or need [27]. However, they also recognize various benefits, including improved well-being through increased interaction and communication with others [27].

Meanwhile, smart phones, tablets, and online applications are being explored as tools to support condition management, healthcare communications, and physical activity. Older adults can use these technologies to monitor symptoms, track condition information (i.e., for heart failure, hypertension, diabetes, and others), and remotely communicate with an automated system or healthcare provider [28]. This time-sensitive process allows a faster response from a physician in health-threatening situations. For example, a smart phone technology known as Kardia<sup>™</sup> Mobile has been approved by the FDA to help those with heart conditions distinguish between symptoms of arrhythmia versus heart failure *via* electrodes attached to an iPhone [28-30]. It captures real-time information and potentially allows faster symptom evaluation [28]. Similarly, other telemonitoring technologies can measure biometric data such as weight, blood pressure, and ECGs *via* a smart phone with feedback delivered to a healthcare provider. One example, known as iGetBetter, allows patients to monitor weight, blood pressure, and heart rate and view results on a tablet connected to the internet [28,31].

Smart phones and tablets are also being used to support patient education and care in various settings. One pilot study explored the use of tablets to increase engagement and improve care transitions among hospitalized patients (age 40+) both before discharge and between visits [32]. Tablets were used to deliver two web-based programs: an educational module about hospital safety and a Personal Health Record (PHR) program to promote engagement in care management. Results indicated the majority of participants (90%) were satisfied/very satisfied with their experience; most (83%) completed the educational module independently and over two-thirds

(70%) used the PHR program successfully [32]. Thus researchers concluded that tablets with internet access can help improve patient education, engagement, and support discharge planning.

### E-health and televisits

“E-Health” (“electronic” health), also known as “m-Health” (“mobile” health), involves healthcare delivery at a distance primarily *via* the internet, designed for flexible, remote monitoring of conditions, physician-patient communications, and virtual televisits [3,4,10,33-35]. E-health involves a range of technologies, including interactive television, personal digital assistants (PDAs), Skype and FaceTime, and online tools to help patients self-manage chronic conditions and interact with physicians [3,4,10,33-35]. E-Health delivered through common technologies has the potential to improve cost-effectiveness, efficiency, quality, and address problems of access, expense, and portability [34,36].

E-Health encompasses personalized email-based support interventions designed to help older adults manage chronic conditions. This approach typically involves a facilitator who sends emails to participants, providing instructions on how to access information online about their conditions. One such intervention that provided e-mail support to adults age 60+ determined that while this is a good option to support self-management of chronic conditions, various concerns need to be addressed, such as the need for assistance with website navigation [37].

Elsewhere, internet-based interventions have been used as an innovative treatment approach for depression or other conditions. One potential advantage of internet-based treatment for depression is the ability to reach depressed individuals who often do not otherwise seek treatment [38]. In one study, two groups received different therapy modalities weekly *via* the internet: either cognitive behavioral therapy (CBT) or problem-solving therapy (PST) [38]. Findings indicated that both online programs were effective in reducing depressive symptoms including decreased anxiety, although with less of an impact on quality of life. Supporting these findings, a meta-analysis of depression interventions concluded that internet treatments delivered through an e-Health approach have the potential to improve symptoms across all ages [39]. Finally, online interventions have been tested to address other issues among seniors, including memory and cognitive decline, social engagement, physical activity, and sleep [7,40-42]. Published results suggest that many older adults are willing to try these e-Health approaches [7].

Virtual televisits through devices with internet access represent another e-Health option by facilitating “face-to-face” appointments. Common websites such as Skype and applications including the iPhone’s FaceTime are useful for connecting older adults with caregivers and/or healthcare providers to enable televisits. This option is emerging as a viable means to support healthcare delivery at a distance and at flexible times, potentially improving quality and cost-effectiveness.

Finally, patient biometrics can be assessed remotely as part of e-Health delivery in ways other than smart phone applications. Remote monitoring technologies for chronic conditions have expanded to include telephone support, biometric evaluation, and other tools. Wearable and implantable devices and trackers have the ability to transmit biometrics, such as heart rate, respiratory rate, activity duration, and weight changes, to a monitoring system or healthcare provider [43,44]. Many versions are available, including watches, pedometers, and other devices such as the FitBit and Jawbone, to

accurately provide rapid, real-time data transmission when linked with a smart phone, allowing recording of physical activity, heart rate, breathing, fall alerts, and changes in other symptoms [28,45-47]. For example, Bluetooth-enabled weight scales allow providers or case managers to track symptoms such as unexplained rapid weight gain in patients with heart failure, potentially identifying condition exacerbations and allowing a quicker response in urgent situations. Bluetooth-enabled scales have shown promise for improving heart failure outcomes as well as potentially reducing healthcare utilization and expenses [43,44]. Finally, wearable alert devices are widely available with a range of variations for purposes from fall detection, condition monitoring, and implanted defibrillator failure to location detection and fitness tracking [48,49]. In studies examining the use of these devices, results have been mixed but suggest the potential to support older adults’ health and safety, although further research and testing have been recommended [48,50,51].

### Exergaming, digital gaming, and physical activity applications

Efforts to help older adults maintain physical activity levels have also turned to technology, including not only wearable activity trackers and pedometers, but also more advanced exergaming, computer-guided group exercise, and online applications accessed through devices [52-63]. In fact, these options are being explored not only for exercise promotion but also for prevention of falls, frailty, and cognitive decline [58,59,61,64,65]. Research indicates that older adults are receptive to exercise-related and gaming technologies and find enjoyment in using them [63]. In recent years, computer-based gaming, or “virtual reality” (VR) exergaming technology, has expanded, with growing availability and affordability of the components required [59]. VR systems allow at-home users to interact with virtual objects and/or events that simulate real-world situations. Initially, these were primarily intended for entertainment but have progressed in design to encourage exercise and support rehabilitation and motor skills by mimicking participation in sports, dance, or other activities that can be done at home [59]. Two VR exergaming systems in particular, Nintendo’s Wii and Microsoft Kinect, have quickly gained widespread popularity across age groups, with the Wii the most commonly used for physical rehabilitation [59]. Studies examining the potential benefits of VR exergaming have found that these programs can enhance balance control and thus reduce the risk of falling within older populations, especially among those at higher fall risk [59,61,64]. In addition, exergaming can reportedly improve mobility and physiological function among frail older adults [60,64].

Meanwhile, technological options for physical activity have expanded with the development of applications and programs delivered through small devices. Smart phone applications and online health promotion programs are now easily accessible to encourage physical activity among all ages including older adults, who are among the most inactive age groups in the US [52,53,58]. Users can often customize applications to design an individualized exercise program or set up motivational reminders [52,53]. Similarly, diet tracking applications allow the input of individual nutrient and caloric intake directly into a smart phone or tablet to calculate and save daily totals [52,53]. Although initial research studies have included modest sample sizes, results suggest the potential of these tools for effectively improving physical activity and health behaviors among older adults [52,53].

Elsewhere, physical activity interventions using technology have been delivered at a distance, in non-face-to-face settings with little or no contact between the intervention provider and older participants. This flexible approach allows individuals to tailor their participation for individual needs and schedules in a low-pressure context to promote physical activity [56,62]. Research has confirmed the effectiveness of these programs in promoting physical activity through technology, suggesting their potential for supporting successful aging with a low-cost, convenient approach [62]. Meanwhile, interventions utilizing tablets and smart phones with internet connections have found that guidance from remote coaches delivering instruction *via* devices can successfully promote exercise engagement and adherence [56,66]. In addition to individual interventions, online group exercise programs have also been tested with results indicating the motivational benefits of group exercise delivered through technology [55].

Finally, digital gaming has been explored for its role in producing cognitive benefits among older adults. Established research links cognitively stimulating activities to delayed onset of rapid memory decline and cognitive impairment [65]. Digital games, including action/rapid firing games, video games, puzzle or strategy games, and role-playing games, often require quick reflexes, agility, sensory discrimination, adaptation, and/or problem-solving skills [65]. These skills are similar to those utilized in “brain training” programs or interventions suggesting that in this context, they may also help to prevent cognitive decline. Furthermore, older adults express overall acceptance and enjoyment in digital games [63]; thus gaming may be a viable option for supporting successful aging as well.

### Interactive home devices and digital pets

Meanwhile, additional innovations are emerging as options to enhance quality of life and social connectedness through user-friendly technologies even if, in some cases, not originally designed for this purpose. Digital connections are expanding with newer concepts, as at-home interactive devices have reached the market. These devices respond to voice commands and questions, answer questions, and interact with the user through a digital “voice” response. Several companies now offer home devices often known as smart speakers or virtual assistants, which have the capability to interact with and respond to users [67]. For technically savvy seniors, especially those who live alone, this technology may provide a sense of engagement with another “individual,” even though that individual is digital. Variations of these devices “talk” to the owner, answer questions about news or other topics, play music upon request, and otherwise engage the user, perhaps suggesting the eventual development of more human-like robot versions as a future direction for this technology [67].

Meanwhile, new and developing digital robotic pets, while not specifically designed for seniors, are being explored as an option for companionship later in life [68-70]. These toys respond to voice prompts and many have the ability to move, imitating the presence of a pet and allowing simple interactions with the owner [68,71]. One review reported that a small number of descriptive studies suggest the potential for improved loneliness and social engagement among older adults using robotic pets [69,70]. However, this review identified no designed research studies evaluating the actual health effects or long-lasting benefits of using digital pets with older adults, with only one study planned to examine the impact on outcomes among individuals with dementia [68]. Thus further work is needed to determine the true potential of wider adoption of these tools.

### Discussion

Although still an emerging area of research, the current literature reviewed here demonstrates opportunities for common technologies to support gaps in care as well as successful aging, independence, and quality of life among older adults. Both developing and established technological resources show promise in supporting these goals [3,4]. Advanced smart home technology is expensive, although potentially more affordable than most long-term care options. On average, a private nursing home room costs about \$250/day or over \$90,000/year; even a semi-private room can cost over \$80,000/year [14,15], options that are out of reach for many families. However, the costs of retrofitting homes for installation and implementation of smart home technologies, as well as ongoing technological support and full-time monitoring, are still unrealistic for those on fixed incomes. In fact, the current smart home market revenue is currently stagnant, primarily due to the high cost of technological components, limited demand, and reluctance to adoption [13,72]. Furthermore, smart home technology to support aging is not covered by Medicare or private insurance plans [11-14].

Additionally, smart home technologies come with significant concerns aside from cost considerations [11-13,72]. Overall, the primary disadvantages reported among seniors include privacy, intrusiveness, usefulness, perceived need, low self-efficacy, the stigma of feeling old, and lack of control [11,12,73]. Furthermore, smart home features designed to be helpful may actually introduce safety and security risks, such as tripping on electronic cords; failed electronic systems in emergencies; and lack of power during outages [12]. These issues remain key considerations of the practicality of smart homes on a larger scale.

Meanwhile, older adults generally have a positive attitude toward the use of more common technologies: nearly 60% of those age 65+ report they believe technology has a positive impact on society; over 80% of Baby Boomers expect technological tools to improve their lives as they age [2,5]. Younger Baby Boomers, especially, have more experience and exposure to modern technologies than generations of the past, thus may be receptive to and comfortable with resources that support independence, condition management, social connectedness, and quality of life [1,2,9,11].

Multiple benefits of smart phones and tablets used for various purposes are apparent. With their smaller size, mobility, and affordability, smart phones and tablets offer a convenient, user-friendly connection to a broadening range of online resources. Additionally, many older adults already use these devices to connect with peers, potentially addressing widespread loneliness and social isolation within this population [28]. The primary challenges of smart phone and tablet adoption by those who do not already use them will likely include training, technical support needs, self-efficacy, comprehensibility, and presentation (i.e., size of text/images on websites for those with vision impairment; use of small devices for those with arthritis) [74]. However, as long as technological and intervention development considers the challenges, these devices could be among the most practical for supporting successful aging. Furthermore, design and development of resources should encompass the appeal and appearance of technologies for various age segments so that the older old do not feel singled out or stigmatized; enjoyment and ease of use are additional factors to consider as well.

Generally, older study participants have been receptive to e-Health resources including e-mail support for condition management

and innovative treatment options [7,43,44]. Interventions testing depression treatment through online delivery of various therapies have demonstrated success in improving symptoms [7,40,41]. Additionally, device-based virtual televisits offer a flexible option for care delivery; while biometric monitoring tools for condition management allow real-time condition tracking and a faster response [43,44]. These resources hold promise for supporting not only aging but also caregiving. In addition, e-Health technologies have the potential to reach and support those who are homebound, an at-risk segment of the older population for whom traveling to appointments could be difficult or impossible. However, as with some other options, common barriers to widespread adoption of e-Health tools include cost, accessibility, privacy, technical support, and perceived need [1,3,4,10,20,33-35]. For instance, constant remote monitoring of biometric data trackers could present cost concerns, as paying for 24/7 monitoring of data transmission by a live operator is likely out of reach for many seniors. Future developments in this area could bring costs down; thus additional research to develop creative solutions in this area appears worthwhile [34,36].

Meanwhile, considering the popularity of common technological devices, exergaming and physical activity applications may provide a viable option as well. Although studies remain limited with small sample sizes, gaming and health-related applications have shown promise and acceptance within older populations [55,56,59,62,63]. Exergaming technologies are affordable in comparison to other options and traditional gym memberships for promoting physical activity. In addition, the option of exercising at home is preferred by many older adults and could be practically accomplished through exergaming and online exercise instruction [55,56,62]. Furthermore, online group programs have the potential to address loneliness, social isolation, and overall well-being through engagement with others [55]. Potential challenges include the need for initial training and support for the user as well as motivation for continued engagement in this type of activity. However, these options appear to hold promise for supporting physical health later in life.

Finally, the developing area of interactive home devices and digital pets offers potential opportunities to support aging primarily for those who choose to remain in their homes and who may be lonely. Although still developing with little research to confirm their benefits, these tools could provide enhanced social support, connectedness, and reduced loneliness while avoiding the high costs of many other technological resources for aging.

The common technologies described here avoid many challenges and concerns of advanced smart home features as applied to support aging at home, including cost considerations, privacy, use, accessibility, and others. However, the lasting benefits of technology use over the longer term remain unclear. Additionally, certain e-Health resources and remote monitoring options remain costly due to the constant live support required. Until these technologies are incorporated into US healthcare payment systems so that monitoring becomes affordable, barriers will exist to widespread generalized adoption of certain resources.

Additionally, different segments of older adults have different needs and challenges related to technology. Research demonstrates that the aged older population (age 80+) faces more barriers and challenges to technology adoption than younger Baby Boomers, including skepticism and lack of experience with technology, as well as a steeper learning curve [11-13]. This age group may also

prefer more traditional approaches as well as a personal element than these technologies can deliver. In addition, many need ongoing training, technical support, and encouragement to use technology; thus a multidimensional approach to reaching different population segments will likely be required [11-13]. Meanwhile, large-scale research initiatives targeting older adults need ongoing funding sources to supply resources, such as interactive home devices, to large numbers of participants. In some cases, older individuals may have the financial means and desire to purchase technological resources for their own use, but for others, access to newer technologies remains a barrier.

One primary limitation of this review was the extremely broad range of topics related to currently available technologies and the number of publications to explore. However, by narrowing our focus to more common, user-friendly options versus advanced smart home technologies, it was possible to describe those options that have received less attention specifically in their potential role to support aging. Little has been published on how the common tools described here are being adopted later in life to support aging; thus this review adds to the literature on the use of technology later in life.

## Conclusion

Current research demonstrates a growing need and unique opportunity to promote technological options to support successful aging and quality of life. However, continued development and use of these technologies must consider the differing needs, preferences, and challenges among older individuals. Since technological solutions are not one-size-fits-all, work in this area should continue to establish a better understanding of the factors, predictors, and situations that impact older adults' likelihood to adopt and use technologies in their daily lives. Moving forward, it will be critical to consider a range of solutions to match the broad spectrum and variation in the aging process within older populations. Furthermore, integrating common technologies on a large scale will depend on addressing additional barriers that are unique to older adults. Additional focus on testing and integrating the more practical technological tools is warranted to support the late-life needs of this growing age group.

## Conflict of Interest and Funding Declaration

### Conflict of interest statement

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### Internal review board approvals

As this is a literature review paper, no human subjects were involved in the research and thus no IRB approval was necessary or obtained.

### Ethics approval and consent to participate

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### Author's contributions

Stephanie MacLeod, MS and Shirley Musich, PhD drafted the majority of the written sections of the manuscript. All authors listed including Ms. MacLeod and Dr. Musich qualify as authors as all were involved in the following roles in addition to assistance with revising the manuscript at draft stages:

- Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data;
- Were involved in drafting the manuscript or revising it critically for important content;
- Gave final approval of the version to be published and participated sufficiently in the work to take responsibility for appropriate portions of content; and
- Agreed to be accountable for the work in ensuring that questions related to accuracy or integrity are appropriately investigated and resolved.

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