World Journal of

Psychiatry

World Journal of *Psychiatry*

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Use of technology and social media in dementia care: Current and future directions

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Abstract

As the population across the globe continues to dramatically increase, the prevalence of cognitive impairment and dementia will inevitably increase as well, placing increasing burden on families and health care systems. Technological advancements over the past decade provide potential benefit in not only relieving caregiver burden of caring for a loved one with dementia, but also enables individuals with dementia to age in place. Technological devices have served to improve functioning, tracking and mobility. Similarly, smartphones, tablets and the ubiquitous world wide web have facilitated the dissemination of health information to previously hard to reach populations largely through use of various social media platforms. In this review, we discuss the current and future uses of technology *via* devices and social media to promote healthy aging in individuals with dementia, and also limitations and challenges to consider in the future.

Key Words: Dementia; Technology; Gerotechnology; Social media; Geriatrics; Wearable technology; Health promotion; Home health; Monitoring

Core Tip: Technological advancements have the potential to re-define successful aging at home for individuals with dementia, bestowing sustained autonomy and independence, and also providing relief for families and caregivers. As gerotechnology continues to develop and is integrated into everyday life, research also continues to study how best to optimize usage and address older adults' preferences and concerns.

Aims of this review are to examine and summarize current literature and technologies available and forthcoming that aid in diagnosis and successful aging in place, as well as challenges to be overcome.

INTRODUCTION

With a rapidly aging population comes the rise in older adults living with chronic conditions. Of these, dementia has become one of the leading causes of disability and dependency worldwide[1]. Dementia is an umbrella term of symptoms that progress over time in which there is a gradual deterioration in cognitive and functional impairment and altered behavior. The etiology of dementia is myriad, with most common being Alzheimer's, and closely followed by vascular, Lewy body, frontotemporal, and mixed dementias. With unique pathologies and causative insults, each has its unique treatment to address the underlying cause. However, no cure currently exists for these dementias at large, nor treatment to alter its progressive course. Eventually unable to live independently, individuals with dementia require increasing levels of assistance and care. Therefore, goals for dementia care are focused on early diagnosis in order to optimize management in terms of physical health, cognition, activity and well-being.

Dementia care both in and outside of the hospital setting can prove challenging and complex. In addition to affecting individual quality of life, tremendous burden is placed on health care systems and families. One solution is to encourage and create a system for home-based dementia care. In 2015, a national consensus panel convened to address the burden of dementia and family caregiving[2]. Recommendations were made to shift the focus of future long-term care models to home based dementia care. Moreover, the majority of older adults prefer to stay in their homes for as long as possible than enter a nursing home when they require higher level care[3]. Technology, therefore, has the capacity to transform the course of dementia care, particularly at home.

Many technologies exist that have potential to support people with dementia and their caregivers through all stages[4]. Integration of existing and future technology presents an important opportunity for ameliorating the burden on individuals, families, and the health care system. A term coined "Gerotechnology" embodies this new interdisciplinary field of designing technology and an environment to promote independent living autonomy of older persons while strengthening the support of their networks[5]. Understanding and acceptance of use of technology in older adults are also key in the enduring adoption into everyday life. A recent study has established a 14-item questionnaire that can help assess older adults' acceptance of technology and effective usage[6].

In this review we address technology and social media targeted at health monitoring, proliferating dementia education and promoting psychosocial wellbeing of those with dementia. We summarize existing and in progress technologies that facilitate successful aging in place. Finally, we discuss limitations and challenges of implementing and integrating these technologies in the increasing population living with dementia.

TECHNOLOGY AS AN AID IN DIAGNOSIS

Research in Alzheimer's disease has grown exponentially over the past few decades[7]. Currently diagnosis of dementia is and remains primarily based on clinical history and presentation of the patient, with cognitive and functional testing. For Alzheimer's dementia, only post-mortem neuropathology is able to formally confirm a diagnosis. However, the advent of advanced medical imaging technologies and fluid biomarkers provide insight in the pathogenesis. As research advances, it is becoming clear that at

some point in the progression of dementia, lost neural networks cannot be regrown and excessive neurodegeneration cannot be reversed. Instead focus is shifting to slowing down early stages of progression and moreover, prevention: By reduction of overall improvement of health and wellbeing, chronic inflammation and oxidative stress[8].

Changes in how individuals use technology has been identified as an early indicator of emerging cognitive impairment. Seelye *et al*[9] designed a proof of concept study using continuous driving monitoring with unobtrusive sensors to identify and monitor subtle changes in driving patterns that may signal mild cognitive impairment (MCI). This study introduces a novel method in early detection and monitoring of functional changes in individuals with developing MCI.

Kamin and Lang[10] conducted a two-year longitudinal study looking at internet use and cognitive function in late adulthood. Looking at 29576 participants between 50 and 100 years of age, this study indicated that Internet use positively affects cognitive function in late life[11]. Similarly, Austin *et al*[12] conducted a longitudinal study in which a cohort of 113 older adult computer users were followed over a mean of 36 mo. They found that between participants with MCI and those who were intact, there was a significant decrease in the number of days with use, mean daily usage and increase in day-to-day use variability. Other studies suggest that even changes in the terms people search over the internet may be a measure of language and cognitive function in older adults[9].

Interestingly, Ihle *et al*[13] revealed in a six-year longitudinal study, the gender differences in the relationship between Internet use and cognitive decline, showing that more frequent Internet use predicted smaller subsequent cognitive decline only in men, but not in women. Together, these studies suggest the usefulness in incorporation of technology use in assessments for instrumental activities of daily living. They emphasize the potential that monitoring computer and technology use in diagnosing MCI and the progression of dementia over time, warranting further research in this area.

SMART HOMES: VOICE-ACTIVATED SMART SPEAKERS

The idea of "smart homes" is not novel. Smart homes are essentially the equipment of homes with sensors and various technology that facilitate the monitoring of inhabitants to improve quality of life and promote physical independence and reduce caregiver burden[14]. Services provided are far reaching from home automation of appliances, temperature and lighting systems, to remote monitoring capability of residents' wellbeing and safety (Table 1). With increasing prevalence and usage of smart home devices, older adults can potentially live independently and safely at home for longer, reducing or prolonging the need for caregivers both informally or formally[15].

Amazon currently has a line of Alexa-enabled home devices such as Echo, Echo Dot, and Echo Show. In addition to Amazon, there are various voice-activated smart speakers that also share similar functions[16]. Compatible smart home devices allow users to control lights and switches, set thermostats, view security cameras, thereby automating and simplifying everyday routines[17]. The Alexa mobile app includes a feature called 'Guard' that sends mobile alerts if an Echo device detects the sound of a smoke alarm or breaking glass. There is even a 'Hunches' feature that can help remind users to turn off a light or lock a door if Alexa has a 'hunch' that it was forgotten. More recently, Amazon recently launched a new feature called 'Care Hub' that allows consumers with an Alexa voice assistant to link their account to an aging relative's Alexa account[18]. This free feature includes activity feeds of smart home interactions, customized alerts for example if no activity is detected for a prolonged period of time, emergency contact notification capability, and quick access features allowing Alexa calling or 'Drop In'.

Several study protocols have been published as potential at home interventions to support caregivers of individuals with dementia[19,20]. The UP-TECH project proposed by Chiatti *et al*[19] was a 12 mo randomized controlled trial based in Italy with the purpose to reduce care burden of family caregivers and maintain Alzheimer's dementia patients at home. Technologies given included various housing adaptations such as sensors that detect falls, gas and water leak, and automatic lights. Outcomes measured were amount of caregiver burden and the number of days spent at home away from hospitalization or institutionalization. Other analyses measured were health economics, cost-effectiveness stratified by training time, social, costs of

Table 1 Summary of smart home and sensor technology

Technology	Functions	Originally developed for	Ref.
Alexa-enabled home devices, and Alexa Care Hub®	Voice-activated smart speakers, connectable smart home devices, remote smart home monitoring	General use, older adults	Chung and Woo[16], and Amazon[17,18]
Tile	Locate misplaced items	General use	Tile[23]
Water-leak sensor	Smart water shutoff, mobile alerts	General use	D-Link[34], and Moen[35]
Google Nest Protect	Smoke and carbon monoxide alarm, 'pathlight' feature	General use	Google Store[38]
iGuard Stove	Smart stove shut-off valve, remote control and monitoring, emergency shut-off	Older adults	GoDaddy[39]
Automatic pill dispensers	Integrated alarms and reminders, multiple medication management, remote monitoring, adherence tracking	Older adults	Vervloet *et al*[42], Boland *et al*[43], Paterson *et al*[44], Hoffmann *et al*[45], Faisal *et al*[46], Ahmad *et al*[47], and Patel *et al*[48]

technologies and consumables for the interventions and health-related costs. In 2019, Socci *et al*[21] published the results showing high user satisfaction. Implementation and findings of this project are intended to support health care and social service professionals and policy-makers in the creation of future programs to address needs of Alzheimer's dementia patients and their care givers.

A similar study protocol based in Sweden, Malmgren Fänge *et al*[20] proposed a large randomized controlled trial called TECH@HOME. Aims were to recruit community-dwelling people with dementia and their primary informal caregivers and study the effects of technology on caregiver burden. Split into intervention and control groups, each intervention group would receive an information and communication technology kit including home-leaving sensors, smoke and water leak sensors, bed sensors, and automatic lights to monitor individual behavior. Home visits throughout the study period would measure primary outcomes of resource utilization, as well as secondary outcomes such as quality of life for both caregiver and person with dementia, caregiver anxiety and burden, and cost-effectiveness. Empirical data highlighted persons with dementia and their family members felt safe with the technology installed at home and felt that the technology was useful[22]. Ultimately sensor-based technology has the potential to be a support in ensuring a safer home environment for people living with dementia.

Results of these studies have the potential to inform policy makers and influence caregivers and families alike on the current state of technology. Implementation of similar study designs across the world are imperative in order to assess and inform of the current status of technology in alleviation of caregiver burden associated with dementia care and prolonging the independence of individuals with dementia in order to remain at home for as long as possible.

SENSORS AND SAFETY

Locator devices
Misplacing items is one of the most common symptoms of dementia, and as it can also be a common symptom of normal aging, persons living with dementia may be unable to find items again. Products such as 'Tile' are Bluetooth-enabled devices that can help locate misplaced items through activation of an audible alarm or last known position found on the mobile app[23]. From a simple tag on a keychain, card to slip into a wallet or laptop, or sticker for the remote control, products are designed to fit and locate the most common lost or misplaced items. Features include location history and also 'Tile Community' to use other individuals using running mobile Tile applications to help locate lost items when in Bluetooth range.

Falls, wandering, nighttime ambulation, security
Dementia-related wandering is present in up to sixty percent of community-dwelling people with dementia, and can be dangerous — even life-threatening — for patients and stressful for families and caregivers[24]. Modeled after the Amber Alert system for missing children, the 'Silver Alert System' was created in 2006 to provide a public alert

system about missing and vulnerable older adults[25]. Furthermore numerous technologies have been developed over the years to ease family and caregiver burden, locate missing persons and facilitate their return[26-28]. Providing a safe environment at home is important to continue to live independently and can be done by monitoring movements and alert carers or loved ones to potential breaches of safe boundaries. It is estimated that 30% of older adults fall at least once a year. Fall-related fractures can cause disability and even lead to premature death. The frequency of falls increases with age, as a result of physical, functional and cognitive impairment. Increasing technology-based interventions have been implemented for fall detection and alert[29].

There are a number of floor alarm mats by different companies. Floor pressure mats are good for fall-alarms when placed beside a bed or chair. Alternately, they can be placed at any doorway, such as an exit or the kitchen, to alert caregivers when their loved-one is on the move. Alerts can be in form of audible alarms or sent to connected smart devices. The doorway anti-wander safety beam can be placed alongside any doorway and send alarm sounds when the beam is crossed.

More innovative technologies include motion sensors embedded into socks and in floor tiles. Other floor pressure mats can be programmed to play recorded messages, for example a reminder to turn off the gas when walking out of the kitchen. There have been innovations such as the global positioning system (GPS) shoe, marketing itself as a way to locate individuals with Alzheimer's disease who have wandered away from home or their care facility. While they work with astonishing accuracy, and can be integrated with mobile application or professional call centers, there are also limitations and ethical considerations which will be discussed later[30-32].

Smart lighting technology also be placed in dark hallways and entryways to automatically turn on with motion sensor or *via* voice activation. Smart contact sensors can be multi-function. It can act as a whole home security system with alerts for open doors and windows, even refrigerator doors to indicate how often an individual has accessed comestibles. Options to self-monitor through mobile application or smart home system or professional monitoring with subscription are available. Combined, these technologies are promising to prevent or call to attention falls and wandering outside of the home and promote safer nighttime ambulation.

Water leaks

About one in fifty US homes file insurance claims annually due to water damage, which amounted to $13 billion in insurance payout for water damage[33]. These figures can easily be alleviated with technology to alert individuals of water leaks the instant they are detected. Smart water-leak sensor technology can be placed near areas of most likely leaks, such as the water heater, bathtub, sink, or toilet. Studies like the TECH@HOME study[20] have incorporated water leak sensor technology in home monitoring kits when studying technological interventions for individuals living with dementia. Currently there are many water leak detectors on the market, mostly embedded with smart technology that can be integrated into smart home systems[34,35]. Smart water shutoff can automatically turn off water supply in an emergency. Others offer wireless sensors that send alerts through mobile app in addition to triggering audible alarms or lights.

Fire safety

In 2004, the U.S. Fire Administration launched an intensive public fire education campaign for elderly Americans, and in 2006, published a report evaluating the fire situation and risks for this particular population[36]. Older adults are 2.5 times more likely to die in fires than the overall population. Common fire causes resulting in injury among the older population are cooking, open flames, smoking and heating. Decreased sensory abilities like smell, touch, vision and hearing that come with aging, and compromised cognition with progressive dementia can all contribute to impairing ability to prevent or respond to fires. Hearing impairment is the second most commonly reported in older adults in the United States[37]. The inability to hear warning sounds of fire or a smoke alarm creates significant fire risk. This decrease in reaction time and awareness places older adults at higher risk of fire, fire injury and fatality. Attention therefore needs to be placed on making the necessary home improvements to reduce fire risk. Unfortunately, many of these are overlooked or postponed because of cost or lack of knowledge or attention.

Technologies such as 'Google Nest Protect' acts as a smoke and carbon monoxide alarm that alerts by voice and siren and is capable of sending smartphone alerts to up to six contacts[38]. Also integrated into its device is a 'Pathlight' feature, a motion-activated night light.

Stove-top technologies such as the smart stove shut-off valve allows for remote

control and monitoring of stove settings and emergency shut-off system. Technologies such as the 'iGuard Stove' boast automatic shut off after 5 min of no presence in the kitchen, day and night-time activity monitor, night lock and caregiver lock modes, and alerts sent to mobile application[39].

MEDICATION AIDS

Unintentional medication nonadherence is increasingly prevalent with an aging population, particularly in older adults with compromised functional and cognitive capabilities, multiple chronic health conditions on complex medication regimens[40,41]. Current strategies to address medication management adherence include pillboxes, visual or audio reminders or alarms, and automatic pill dispensers[42-44]. Of the multiple automated pill dispensers currently on the market, these products have many features including integrated alarms and reminders and ability to manage multiple medications. Dispensers are connectable to smartphone *via* application and can notify users and allow remote monitoring. Applications can track adherence and also notify when certain medications are running low. Some devices are able to store and dispense up to 90-d supply of up to 10 different medications. Unfortunately, this creates limitations for individuals taking more than the maximum allowed medications each machine is able to manage, requiring need to decide which scheduled medications are most important to track, or allow another application to manage medications outside of the device. Other limitations are the type of medication: Some dispensers will not work with half pills, gummies, powdery, sticky or dissolvable pills.

Hoffmann *et al*[45] studied whether automated home medication dispensers could help solve unintentional medication nonadherence. Using a 6-mo prospective study in 21 patient-caregiver dyads, they found that mean adherence increased from 49.0% at baseline to 96.8% ($P < 0.001$).

Faisal *et al*[46] and Ahmad *et al*[47] examined user experience with electronic medication adherence products. Both studies have demonstrated that these products have potential to promote independent medication management in older adults. Choice of products are based on product features, facility of use, portability, and affordability. Unfortunately, many medication dispensing systems have a monthly managing free in addition to the upfront cost of the machine itself, therefore use of such technology can be limited by cost.

Patel *et al*[48] used a prospective, mixed methods study to test the usability and workload of twenty-one electronic medication adherence products. Each of 39 participants tested five products, one at a time and usability and workload were compared in the different products. This study highlights the importance of comparing products within target populations in order to guide clinicians, caregivers, and users themselves in choosing the most optimal product for their particular needs.

Alternative to automated medication dispensers, mobile applications can be a useful standalone assistive technology to ensure medication adherence. Chew *et al*[49] looked at the usability and utility of a mobile application called 'Med Assist' to improve medication adherence. To date, there are several medication adherence applications, but few studies have been conducted among their target population. Through two rounds of 'think aloud' interview and a retrospective interview at the end of using the application for a week, results showed positive feedback from participants regarding usability and reliability. Ease of navigating through the application, multiple user support capability and medication refill reminders were all positive aspects that participants found that suggest the efficacy of this and similar mobile health applications to improve medication adherence.

WEARABLE TECHNOLOGY

Wearable technology, particularly wrist-worn devices, can impact key aspects of dementia care management by providing insight into specific factors that are key determinants of health and wellbeing[50,51]. Devices are able to provide quantified information on sleep and physical activity, with more advanced technology having embedded heart rate monitor, arrhythmia and fall detection, and GPS. These objective measurements have potential to guide physicians in clinical decisions by having a tool that simplifies and facilitates data collection in a manner previously impossible. Available devices offer easily accessible and user-friendly interface. Contrary to life-

alert or medical alert buttons that have stigma of making wearers 'feel old', wrist-worn devices offer more sleek and discreet designs that can appeal to older adults. With so many available functions, these devices can aid in the care and management of older adults with dementia.

Megges *et al*[52] studied the user experience and clinical effectiveness of two similar wearable GPS watch devices. Over a period of 4 wk, measures such as usability, design features, and overall product satisfaction were taken by patients and caregivers. Feedback and findings included preference for fewer buttons, clear display and font, and ample battery life. Future comparison of GPS devices, particularly watches, are of interest in order to study how likely they are to be adopted.

A recent case study described how use of a wrist-worn device was able to aid physicians in diagnosis, treatment decision making and prognostic monitoring of treatment of an older adult's late-life depressive symptoms[53]. The patient was encouraged by the ability to track and visualize his own activity and sleep and reported positive reinforcement for remaining engaged in exercise as it noticeably improved his depression.

As many older adults already own wrist-worn devices demonstrated by the plethora of commercial wearable devices available by companies such as Apple[54], Fitbit[55], Garmin[56], and Huawei[57], it is no wonder that these devices are becoming the focus of future research that can not only support older persons with dementia, but also revolutionize the way we collect 'big data' for studying populations in aggregate[58].

Amazon most recently launched 'Halo', a wearable band and health and wellness tracker detecting body fat composition, sleep and activity tracking, and most uniquely, tone of voice analysis[59]. Voice qualities such as pitch, intensity, rhythm, tempo analyze and report emotion states of 'hopeful, elated, hesitant, bored, worried, confused, affectionate' for users to become more aware of their mood, interactions and relations throughout the day. Goals of this device are focused more on providing means for lifestyle changes including at-home workouts, guided meditations and sleep sounds.

SOCIAL MEDIA

Today more than ever, people are turning to the internet for health information. Social media are a valuable tool to deliver health education to different populations. Different platforms are available on mobile devices that facilitate information acquisition and sharing and the use of these by people globally are on the rise.

Studies have shown that YouTube is effective in delivering dementia education to older adults[60,61]. Similarly, Twitter is a novel platform for Alzheimer-related dementia awareness[62]. Other studies explore how social media platforms such as WhatsApp are becoming strong means of disseminating health information[61,63]. Further efforts in studying and optimizing how we use social media to recruit, disseminate and share health information can prove invaluable in reducing the gap in health literacy and ensure healthy aging and promotion of healthy outcomes.

It is important to consider the perceived usefulness of technology in the older adult population. Best *et al*[64] conducted a study showing a positive relationship in the perception of usefulness of computers in providing health-supporting technologies. Furthermore, Berkowsky *et al*[65] looked at different factors that predict technology adoption among older adults. With fifty-two older adults participating, they found that self-assessed abilities and computer-internet skills were predictive of individual willingness to adopt technologies. However most robust predictors were perceived value and impact on the quality of life, and confidence in ability to learn the technology. Therefore, in developing new technologies, consideration must be made in balancing functionality with complexity in order to maximize potential of technology adoption among the aging generation.

ARTIFICIAL INTELLIGENCE

The use of artificial intelligence, or robotic technology, has been explored over the years. Robots have been made to either be physically assistive (performing physical tasks), or socially assistive (providing social and psychological support).

Therapeutic robots

With progression of dementia comes increased behavioral and psychological symptoms of dementia that can be difficult for family and caretakers to manage. Non-pharmacologic interventions are sought after before turning to psychotropic medications. Therefore, therapeutic robots in form of animals may be promising forms of therapy that are also facility friendly as some do not allow animals to visit and are furthermore not limited by animal allergies.

One of the earliest examples of such social robot is PARO (comPAnion RObot), a baby harp seal robot developed in Japan as pet therapy for patients with dementia[66]. PARO is powered by artificial intelligence to respond to the user and the environment, can move its tail and fliggers, open and close its eyes, and make sounds similar to a real baby harp seal. Now an FDA approved biofeedback device, PARO's benefits, including psychosocial, have been widely studied over the past ten years all over the world. Studies have shown PARO to be a viable alternative with therapeutic benefit in managing symptoms of anxiety, depression, and chronic pain in patients with dementia, improving sleep, social interaction and overall quality of life[67-73]. Moyle *et al*[74] led one of the largest pilot studies of use of PARO at long-term care facilities in Australia. By using a cluster-randomized controlled trial, studying four-hundred participants with documented diagnosis of dementia across twenty-eight long-term care facilities across Australia, results revealed that participants with interaction with PARO (15-min sessions 3 times a week for 10 wk) were more verbally and visually engaged, and had improved mood states and agitation.

Ollie the baby otter was built by a team of undergraduate engineering students at Massachusetts Institute of Technology in 2013[75]. The prototype was created with the intention of being a therapy robot to help with anxiety and depression in patients with dementia, and more affordable than the Japanese robotic seal PARO. Similarly NeCoRo was designed as a robotic lap cat by a company called Omron in Japan and has also been the subject of research of robotherapy for older persons with dementia[76,77].

In December 2015, Hasbro released a line of companion pets called 'Joy for All' intended to provide stuffed animal therapy for individuals experiencing age-related memory loss. Now expanded into its own company: Ageless Innovation, the Joy for All line of robotic companion pets advertises therapeutic benefits such as decreasing anxiety and agitation, increased feelings of self-worth, improved mood and physical activity, and increased interaction with others[78]. Currently available are a golden retriever pup and a variety of cats all with positive testimonials from the older adult market.

The Hug by Laugh research project was development to support people with late stage dementia to amuse, comfort, engage, bring joy and improve overall wellbeing[79]. Hug is equipped with a beating heart and ability to play music that can be personalized to a favorite playlist.

Other technologies such as humanoid social robots are also being studied. One in particular called Kabochan was studied in 103 residents with dementia across seven long-term care facilities in Hong Kong. Assessed by randomized controlled trial over 32-wk, Ke *et al*[80] suggest that engaging with humanoid social robots may be promising in changing perceived ease of use of technology and that Kabochan was about to reduce short-term neuropsychiatric symptoms and caregiver distress[81].

The future of robotic product designs is promising in delivering social support, enhancing well-being and quality of life for individuals living with dementia (Table 2). As more robotic product designs are developed, socially interactive robots are being studied more and more, providing valuable insight into features and functions that these technologies can serve[82].

Assistive service robots

Service robots have the potential to assist older adults with dementia by helping to complete everyday tasks. Equipped with video chat capabilities, such robots are also able to support socially by reducing isolation. Services include reminders to complete activities of daily living such as brushing teeth, drinking water, dressing, and taking medications. Others are being developed with functional arms to reach for and bring items to the user. With the number of innovations, it becomes important firstly to study preferences and perspectives of users and whether technologies will be likely to be accepted and adopted into assisting with care of persons with dementia.

Korchut *et al*[83] worked to identify challenges for service robots in consideration of the requirements of older persons with cognitive impairments. Based on 264 surveys conducted in focus groups of medical staff, potential users and caregivers across

Table 2 Summary of therapeutic robots

Technology (company)	Form	Functions and intentions	Ref.
PARO	Baby harp seal	Managing psychosocial symptoms of anxiety, depression and social interaction	Hung *et al*[66], Petersen *et al*[67], Pu *et al*[68], Lane *et al*[69], Jøranson *et al*[70], Liang *et al*[71], Jøranson *et al*[72], Jøranson *et al*[73], and Moyle *et al*[74]
Ollie (Massachusetts Institute of Technology)	Baby otter	Relieve psychosocial symptoms of dementia	IEEE Spectrum[75]
NeCoRo (Omron)	Lap cat	Tactile and recognition sensors and feedback to engage individuals with dementia	Megadroid[76] and Libin and Libin[77]
Joy for All (Hasbro)	Golden retriever pup and cats	Providing social support for individuals experiencing age-related memory loss	Ageless Innovation[78]
Hug by Laugh	Humanoid	Amuse, comfort, engage, beating heart, personalized music playlist, bring joy to support people with late-stage dementia	Hug by Laugh[79]
Kabochan	Humanoid	Reduce neuropsychiatric symptoms and caregiver distress	Ke *et al*[80] and Chen *et al*[81]

Poland and Spain, priority function requirements of service robots were related to reacting in emergency situations and reminders about medication. Almost 60% of surveys indicated reminders about boiling water, turning off the gas and lights as priority. Similarly, Bedaf *et al*[84] surveyed the preferred characteristics of service robots across older adults, informal and professional caregivers across The Netherlands, France and the United Kingdom. Expectations involved customizability of service robots to match user needs and preferences, and also functioning and behavior with qualities similar to that of a human. Wang *et al*[85] further documented perspectives of older adults and their caregivers on using home assistive robots. They found that older adults were curious and open to the idea of using assistive robots, provided that there is clear perceived need and benefit.

In sum, service robots' ability to help older adults carry out daily activities may help to relieve caregiver strain and promote social relationships and cognitive support. However, balance needs to be maintained in order to uphold autonomy, privacy and dignity for the older adult.

DRIVERLESS VEHICLES

Driving is the predominant mode of transportation for older adults in the United States. However, driving with a compromised functional ability or lengthened reaction time, individuals with progressive dementia can eventually become a danger to themselves and others while on the road. Cessation of driving severely reduces ability to maintain previous social participation, and even disrupt a means to live including transportation to shopping and doctor appointments. Therefore, taking away a license to drive can severely prove a hindrance to living independently. Driving mobility may be composed of both either individual ability to drive or ability to obtain a ride or another means of transportation likely from a friend or caregiver. This added dependence can eventually create burden or strain on others. Automated vehicles are a rapidly developing technology with a spectrum of features from providing warnings and momentary assistance during full human operation, to transient assistance and support in steering or braking, to full automation.

In assessing awareness and openness in using automated vehicle technology, Oxley *et al*[86] found that despite low awareness of in-vehicle safety features among a sample of older adult active drivers, there was greater interest in purchasing vehicles with safety features when aware.

'Waymo' began as the Google self-driving car project in 2009 with the mission of facilitating safe transportation and access to mobility for those who may be unable to[87]. Similarly, self-driving cars by Tesla[88], General Motors[89], Toyota[90], Honda[91], and so many more reflect the rapid proliferation of this technology in the near future. 'Voyage', a start-up company based in California, is working to develop self-driving technology with the mission to provide transportation for millions of senior citizens living in retirement communities[92].

While still in early testing phases before phasing into the market, it is unclear how it

will be perceived and adopted by the public. But it is clear that there is a broad range of potential positive impacts of automated vehicle technology in the lives of older adults. Even more broadly it can help bridge disparities in social and environmental determinants associated with health[93].

CONCLUSION

With current trends towards 'aging in place', technology holds promise in helping to maintain autonomy of persons with dementia over time. When envisioning the future for older adults in the context of aging in place, technologies should be developed with goals of supporting both autonomy and independence in addition to safety[94]. While dementia is indeed a spectrum of symptoms with various etiology, and there is little to formally diagnose, for example Alzheimer's, until post-mortem, it is difficult to ascertain specific recommendations specific to each type of dementia. There is currently no neuropsychological assessment aimed at determining which technology or social media would be best suited for individuals with specific dementias. Rather, decision to adopt and implement technologies into everyday life is an individualized decision based on personal needs and goals. Creation of a formal standardized assessment to guide recommendations towards particular technology or social media is an area of future consideration and direction. Though there is indeed a limitation of specificity in utilization, with more scientific advancements in uncovering biomarkers for different dementia phenotypes, we foresee more specific recommendations to come in the future.

With the rise in use of technology, it also behooves us to consider ethical ramifications. Firstly, the existence of assistive technology has the intention of providing safety and assurance to help individuals be able to age in place. However, the mechanism of doing so introduces alternative methods of surveillance, thereby limiting privacy and restricting movement for persons who were once regarded independent. Wearable technology, home safety monitoring and location devices may be assumed as a breach of privacy even if the monitor is a close family member or friend. Be it covert or with full knowledge, or for an individual without capacity to make such decisions, the perceived loss of independence for the sake of maintaining a level of independence begs the question of how much privacy is permissible to be lost before crossing boundaries of invasion of privacy and autonomy. Such a balance of privacy *vs* utility needs to be addressed and taken into consideration when developing new technologies.

With respect to use of robotic technology, social robots' purpose is to enhance social interaction. The notion of person-to-person interaction is invaluable and can never really be replaced but critics may argue that technology, particularly use of robotic technology, undermines this entire concept. However humanoid, the use of robots in place of humans in order to partially relieve caregiver burden is a fine line to tread. A case can be made, however, for robotic pets to allay negative psychological characteristics inherent across various stages of dementia. It can be a practical alternative in environments with insufficient staffing resources, allergy limitations to real animals, safety concerns about pet behaviors or disruptive behaviors of individuals towards a real animal. Notwithstanding, the progressive loss of ability to socialize and increased behavioral symptoms are characteristic of late dementia, imploring the determination of when during the course of dementia would robotic technology, if ever, shall be deemed appropriate regardless of severity. Work needs to be done to evaluate to what extent is replacement of human interaction considered enhancement of social interaction instead of limiting and viewed as a devaluation of caring.

Practical challenges in widespread adoption of gerotechnology among older adults include financial limitations of cost of device, installation, and monitoring. Adoption of such promising technologies are thereby limited foremost by economic ability to finance, both personally and within scope of health insurance plans. This highlights a burgeoning facet that needs to be addressed in the scope of health economics. Efficient, cost-effective distribution of this increasingly valuable resource is necessary in order to most effectively alleviate healthcare burden of caring for individuals with dementia. In terms of prioritizing public health and management of health services, looking into maximizing the years of healthy life from use of these technologies can elucidate a clearer picture of the benefits to be expected. Critics may argue that the benefits are not worth the price tag that comes with equipping every older adult with technologies that enable aging in place. More quantitative evidence to measure effectiveness of these

technologies can be useful in deliberating health policy efforts, focusing on aid in funding and finance to make technologies more affordable and thereby more available to beneficiaries. Partnerships with companies to lower cost of manufacturing would help to ultimately lower cost for consumers. Currently, many if not all health insurances do not cover these technologies and individuals must pay out-of-pocket. Further work therefore needs to be done to highlight the potential of these technologies to alleviate healthcare burden in order to drive healthcare policy to aid in funding and finance to enable people with dementia and their care-givers access to these services. Work also needs to be done in educating the public, *via* ever present social media, to awareness and necessity of available technologies, and for assistance and support on how to use the technologies.

Furthermore, in developing these technologies, preferences and sustainability across all stages of aging and dementia need to be considered in order to deliver high-value, needs-based, dementia-centered care. Technology truly has the potential of creating a patient-centered care home that can ensure people living with dementia have a safe, healthy environment to live independently for as long as possible. As such an interdisciplinary field, gerotechnology presents a collective endeavor to equip older adults with the resources to successfully age in place.

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