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Dementia care, fall detection, and ambient assisted living technologies help older adults age in place: a scoping review

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Abstract

Objectives: We aimed to describe recent technologic advances in the three domains of dementia care, falls, and home supports; summarize existing literature on usability; and identify knowledge gaps.

Methods: A comprehensive search of five databases for recent peer-reviewed publications was conducted in May 2020. Independent reviewers performed title/abstract review, full-text screening, data extraction, and study characteristic summarization.

Results: Out of 2,696 citations, 151 articles were retrieved for full-text evaluation, after which 54 studies were included in this scoping review. For each domain, different technologies are available to enhance the health and well-being of older adults; many users deemed them usable and useful. Technologies targeted improving function, psychosocial and cognitive status, home safety, and caregiver burden. Barriers to widespread uptake include privacy concerns, suboptimal user experience, and willingness to accept assistance.

Conclusion: Technologic innovations directed towards dementia care, fall detection, and ambient assisted living can aid older adults ‘aging in place.’

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The authors declare that there is no conflict of interest.

Introduction

Gerontechnology — defined as technology designed to enable the health of older persons (Micera et al., 2008) — has become a key focus of biomedical research. Ideally, technology should assist older persons with “aging in place,” or living in their own homes independently, when disabilities such as cognitive impairment or mobility issues occur. Beyond living with a sense of independence, older adults may associate “aging in place” with the continuation of the social connections they developed with neighbors and friends as well as a reassuring sense of familiarity with the community they reside in — important biopsychosocial considerations that can be supported by technology (Wiles et al., 2012). Potential benefits also include lower healthcare costs (Aanesen et al., 2011) and improved quality of life and safety (Finch et al., 2017). Uptake of technology by older adults has been increasing (Anderson & Perrin, 2017), but remains dependent on the usability — or ease of using the devices. The three domains of dementia care, falls, and home supports are some of the greatest challenges faced by older adults in ‘aging in place.’ Connecting these domains and serving as the impetus for this review, persons with dementia (PWDs) have been shown to have an increased risk of falls in the home setting, highlighting the need for effective home support interventions to encourage ‘aging in place’ (Petersen et al., 2018).

Dementia care

According to the World Health Organization (WHO) (2019), an estimated 50 million people have dementia, with 5–8% of older adults affected worldwide. PWDs face unique challenges including loneliness, agitation, and wandering behaviors, with recent evidence identifying the importance of technology (e.g., smartphone applications) in supporting PWDs (Brown et al., 2019). Key areas in which technology can be used to benefit PWDs include assessment of cognitive impairment, assistance with activities of daily living (ADLs), facilitation of leisure activities, and support of caregivers (Astell et al., 2019).

Fall detection

Falls are the leading cause of fatal and non-fatal injuries among older adults over age 64 (Bergen et al., 2016). Globally, approximately one-third of older adults fall annually and 20–30% of older adults who fall experience injuries (WHO, 2008). In the United States, the estimated annual Medicare cost for older adult falls of $31.3 billion is expected to increase as the population ages (Burns et al., 2016). Automated alerts that passively detect falls and notify emergency staff are particularly important as injuries, a lack of home companions, and frailty can make it difficult for individuals to obtain assistance independently. Historically, research efforts have focused on refining technology to accurately detect falls, notify contacts of fall occurrences, and develop profiles of high-risk individuals (Baik, 2019).

Home supports

By 2030, only four caregivers will be available for each older adult to provide support, a marked decrease from 2010 when seven caregivers were available (AARP, 2019). As a result, we should anticipate a greater need for in-home nursing services, assisted living facilities, and long-term care facilities (Colombo et al., 2011). Because adults often prefer

to ‘age in place’ in their familiar home environment rather than moving to facilities, unpaid caregivers and/or family members are often called upon to provide assistance. Because of the projected shortfall in caregivers, solutions such as ambient assisted living (AAL) could become more meaningful.

AAL is defined as “the use of information and communication technologies in a person’s daily living and working environment to enable them to stay active longer, remain socially connected and live independently into old age” (Monekosso et al., 2015). Generally, AAL includes smart devices, wireless networks, and medical sensors. These technologies can simplify and enhance safety for older persons by providing technological assistance with daily tasks and health and home monitoring (Kunnappilly et al., 2019).

Objectives

There is a growing body of gerontechnology literature, but no existing reviews focusing collectively on the three domains of dementia care, falls, and ambient assisted living and the usability of currently available technology. Additionally, recent reviews of these three individual domains (Astell et al., 2019; Pietrzak et al., 2014; Ganesan et al., 2019) neglect to report on the usability of technologies or address their relevance to ‘aging in place.’ Therefore, our aim was to highlight three growing areas of gerontechnology — dementia care, fall detection, and ambient assisted living — describe recent advances in the field, summarize existing usability studies, and identify knowledge gaps that should be addressed in future research.

Methods

To generate a summary of our three gerontechnology areas of interest, we performed a scoping review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Liberati et al., 2009). We performed a scoping review because this design is especially useful to synthesize a topic with numerous interventions and outcomes. In this review, we aimed to examine interventions that could improve the quality of life for older persons.

Inclusion criteria

We selected studies based on a broad set of inclusion criteria to ensure inclusion of all relevant literature. We included articles on (1) dementia care, focusing on loneliness/social isolation, behavioral and psychological symptoms, wandering, care coordination, and fall detection; (2) fall detection via sensors or wearable devices; and (3) ambient assisted living, focusing on home monitoring. We only included articles focused on older adults, defined as individuals 65 years or older. We included interventional, observational, and pilot studies and excluded conference publications, published theses, and review articles. We also excluded articles that were not home-based, caregiver/provider-centric, not related to our three main concepts, not focused on independent living, and inappropriate study populations. Because the field of gerontechnology is rapidly evolving, we decided on a publication date cut point of studies published only in 2015 or later.

Literature search and article selection

We conducted a literature search in the following five databases: PubMed, CINAHL, EMBASE, PsycINFO, and MEDLINE. We used the following search strategy: (dementia or 'cognitive impairment' or 'Alzheimer's disease' or 'cognitive dysfunction' or monitoring or 'fall detection' or 'clinical alarms' or 'ambient intelligence' or 'ambient assisted living' or 'smart home' or 'AAL') AND ('older adults' or aged or elderly or 'older people' or geriatric*) AND (technology or 'assistive technology' or sensor or camera or wearable) AND ('randomized controlled trial' or 'controlled clinical trial' or randomized or randomised or randomization or randomisation or placebo or randomly or trial or groups or 'clinical trial' or 'clinical trials' or 'evaluation study' or 'intervention study'). Our keywords and search strategy are available in Table 1. We used the reference management software, EndNote version X9, to manage the identified articles and to check for duplicates. All database searches were concluded in May 2020.

Data extraction

Two authors independently performed title and abstract screening. Full text articles of studies deemed potentially relevant from initial screening were further assessed for inclusion. Disagreements were managed through adjudication by the senior author. Data extraction of all data for the summary tables was performed, including: 1) study characteristics (i.e. author, year), 2) sample size, 3) average participant age (or range if not available), 4) intervention type or qualitative interview details, and 5) main results and findings. Due to the scoping review approach, as well as the volume and heterogeneity of included articles, a formal assessment of study quality or risk of bias was not completed.

Results

A multi-sourced database search returned a total of 2,696 articles, with 1,999 articles remaining after duplicate removal. Of those, 1,848 articles were excluded after screening titles and abstracts as their contents were unrelated to our three domains (dementia care, fall detection, and ambient assisted living) in older adults. Of the remaining 151 articles selected for full-text review, we identified 54 articles eligible for inclusion. The PRISMA flow diagram summarizes study identification and selection (Figure 1).

Characteristics of included articles

The majority of the included studies were conducted in the United States (n=10, 18.5%), France (n=6, 11.1%), the United Kingdom (n=5, 9.3%), Italy (n=4, 7.4%), and Germany (n=3, 5.6%). Two-thirds of the studies focused exclusively on older adults (n=38), with the remaining one-third (n=16) additionally including caregivers and/or health professionals. Sample sizes varied widely among our included studies, with the smallest number of participants being four and the greatest number being 495. Twenty-three (42.6%) studies were pilot studies, ten (18.5%) were randomized trials, six (11.1%) were mixed-methods studies, five (9.3%) incorporated focus groups, four (7.4%) included a crossover design, three (5.6%) utilized semi-structured interviews, two (3.7%) were cost analyses, and one (1.9%) distributed a questionnaire. Supplemental Table 1 summarizes the characteristics of included studies.

Dementia care

A wide range of technologies were included in the 27 studies on dementia care: virtual reality (n=4, 14.8%), care robots (n=4, 14.8%), home monitoring systems (n=3, 11.1%), wearable cameras (n=2, 7.4%), apps (n=2, 7.4%), computer-based interventions (n=2, 7.4%), augmented reality (n=2, 7.4%), Xbox 360 Kinect (n=2, 7.4%), wearable activity monitor (n=1, 3.7%), active music therapy (n=1, 3.7%), electric calendar (n=1, 3.7%), and intelligent cognitive assistant (n=1, 3.7%). Two studies (7.4%) explored assistive technologies in general.

PWDs were generally receptive of the various technologies intended for dementia care and found them to be feasible (Appel et al., 2019; Dethlefs et al., 2017; Djabelkhir et al., 2017; Farina et al., 2019; Hattink et al., 2016). Many of these interventions led to improvements in cognitive, psychosocial, and motor functioning (Djabelkhir et al., 2017), including cognitive performance (Zając-Lamparska et al., 2019), ADL function (Liao et al., 2020; Nishiura et al., 2019; Silva et al., 2017), depressive symptomatology (Giovagnoli et al., 2018; Lazarou et al., 2016; Silva et al., 2017), appetite (Giovagnoli et al., 2018), sleep quality (Lazarou et al., 2016), MoCA scores (Amjad et al., 2019; Lazarou et al., 2016; Liao et al., 2020), Mini-Mental State Examination scores (Amjad et al., 2019; Lazarou et al., 2016; Nishiura et al., 2019), verbal memory (Liao et al., 2020), and long-term spatial memory (Serino et al., 2017). PWDs found these technologies to be more useful and had higher intention to use them than healthy controls (Pino et al., 2015). Additionally, separate studies addressed the positive effects of assistive robots regarding PWDs' safety concerns (Darragh et al., 2017; Forsyth et al., 2019) and remote health monitoring (Darragh et al., 2017).

Several barriers to adoption and use were identified: lack of experience with technology (Pino et al., 2015), lack of desire for assistance by technology (Wu et al., 2016), difficulties learning how to use technology (Wu et al., 2016). PWDs also were noted to be concerned about privacy (Gelonch et al., 2019; Hattink et al., 2016) and suggested that assistive technologies may lead to social isolation (Asghar et al., 2018), with assistive robots lacking authenticity and the 'human presence' (Wu et al., 2016). Most of these barriers can be overcome with education and training (Megges et al., 2017).

Fall detection

The majority of the included studies on fall detection studied wearable sensors (n=5, 83.3%). Only one (n=1, 16.7%) study focused on environmental sensors, such as wall mounted devices. Older adults generally found fall detection devices to be acceptable and preferred wearable devices over environmental devices (Chaudhuri et al., 2017). The wearable devices examined had high sensitivity and specificity for fall detection (Di Rosa et al., 2017; Ejupi et al., 2017; Saadeh et al., 2019). Concerns regarding wearable devices included occasional false positives (Demiris et al., 2016) and insufficient battery life (Chaudhuri et al., 2017; Thilo et al., 2019). Some older adults failed to see the need for fall detection devices and were embarrassed by them (Demiris et al., 2016), but others reported that fall detection devices enhanced their independence (Chaudhuri et al., 2017).

Ambient assisted living

Studies addressing AAL focused on home monitoring systems (n=13, 61.9%), wearable devices (n=3, 14.3%), exergame/walking applications (n=2, 9.5%), care robots (n=1, 4.8%), and digital calendars (n=1, 4.8%). One study (n=1, 4.8%) focused on AAL technologies in general. Authors found that AAL improved inhibition and working memory (Adcock et al., 2020), increased physical activity and self-reported quality of life scores (Jang et al., 2018), a sense of safety and security (Halcomb et al., 2016; Pigini et al., 2017), assistance in health monitoring and management (Halcomb et al., 2016; Pigini et al., 2017), and improved ADL functioning (Baric et al., 2019).

Although most of the AAL interventions were found to be usable and acceptable, caregivers rated monitoring systems higher than older adults (Cohen et al., 2016), noting that AAL increased their sense of control (Epstein et al., 2016) and reduced their caregiving burden (Dupuy et al., 2017). Some older adults, however, felt that AAL technologies were not what they needed (Berridge et al., 2019) and they did not appreciate being monitored (Epstein et al., 2016; Macis et al., 2020). One study highlighted that older adults were concerned about privacy (Batsis et al., 2018), but other studies found that privacy was not a barrier to AAL technology adoption (Pigini et al., 2017; Pol et al., 2016). Studies examining AAL technologies identified a need for increased focus on user-centered design (Batsis et al., 2018) and greater individualization of interventions (Epstein et al., 2016). Although some older adults were concerned about the costs of the technology (Joe et al., 2018; Son & Kim, 2019), the two cost analyses included in this review indicated that remote monitoring could provide savings by reducing the use of medical services (Finch et al., 2017) and delaying entry into assisted living facilities (Rantz et al., 2015). Figure 2 identifies the technologic opportunities and barriers of the three key domains identified.

Discussion

In this scoping review we examined the current evidence base on gerontechnology in dementia care, fall detection, and ambient assisted living and found that individuals and caregivers found most technologies usable and useful. Benefits included improved cognitive and psychosocial functioning for the individual and a greater sense of security for caregivers of PWDs. If accepted by older individuals, AAL has the potential to reduce the need for long-term care facilities and offset expensive home care, empowering individuals to remain in their communities and live independently longer. In turn, this could improve the lives of caregivers, who could feel more confident leaving their loved one at home and potentially retain employment out of the house instead of being available to provide care full-time.

We found several concerns about adopting technology for health still exist. Privacy concerns remain particularly among older adults who may not feel monitoring is necessary. Although some older adults benefit from having continuous monitoring, the intrusiveness of these devices may prove to be uncomfortable or even unacceptable for some populations. This finding is in line with a previously published review of the literature (van Boekel et al., 2019), and future work on digital interventions for older adults must ensure the desire for privacy is respected and not infringed upon.

Affordability is another barrier to adoption. Although the cost analyses included in this review demonstrate the cost-effectiveness of the studied interventions, relatively high up-front costs of many of these technologies often preclude their widespread adoption. In the absence of insurance coverage of these interventions, older adults may not be able to access these devices. As such, device manufacturers and insurers should work to provide older adults with reasonably priced technologies to ensure equitable access. In the United States, public and private funding sources offer coverage of some mainstream assistive technologies. Continued expansion of the range of covered technologies is a necessary step in ensuring older adults do not have to worry about affordability of assistive technologies.

Finally, many of the devices we covered are designed for specific purposes, such as fall detection, cognitive training, and remote monitoring. Because of this, older adults will likely have to use multiple health technologies to address their wide range of health concerns, which increases cost and complexity. Streamlining and consolidating these devices into the fewest number possible would reduce the amount of training necessary and could simplify the user experience. Newer consumer devices, such as the Apple Watch (2020 Apple Inc., Cupertino, CA), may be able to serve as a model of integrated health monitoring devices for older adults, as it combines fall detection and reporting with heart rate monitoring, a pedometer, and other health applications.

Strengths and limitations

Although our search strategy followed best practices for scoping reviews it focused on topics of chief concern to older persons and their caregivers — dementia care, fall detection, and ambient assisted living — and findings are therefore not generalizable to all gerontechnologies. Although this review highlights knowledge gaps regarding technology and ‘aging in place,’ which will help guide future research, our findings are limited by the methodological quality of the included studies. Given the heterogeneity of the included studies and a lack of side-by-side comparisons, we were unable to suggest some technologies as superior to others. Although efforts were made to follow scoping review guidelines, readers should note that there is not one accepted and universally followed methodology for these reviews (Pham et al., 2014). Finally, many studies did not assess long-term outcomes, and therefore readers will need to ascertain on their own whether the reported short-term benefits outweigh the potential downsides of cost.

Future directions

This scoping review contributes important new information regarding the use of gerontechnology in older adults ‘aging in place’ and highlights several notable gaps in the literature. Because most included studies were pilot, observational, or qualitative studies focusing on feasibility and acceptability and short-term outcomes, more randomized controlled trials and studies comparing technologies are needed. Additionally, although this review included two cost analyses, additional investigations should prioritize analyzing the cost-effectiveness of these innovations for older adults, their caregivers, and healthcare systems. Once a technology is found to be beneficial, studies examining implementation techniques to enhance the uptake of technology among older adults who may benefit will be critical.

In the area of dementia care, more studies should focus on how assistive technologies can foster or maintain a sense of human connection. Many of the studies we have examined highlighted the measurable benefits to cognitive and physical functioning, but only two (Hattink et al., 2016; Silva et al., 2017) evaluated their impact on PWDs' quality of life. Additionally, further research is needed on how best to orient PWDs to new technologies and ease their adoption.

In this review, we identified a shortage of user-centered fall detection devices research. Although the devices tested were able to detect falls with high levels of sensitivity, individuals cited concerns about usability, poor battery life, obtrusiveness, and unacceptably high false positive rates. Consequently, future fall detection research should focus on understanding the user experience, incorporating user feedback into device designs, and minimizing false positives.

AAL technologies have great potential as they can detect abnormal and potentially dangerous activity and can monitor the physical and cognitive health of older adults. This could open research horizons in telemedicine if the data can be efficiently summarized, routed to the necessary parties, and synthesized into a treatment plan. AAL technologies could also offer a more reliable method to detect cognitive decline or a decrease in the ability to perform ADLs without depending on self-report, which can be burdensome for individuals and their families. Research progress in these key domains could ensure that technologies that monitor and enhance health for older adults is made available and is a necessary step before clinicians endorse them as health devices.

Conclusion

As the population of older adults increases and caregivers become less available, technology could enable 'aging in place.' Progress has been made in dementia care, fall detection, and home supports. We found that technology can improve ADLs, cognitive and psychosocial status, home safety, and caregiver burden. Wearable sensor data could be used by clinicians for disease prevention, diagnosis, and treatment in addition to use for self-monitoring. Future gerontechnology research must focus on addressing privacy concerns, enhancing usability for older adults with varying abilities, and addressing drawbacks of the currently available technology such as poor battery life and insufficient accuracy. If these concerns are addressed, technology could be a valuable tool to promote independence into late life.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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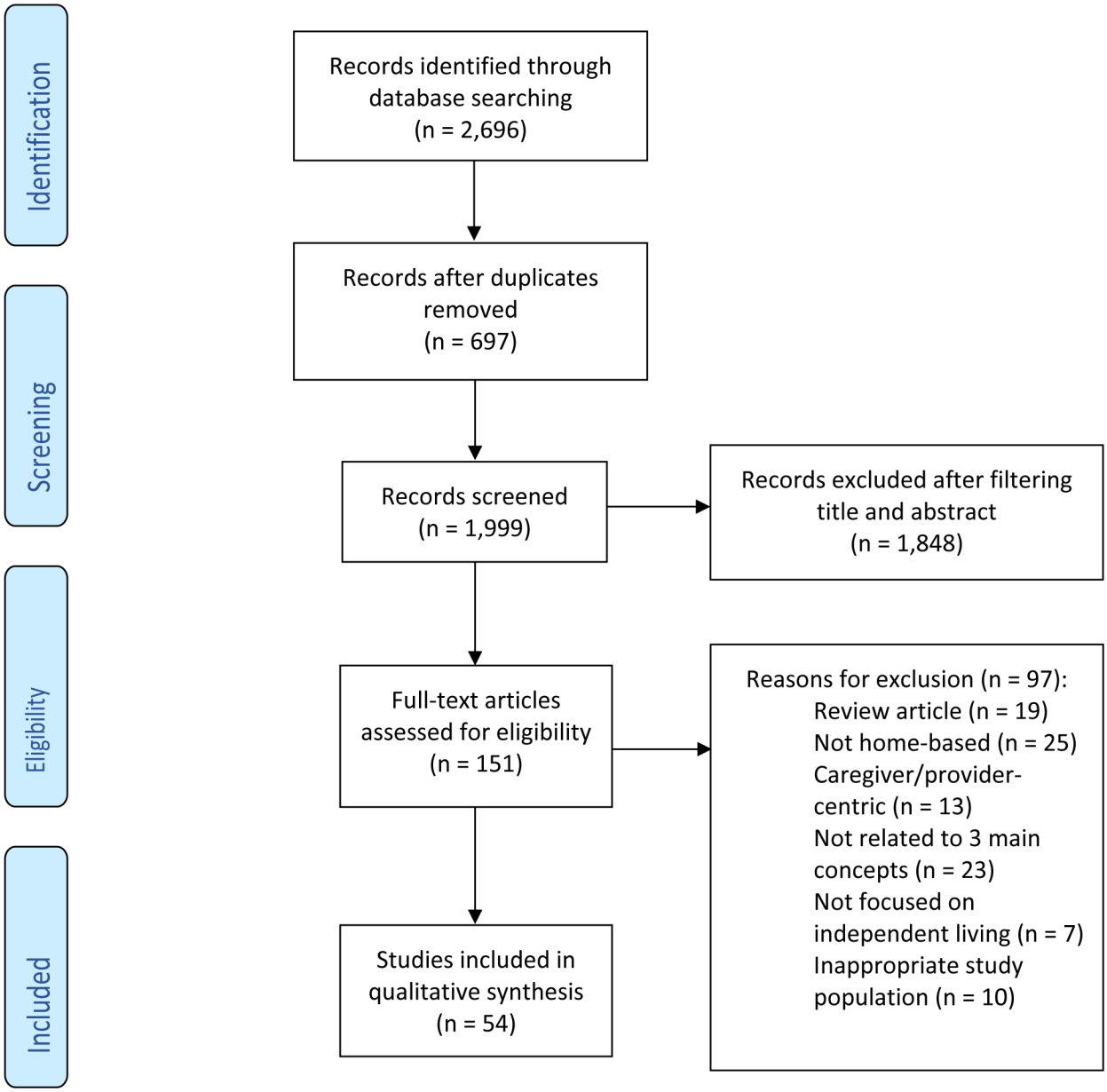

Figure 1.
PRISMA flow diagram of studies included in the scoping review.

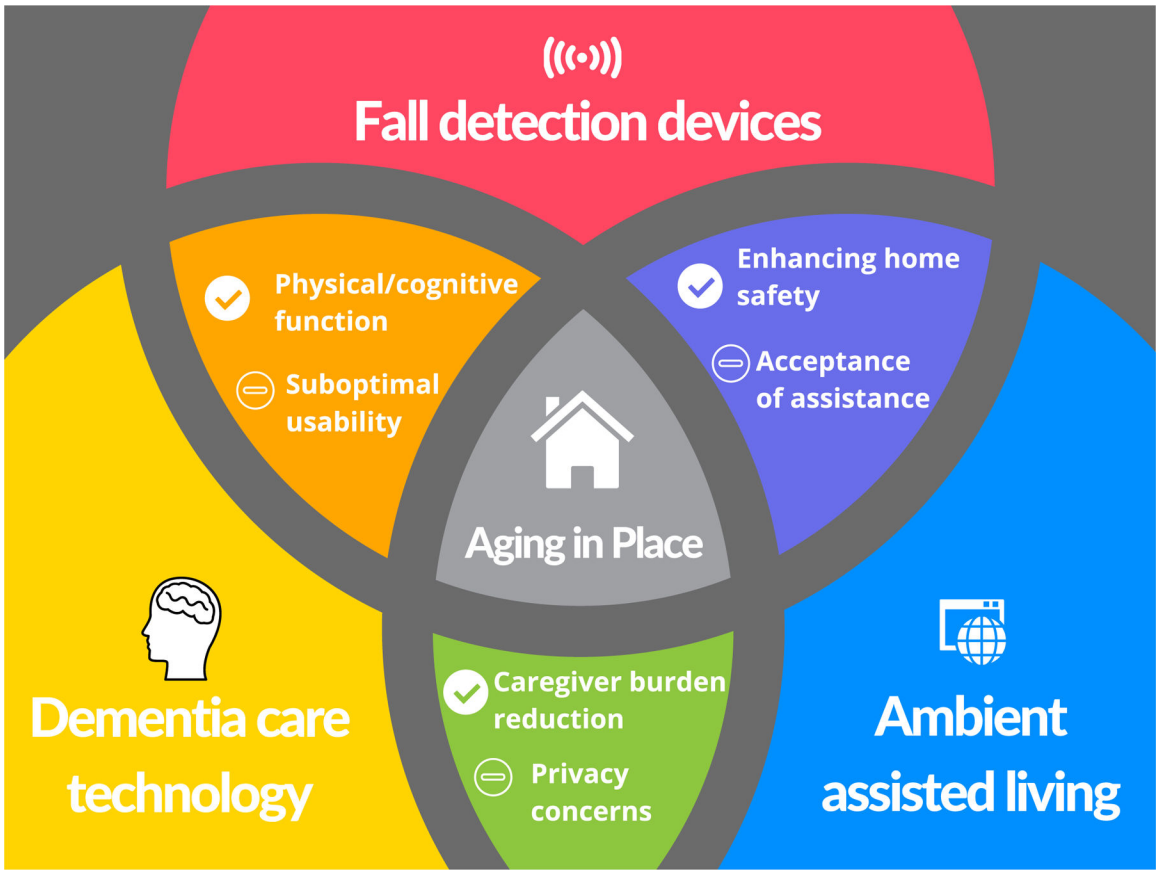

Figure 2.
Opportunities and barriers of dementia care, fall detection devices, and ambient assisted living technologies.

Table 1.

Search Outcomes

Search Number	Search Words/Identifiers	Number of Results
S1	dementia OR 'cognitive impairment' OR 'alzheimer disease' OR 'cognitive dysfunction' OR monitoring OR 'fall detection' OR 'clinical alarms' OR 'ambient intelligence' OR 'ambient assisted living' OR 'smart home' OR aal	3,121,462
S2	'older adults' OR aged OR elderly OR 'older people' OR geriatric*	15,051,547
S3	technology OR 'assistive technology' OR sensor OR camera OR wearable	3,505,133
S4	S1 AND S2 AND S3	35,098
S5	S1 AND S2 AND S3 (last 5 years)	15,764
S6	'randomized controlled trial' OR 'controlled clinical trial' OR randomized OR randomised OR randomization OR randomization OR placebo OR randomly OR trial OR groups OR 'clinical trial' OR 'clinical trials' OR 'evaluation study' OR 'intervention study'	13,276,874
S7	S5 AND S6	2,696
	Duplicates removed	697
	For consideration	1,999
	Excluded	1,945
	Final articles included in review	54