Moreno et al., Gerontechnology (2025) 25:1
https://doi.org/10.4017/gt.2025.24.1.1160.04

Technology-assisted home support of community-dwelling older adults living with dementia and their family caregivers: A ten-year systematic review

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Abstract

Background: Dementia represents a primary global public health concern. Gerontechnology can support community-dwelling older adults living with dementia and their family caregivers to age in place.
Research Aim: The current systematic review of the literature aims to provide a comprehensive description of technologies designed and tested to assist community-dwelling older adults living with dementia to do so.
Methods: A systematic literature search was conducted in five different databases (CINAHL, Medline, PsycINFO, AgeLine, and Web of Science) and validated by two independent librarians. Using COVIDENCE software, two independent reviewers screened records from 2012 to 2022, available in English, French, and Spanish.
Results: There were 1563 references published. After removing the duplicates, 877 titles and abstracts were screened and the full text of 132 studies was assessed for eligibility, with only 20 records meeting inclusion criteria.
Conclusion: The technologies identified have overlapping functionalities including: a) behavioral monitoring, b) health monitoring, c) caregiver education, d) communication, e) tracking devices, and f) reminders, emergency warnings, and solutions for social isolation and daily activities support. We present a theoretical model to conceptualize gerontechnology use in people living with dementia and their family caregivers and provide recommendations for clinical practice, research, technological development, and public policy to foster the development and implementation of gerontechnology in the dementia continuum.

Keywords: Gerontechnology, Dementia, Community-Dwelling Older Adults, Family Caregivers, Aging in Place, Home Support

Introduction

Estimates indicate that in 2021, one in ten people worldwide were aged 65 or above, while in 2050, this age group is projected to account for one in six people globally (United Nations Department of Economic and Social Affairs, 2019, 2023). In 2022, the world population passed the threshold of eight billion inhabitants (Parant, 2023). Progressive aging of the worldwide population is a direct effect of declining fertility rates and increasing life expectancy. With population aging, dementia cases are expected to increase.

Age is a primary risk factor for the development of dementia worldwide (Aung et al., 2019; Brayne & Miller, 2017; Hou et al., 2019). Estimates indicate that 2.7% of adults aged 65 to 74 and 15.1% of people aged 80 to 89 years old will develop a major neurocognitive disorder (Cao et al., 2020). Already in 2019, 57.4 million individuals lived with dementia worldwide and estimations for 2050 indicate that the number of people with dementia will increase to 152.8 million cases globally (Nichols et al., 2022). Alzheimer's disease is the most common of neurocognitive disorders, particularly in women (Castro-Aldrete et al., 2023). As it and other neurocognitive disorders progress, individuals may become more vulnerable to other health problems, such as mild infections (Lopez & Kuller, 2019) and will even-

tually experience loss of autonomy (Iadecola et al., 2019). Cognitive, pharmacological, and social interventions aim to address symptoms, activities of daily living, social isolation, and dependence on professional and family caregivers. However, they are expensive and can be inaccessible for individuals living with dementia.

Many older adults living with dementia are on waitlists for nursing homes (National Institute on Ageing, 2019). The average cost for institutional care for a person with dementia is approximately 47,742 USD per year in Europe and between 63,007 USD and 81,000 USD in the United States (Aranda et al., 2021). Costs are expected to increase in the future (Cantarero-Prieto et al., 2020; Velandia et al., 2022) , making this option inaccessible for middle-class families. In the U.S., the annual cost for a semi-private room in a skilled nursing home increased by nearly 22 000 USD in the past eight years (to 103 700 USD per year) while the cost for a private room increased by nearly 26 000 USD in the same period (to 118 457 USD per year) (Hoyt, 2024). It is projected that by 2030, the annual cost will reach 123 823 USD for a semi-private room and 141 444 USD for a private room. Given this path seems to be unsustainable, there is a need for more home care, reserving institutional care for older adults with moderate to severe care needs (Clavet et al., 2022).

Most older people wish to age at home, including older adults having received a diagnosis of dementia. Considering the progressive increase in dementia care costs, it is important for families to explore alternatives to support their loved ones, such as the use of technologies (Chen, 2020; Lee et al., 2021). Gerontechnology is an interdisciplinary field linking existing and developing technologies to meet the aspirations and needs of aging and aged adults (Chen, 2020).

Gerontechnology supports "successful aging" and is a response to the combination of the aging of society and rapidly emerging new technologies. Particularly, technologies can be a support to traditional care that can relieve stress experienced by family caregivers (Huelat & Pochron, 2020; Shu & Woo, 2021). They may improve the overall wellbeing, perception of self-efficacy, and satisfaction of family caregivers of older adults without cognitive impairment (Moreno et al., 2024) and older adults living with dementia (Pappadà et al., 2021).

With the latest demographic and institutionalization challenges, it is important for older adults living with dementia and their family caregivers to consider gerontechnology. Time spent on physical and medical care of older adults living with dementia is associated with worsening emotional health of family caregivers who on average provide 2.8 hours of unpaid care per day (Freedman et al., 2022). Recent advances suggest that technology use could potentially help reduce the time burden associated with caregiving or enable caregivers to accomplish part of their tasks remotely. For instance, sensors can inform family caregivers about the activities the older adult is performing at home (Nap et al. 2024), the use of wearables can help to identify falls (Stavropoulos et al., 2020), cameras and car loggers can provide information about driving behaviors in the context of mild dementia (Muurling et al., 2024), portable GPS technology can help to identify when older adults living with dementia are out of their home boundaries (Cullen et al., 2022), and remote monitoring platforms can signal health deterioration at home (David et al., 2023).

Gerontechnology can promote functional recovery, help to palliate physical and cognitive impairments, assist older adults with their social needs, and support professional caregivers to reach more older adults living with dementia (De Michieli et al., 2023). Thus, it is critical to update current knowledge of evidence-based technologies tested among both people living with dementia and their family caregivers. By doing so, stakeholders may have a better understanding of the different technological options available. Health care professionals will be in a better position to answer when individuals with dementia and families ask questions about their use and efficacy. As institutional care becomes increasingly unsustainable, it is crucial to continuously update our knowledge of evidence-based technologies for home support tested with both older adults and their family caregivers (Moreno et al., 2024).

The current systematic review of the literature aims to provide a comprehensive description of the technologies designed and tested to assist community-dwelling older adults living with dementia and their family caregivers to age in place, despite neurocognitive impairment. It is guided by four main questions: a) What are the technologies for home support that have been tested in community-dwelling older adults living with dementia and their family caregivers between 2012 and 2022?; b) What are the benefits, difficulties, and adverse effects of these technologies for community-dwelling older adults living with dementia and their family caregivers?; c)What is the quality of the studies on gerontechnology conducted with dyads comprised of community-dwelling older adults living with dementia and their family caregivers?; and d) Are there any rec-

ommendations that could be useful to address the specific challenges preventing the use and dissemination of these technologies in community-dwelling older adults living with dementia and their family caregivers?

Methods

Data sources and search terms

To conduct this systematic review, records were identified from five databases: CINAHL, MEDLINE, PsycINFO, AgeLine, and Web of Science. The database search was conducted from January 1, 2012, to May 16, 2022, by the principal investigator (AM) in collaboration with two librarians with a background in Psychology and Geriatrics. The two librarians participated in different iterations and validations of the search strategy. *Table 1* presents the search strategy, as well as truncation symbols (denoted by *) and Boolean operators (AND, OR). The systematic review was registered in PROSPERO (registration number: CRD42022343746).

Identification and study selection

The inclusion and exclusion of the scientific literature were conducted using the following criteria: a) Literature addressing the use of technology-assisted home support in community-dwelling older adults living with dementia and their family caregivers, b) Research articles (case reports or group studies), c) Literature published from 2012 to 2022, d) Articles available in English, French, or Spanish, and e) Records following a qualitative, quantitative, or mixed methods design.

As shown in *Figure 1*, 1560 records were identified, and three additional references were added to the review through other sources. After removing 686 duplicates, 877 records were available for screening. The screening of titles and abstracts was conducted separately by two independent reviewers based on inclusion/exclusion criteria (HD and KA), using COVIDENCE software (Veritas Health Innovation, 2014). Conflicts were resolved by a third reviewer (AM). One hundred and thirty-two records met the inclusion criteria. The full text of 132 records was independently examined by two reviewers (HD and CC) and a total of 20 records were included in the systematic review.

Data extraction

Two independent reviewers (HD and CC) conducted the data extraction of the 20 studies while a third reviewer (AM) checked the content to ascertain the accuracy of the extraction process. The following information was extracted: a) study design, b) objectives, c) the country where the technology was tested, d) sociodemographic data (i.e., age, sex, ethnic origin), including clinical data for individuals with dementia (i.e., type of neurocognitive disorder and the severity of dementia, e) technology name, description, and price, f) intervention duration, g) outcome measures used to address user experience, usability, and feasibility, h) benefits and difficulties using the technology, i) adverse effects, j) main results, and k) conclusions.

Mixed Methods Appraisal Tool (MMAT)

The quality of the 20 records was independently assessed using the Mixed Methods Appraisal Tool (Hong et al., 2018). This tool is used to evaluate the quality of empirical studies in systematic reviews of the literature. The MMAT can be used to assess the quality of studies using a qualitative, quantitative, or mixed method design. Scores range from zero to five, with higher scores indicating studies of better quality. Two reviewers (HD and CC) independently assessed each one of the records.

Results

Research design

Four of the 20 records followed a quantitative research approach (Harris et al., 2021; Guisado-Fernandez et al., 2020; Liang et al., 2017; Megges et al., 2018), six had a qualitative research design (Evans et al., 2021; Gross et al., 2021; Malmgren Fänge et al., 2020; Pike et al., 2021; Procter et al., 2018; Ryan et al., 2020), and 10 a mixed-methods approach (Bankole et al., 2020; Boyd et al., 2017; Fowler-Davis et al., 2020; Inoue et al., 2021; Meiland et al., 2012; Mitchell et al., 2020; Nijhof et al., 2013; Rose et al., 2018; Stara et al., 2021; Williams et al., 2013).

Country of origin

The majority of the studies were conducted in the United Kingdom (n = 7) (Boyd et al., 2017; Evans et al., 2021; Fowler-Davis et al., 2020; Harris et al., 2021; Pike et al., 2021; Procter et al., 2018; Ryan et al., 2020), followed by the United States of America (n = 4) (Bankole et al., 2020; Mitchell et al., 2020; Rose et al., 2018; Williams et al., 2013), Ireland (n = 2) (Gross et al., 2021; Guisado-Fernandez et al., 2020), Sweden (n = 1) (Malmgren Fänge et al., 2020), Italy (n = 1) (Stara et al., 2021), The Netherlands (n = 1) (Nijhof et al., 2013), Japan (n = 1) (Inoue et al., 2021), Germany (n =1) (Megges et al., 2018), New Zealand (n =1) (Liang et al., 2017), and finally a European multisite study (n =1) (Meiland et al., 2012).

Participant characteristics

The collective sample of the 20 records included a total of 324 community-dwelling older adults living with a major neurocognitive disorder (dementia) with a mean age of 78.1 years (SD = 4.7, Max = 87.3, Min = 70), as well as 326 family caregivers with a mean age of 62.3

Table 1. Search terms and results from each database

Database	Search strategy	References
PsycINFO (OVID)	((home adj2 care) or own home or (living adj2 independent*) or (aging adj2 independent*) or (base adj2 home) or community dwelling or living alone or aging in place).mp or Home Care/ or Living alone/ or Home Environment/ or Aging in place/) AND ((techno* or gerontotechnology or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*).mp or Technology/ or Digital technology/ or Mobile technology or Information and communication technology/ or Assistive technology/ or Wireless technology/ or Monitoring/ or Self-Monitoring/) AND (dement* or alzheimer* or lewy bod* or major neurocognitive disorder* or (frontotemporal adj2 (disorder* or degenerat*)) or posterior cortical atrophy or benson* syndrome or Primary progressive aphasia or ((cognit* or memory or cerebr* or mental*) adj3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*))).mp or dementia/ or dementia with lewy bodies/ or exp presenile dementia/ or semantic dementia/ or exp senile dementia/ or vascular dementia/ AND (relative* or informal carer* or caregiver* or dyad* or spouse* or famil* or support person*).mp or caregivers/ or dyads/ Limite: 2012-2022	243
Medline (OVID)	(((home adj2 care) or own home or (living adj2 independent*) or (aging adj2 independent*) or (base adj2 home) or community dwelling or living alone or aging in place).mp or Independent living/ or Home care services/) AND ((techno* or gerontotechnology or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*).mp or exp technology/ or wearable electronic devices/ or hearing aids/ or exp Video Recording or Reminder Systems/ or Mobile Applications/ or user-computer interface/ or Geographic Information Systems/ or self-help devices/ or communication aids for disabled/ or Robotics/ or exp Monitoring, Ambulatory/ or exp Signal Processing, Computer-Assisted/) AND (dement* or alzheimer* or lewy bod* or major neurocognitive disorder* or (frontotemporal adj2 (disorder* or degenerat*)) or posterior cortical atrophy or benson* syndrome or Primary progressive aphasia or ((cognit* or memory or cerebr* or mental*) adj3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*))).mp or dementia/ or alzheimer disease/ or aphasia, primary progressive/ or creutzfeldt-jakob syndrome/ or exp dementia, vascular/ or diffuse neurofibrillary tangles with calcification/ or exp frontotemporal lobar degeneration/ or huntington disease/ or lewy body disease/ AND (relative* or informal carer* or caregiver* or dyad* or spouse* or famil* or support person*).mp) or exp Family/ or exp Caregivers/ Limite: 2012-2022	435
CINAHL	TIAB((home N2 care) OR "own home" OR (independent* N2 living) OR (independent* N2 aging) OR (home N2 base*) OR "community dwelling" OR "living alone" OR "aging in place") or MH ("Home Care Equipment and Supplies" or "Home Health Care+") AND TIAB(techno* or gerontotechnology or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*) or (MH "Technology+") or (MH "Assistive Technology Devices+") or (MH "Assistive Technology Services") or (MH "Robotics") AND TIAB (dement* or alzheimer* or “lewy bod*” or “major neurocognitive disorder*” or (frontotemporal N2 (disorder* or degenerat*)) or “posterior cortical atrophy” or “benson* syndrome” or “Primary progressive aphasia” or ((cognit* or memory or cerebr* or mental*) N3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*))) or (MH "Dementia+") AND TIAB(relative or "informal care*" or caregiver* or dyad* or spouse* or famil* or "support person*") or (MH "Caregiver Support") or (MH "Caregivers") or (MH "Dependent families") or (MH "Patient-Family Relations") or (MH "Family relations") Limite : 2012-2022	274

years (SD = 7.2, Max = 71.8, Min = 46.2). A few community-dwelling older adults living with dementia had more than one family caregiver. Most of the sample of the community-dwelling older adults living with dementia were females (58.5%), as well as the aggregated sample of family caregivers (64.7%). When race/ethnicity was reported, the samples were predominantly Caucasian, despite efforts to recruit diverse participants (Bankhole et al., 2020). Most of the community-dwelling older adults living with dementia were diagnosed with mild to moderate dementia with a mean Mini-Mental State Examination (MMSE) score of 18.5 (SD = 4.9, Min = 11, Max = 25.2) or a mean Addenbrooke's cognitive examination III (ACE III) score of 68.3 (SD = 0.65, Max = 68.8, Min = 67.9). However, only 11 of the 20 studies indicated the use of a screening test to objectively rate the level of cognitive impairment of their participants. Most of the studies did not report the number of years since diagnosis, with one study including mostly community-dwelling older adults living with dementia diagnosed in the past three years (Megges et al., 2018).

Only one study described the time spent together, with dyads spending approximately 18 to 21

Table 1. Search terms and results from each database (cont.)

Database	Search strategy	References
Web of Science	Topic((home NEAR/2 care) OR "own home" OR (independent* NEAR/2 living) OR (independent* NEAR/2 aging) OR (home NEAR/2 base*) OR "community dwelling" OR "living alone" OR "aging in place") AND Topic(techno* or gerontotechnology or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*) AND Topic(dement* or alzheimer* or "lewy bod*" or "major neurocognitive disorder*" or (frontotemporal NEAR/2 (disorder* or degenerat*)) or "posterior cortical atrophy" or "benson* syndrome" or "Primary progressive aphasia" or ((cognit* or memory or cerebr* or mental*) NEAR/3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*))) AND Topic(relative* or "informal care*" or caregiver* or dyad* or spouse* or famil* or "support person*") Limites: 2012-2022 + Exclude Proceedings papers	498
Ageline (EBSCO)	(TI((home N2 care) OR "own home" OR (independent* N2 (living OR aging)) OR (home N2 base*) OR "community dwelling" OR "living alone" OR "aging in place")) OR (AB((home N2 care) OR "own home" OR (independent* N2 (living OR aging)) OR (home N2 base*) OR "community dwelling" OR "living alone" OR "aging in place")) OR (DE ("Aging in Place" or "Living Alone" or "Independent Living" or "Noninstitutionalized Populations" or "Home Care" or "Home Health Care")) AND (TI(techno* or gerontotechnolog* or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*)) OR (AB(techno* or gerontotechnolog* or gerontechnolog* or digital or tablet or intelligen* or touchscreen or computer or smart or machine or numeric or virtual or monitor* or sensor* or robot*)) OR (DE "Technology" OR "Information Technology" or "Artificial Intelligence" or "Monitoring Devices" or "Computers" or "Computer Software" or "Home Modification" or "Assistive Devices")) AND (TI (dement* or alzheimer* or "lewy bod*" or "major neurocognitive disorder*" or (frontotemporal N2 (disorder* or degenerat*)) or "posterior cortical atrophy" or "benson* syndrome" or "Primary progressive aphasia" or ((cognit* or memory or cerebr* or mental*) N3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*)))) OR (AB (dement* or alzheimer* or "lewy bod*" or "major neurocognitive disorder*" or (frontotemporal N2 (disorder* or degenerat*)) or "posterior cortical atrophy" or "benson* syndrome" or "Primary progressive aphasia" or ((cognit* or memory or cerebr* or mental*) N3 (impair* or los* or deteriorat* or degenerat* or complain* or disturb* or disorder*)))) OR (DE "Dementia" OR "Alzheimers Disease" OR "Early Onset Dementia" OR "Frontotemporal Dementia" OR "Lewy Body Dementia" OR "Vascular Dementia" or "Aphasia") AND ((TI (relative* or "informal care*" or caregiver* or dyad* or spouse* or famil* or "support person*")) OR (AB (relative* or "informal care*" or caregiver* or dyad* or spouse* or famil* or "support person*")) OR (DE "Informal Support Systems" or "Family Assistance" or "Caregivers" or "Long Distance Caregivers"or "Relatives" OR "Adult Children" OR "Couples" OR "Daughters" OR "Extended Family" OR "Grandchildren" OR "Grandparents" OR "Great Grandparents" OR "In Laws" OR "Parents" OR "Siblings" OR "Sons" OR "Spouses" OR "Step Relatives" or "Family Assistance" or "Family Relationships" OR DE "Care Receivers" OR DE "Caregiver Education" OR DE "Caregiving Burden" OR DE "Caregiving Rewards" OR DE "Dependent Parents" OR DE "Eldercare Programs" OR DE "Home Care Workers" OR DE "Respite Care" OR DE "Sandwich Generation" OR DE "Filial Responsibility")) Limite : 2012-2022	110

hours together daily (Bankhole et al., 2020). Also, the time providing help to the care recipient is not systematically reported, with one study indicating that the family caregivers had spent on average 42.7 months providing help to community-dwelling older adults living with dementia (Mitchell et al., 2020). The living arrangement was not systematically disclosed, with a few community-dwelling older adults living with dementia living alone but having a family caregiver (Stara et al., 2021) or living permanently with the family caregiver (Mitchell et al., 2020). For the few studies reporting the type of relationship, family caregivers were mostly adult children (Malmgren Fänge et al., 2020), daughters (Fowler-Davis et al., 2020), or spouses (Meiland et al., 2012). When reported, the samples were generally highly educated (Mitchell et al., 2020; Rose et al., 2018).

Quality assessment

The results of the independent assessment of the quality of the studies using the Mixed Methods Appraisal Tool (MMAT) indicated that most were relatively good studies in terms of quality standards with a mean MMAT score of 4.2 (SD = 0.6). In general, studies with lower methodo-

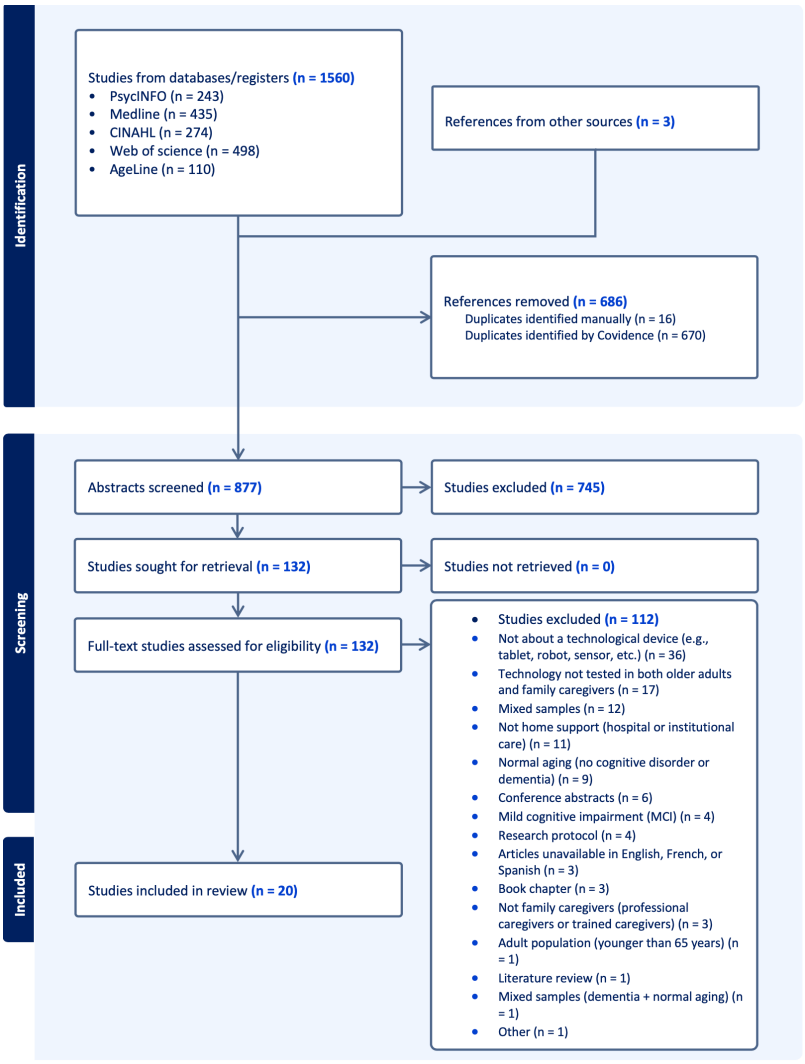

Figure 1. PRISMA flow diagram

logical quality used a mixed-methods research design but did not successfully integrate qualitative and quantitative data or included pilot case studies with small sample sizes.

Description of technologies tested in dyads

The current systematic review examined 20 studies with 17 different technologies for home support in dyads of community-dwelling older adults living with dementia and their family caregivers. The duration of the test period using a specific gerontechnology was on average 32.1 weeks (SD = 65.3), with an important variability regarding the duration of the studies, with a maximum of 288 weeks (Mitchell et al., 2020) and a minimum of one week of testing (Bankole et al., 2020). In one of the studies, 33.3% of the community-dwelling older adults living with dementia rejected the technology for personal or clinical reasons (Pike et al., 2021). Three of the technologies were animal-like robots in a seal (Inoue et al., 2021; Liang et al., 2017) or cat shape (Pike et al., 2021). Appendix A shows a table with the description of technologies for home support tested simultaneously in community-dwelling older adults living with dementia and their family caregivers including the gerontechnology name and description, its function, price, the duration of the intervention, as well as clinical information for the diagnosis and the severity of dementia. Readers can also refer to Appendix B to obtain detailed information about the characteristics and main findings of the studies included in the current systematic review (i.e., study design, country, objectives, measures, results, user acceptance, benefits, difficulties using the technology, adverse effects, and the main conclusion of the study).

Gerontechnology categories

In general, gerontechnology for home support of community-dwelling older adults living with dementia and their family caregivers falls into the following six categories: a) Behavioral monitoring of community-dwelling older adults living with dementia (n=6), b) Health monitoring of community-dwelling older adults living with dementia (n=1), c) Caregiver education and monitoring (n=2), d) Communication and interaction facilitators for dyads (n=3), e) Tracking devices (n=2), and f) Reminders, emergency warnings, and solutions for social isolation and daily activities support (n=3). It is important to mention that a few of these technologies belong to more than one category and that there are some overlapping functions among them.

Table 2. Average scores of the Mixed Methods Appraisal Tool for the studies included in the systematic review

Study	Mean MMAT score
Bankole et al., 2020	3.5
Boyd et al, 2017	3.3
Evans et al, 2020	5.0
Fowler-Davis et al., 2020	4.0
Guisado-Fernandez et al., 2020	4.0
Gross et al., 2021	4.3
Harris et al, 2021	3.5
Inoue et al., 2020	3.5
Liang et al., 2017	3.7
Malmgren Fänge et., 2019	5.0
Meiland et al., 2012	4.0
Megges et al., 2018	4.5
Mitchell et al., 2020	4.0
Nijhof et al., 2013	4.5
Pike et al., 2021	5.0
Procter et al., 2018	4.0
Rose et al., 2018	5.0
Ryan et al., 2020	4.5
Stara et al., 2021	4.5
Williams et al., 2013	3.5
Total	4.2 (SD = 0.6)

Behavioral monitoring of community-dwelling older adults living with dementia

Behavioral monitoring includes six technologies focusing on tracking the behavior of an individual at home. After establishing a baseline of their functioning, variations from the baseline can be interpreted as signs of cognitive or functional decline. For instance, the Behavioral and Environmental Sensing and Intervention (BESI) is a technology to identify agitation and was tested in 12 dyads of individuals with mild to severe dementia and their family caregivers (Bankole et al., 2020). BESI could show a relationship between agitation and environmental factors, with humidity, light, and temperature being strongly associated with agitation. A study conducted with the 3RingsTM digital plug in 30 dyads of community-dwelling older adults living with unspecified dementia and their family caregivers showed that the predictability of the person with dementia's pattern of behavior helped to reassure their relatives, with alarms giving the impression to the family caregiver of being able to "check less and relax more" (Fowler-Davis et al., 2020). The TECH@HOME technology kit is a passive technology tested in nine individuals with mild to moderate dementia and 21 family caregivers allowing the detection of potentially dangerous behaviors at an early stage and sending family members a routine morning message saying that everything was okay, which was generally experienced as positive (Malmgren Fänge et al., 2020).

ADLife is an assistive system tested in a sample of 14 dyads of individuals with mild to moderate unspecified dementia and their family caregivers (Nijhof et al., 2013). ADLife was perceived as helpful to better understand the behavior and movements of the person with dementia, and was reassuring when family caregivers could not visit or make telephone calls. This was the only study of a gerontechnology providing a cost analysis indicating that there were savings for people with dementia remaining at home with technology when compared to the costs of a nursing home. The RAM (Remote Activity Monitoring) was tested in 30 dyads of individuals with moderate Alzheimer's disease and their family caregivers to facilitate the behavioral monitoring of unusual activity providing emergency warnings when any significant deviations from a baseline pattern were detected (Mitchell et al., 2020). A total of 72.4% felt that the information provided on how to use RAM was clear, two thirds of participants (66.7%) felt the technology worked well, and 64.2% felt that RAM met their needs, helping them to better plan their caregiving on a day-to-day basis. Some participants found that having a record of the care recipient's activity aided in discussing care with doctors and other professionals, and a few indicated that RAM promoted independent living for care recipients who were able to live in their homes longer than they would have been able to otherwise.

Finally, TEMPO (Technology-Enabled Medical Precision Observation) was helpful in the identification of patterns of urinary incontinence in 12 dyads of individuals with dementia in the mild to extreme impairment range and their family caregivers (Rose et al., 2018). This was the only technology addressing incontinence in this population.

Health monitoring of community-dwelling older adults living with dementia

The Technology System is the only technology directly targeting health monitoring using a portal and connected devices, tested in eight dyads of community-dwelling older adults living with mild dementia and their family caregivers (Gross et al., 2021). The Technology System was also connected to healthcare providers. The results of the study showed that the Technology System allowed them to better manage the illness of their loved ones, that the technology acted as a motivator in people with dementia to get more involved in their own wellbeing, and that the feeling of being connected with healthcare providers gave family caregivers a significant sense of comfort.

Caregiver education and monitoring

Only two technologies focused on both caregiver education and monitoring. The Connected Health Platform (CH-platform) provides both health monitoring and caregiver education with summary reports of changes in the person with dementia care plan, and a dashboard with an overview of the person with dementia activity levels, sleep patterns, blood pressure, and weight recorded

by the monitoring devices (Guisado-Fernandez et al., 2020). CH-platform was tested in 11 dyads of community-dwelling older adults living with mild dementia and their family caregivers. Family caregivers benefited from education about dementia and advice about daily care. CH-platform also included self-report questionnaires to address family caregivers' mood, energy levels, sleep quality, and anxiety levels, and a diary to keep track of events. However, the positive effects of this technology were not easily captured in research given the heterogeneity among dyads.

"Behavior Capture" and "Behavior Connect" are two technologies originally conceived for individuals with autism and tested in one individual with moderate to severe Alzheimer's disease and his family caregiver to increase caregiver support with behavioral problems in the care recipient (Williams et al., 2013). Using video monitoring targeting problematic behaviors, the family caregiver could find solutions when the videos were used by the healthcare professionals to provide advice about a specific problematic behavior.

Communication and interaction facilitator for dyads

Three technologies addressed communication and interaction in community-dwelling older adults living with unspecified dementia and their family caregivers. PARO is a baby seal-shaped robot that has been tested in seven community-dwelling older adults with moderate Alzheimer's disease and eight family caregivers (Inoue et al., 2021), as well as in 30 dyads of individuals with non-specified dementia and their family caregivers (Liang et al., 2017). Individuals with dementia would react to it with interest and would initiate interaction, providing some respite to the family caregiver. However, the solution proved to be more interesting for community dwelling older adults living with dementia in early severe stages. Older adults with more severe dementia showed neutral, mixed, or negative responses.

The "Ageless innovation" robot cat was tested in 12 individuals with Alzheimer's disease of undocumented severity and six family caregivers (Pike et al., 2021). The participants who accepted it knew that it was not real, but they still kept it with them most of the time, and some even took care of it like a real animal. Communication increased because the cat represented a topic of conversation that the person with dementia liked to talk about. Some participants and families found that there was a real stimulation occurring that went beyond motivating conversation. The robot's zoomorphic properties lead to distraction through stroking or listening to purring, and it stimulates positive emotions such as affection. The robot contributes to reinforcing routines, adherence, and acts as a company. However, it is not strictly a robotic device as in its off-the-shelf form, it is not programmable.

Finally, the App InspireD (Individual Specific Reminiscence in Dementia) is a reminiscence technology tested in 15 community-dwelling individuals with mild to moderate dementia and 17 family caregivers (Ryan et al., 2020). Despite a lack of confidence at the outset, the App allowed participants to revisit the past, viewing photographs (especially photographs of family members, family holidays, and of early life), playing music and watching videos. The home-based nature of the App made participants feel safe and secure by engaging in a process focusing on what still remained and what they could still gain rather than a continued focus on the losses associated with dementia. Participants reflected that they felt closer to their loved ones, helping family caregivers to use it at home as an aid for communication and a stimulus to share memories.

Tracking devices

Two tracking devices demonstrated to be useful in dyads. A study tested the efficacy of two commercial watches with a location and telephone function in a sample of 17 dyads of community-dwelling older adults with mild to moderate dementia and their family caregivers (Megges et al., 2018). The watches were efficient to assist family caregivers in locating people with dementia when wandering events occurred using the watch to call or via the localization function.

Another study tested the efficacy of two GPS tracking watches in five dyads of community-dwelling older adults with different kinds of dementia of unknown severity (i.e., Alzheimer's disease, vascular, and mixed dementia) and their family caregivers (Procter et al., 2018). The results of this study showed that this technology could provide information to inform family caregivers when the person living with dementia was out of their usual geographic boundaries via a call operator, so that they could be found. They also identified administrative delays to deliver the technology, challenges matching the technology options with clients' needs, and the need to identify at least one "responder" to deal with the alerts (and the false alerts). One of the watches was discontinued during the study, which prevents its use in the future.

Reminders, emergency warnings, and solutions for social isolation and daily activities support

A total of three technologies focused on providing reminders, emergency warnings, and solutions for social isolation and daily activities support for dyads. Three studies tested the efficacy of the Digital Prompter to support the daily activities in 12

(Boyd et al., 2017), 11 (Harris et al., 2021), and 26 (Evans et al., 2021) dyads of community-dwelling older adults living with mild to moderate dementia and their family caregivers. Using it with or without training (technology and a manual), the Digital Prompter was easily used to integrate different steps to accomplish a task using verbal and visual cues. All the family caregivers and all but one of the older adults living with dementia were able to use the Digital Prompter with and without training to achieve at least some of or all of the goals they had set themselves at the start of the intervention (Evans et al., 2021; Harris et al., 2021).

Finally, the COGKNOW Day Navigator (CDN) was tested in a sample of 42 individuals with mild Alzheimer's disease and 41 family caregivers in three different countries (Meiland et al., 2012). CDN included the use of reminders, support in social contacts and daily activities, and emergency warnings available in a stationary touch screen featuring reminders (i.e., date, weekday, and time indication, either analogue or digital, 24-h or AM/PM), pop-up reminders (remotely configurable, one-time, or daily, user-defined text/image/audio/repetition), and a find mobile function in case the mobile device was lost. It supported social contacts (i.e., picture dialling using existing phone or voice modem with a handset), and daily activities (i.e., radio/lamp control, music player, and activity assistant). The technology also supported the feeling of safety (i.e., help/emergency via personalized contact/help icon, pop-up safety warnings for doors and household appliances, and navigation when outdoors). Even though the CDN was generally well accepted and valued as a user-friendly and useful device to support people with mild dementia and their family caregivers living in the community, there were not statistically significant changes in the overall impact, quality of life, or autonomy in dyads using this technology.

The results of a study conducted in 20 community-dwelling older adults with mild Alzheimer's disease and 14 family caregivers using a conversation agent named "Anne" indicated a reduction in anxiety in individuals with dementia (Stara et al., 2021). The innovative aspect of Anne is that users could interact with the system through voice and by stimulating a more humanlike interaction rather than just navigating with the touchscreen. Anne can support people living with dementia with video calls, a personal calendar, medication reminders, and entertainment with news, games, photos, and music. It's also possible to make video calls to other persons in the repertoire. The most popular features as documented by the frequency of use were games, medication, news, and radio. None of the participants withdrew from the trial and participants were able to use it at home independently.

Advantages, disadvantages, and adverse effects of using these technologies

Participants in these studies reported several advantages and disadvantages using the technologies. In general, there is a learning curve when introducing a new technology at home. This may be the cause of frustrations until both older adults living with dementia and their family caregivers become familiar with it. Once familiarity is not an issue, technical difficulties can be a source of frustration and a factor leading to abandoning their use.

Of the 20 records included, participants indicated that the technologies could address real-life problems typically observed in individuals living with dementia including agitation (Bankole et al., 2020), difficulties performing increasingly complex tasks (Evans et al., 2021), mood changes and isolation (Guisado-Fernandez et al., 2020; Liang et al., 2017), the need for rapid identification of emergency events requiring an urgent response (Malmgren Fänge et al., 2020), wandering events (Megges et al., 2018; Procter et al., 2018), memory problems (Meiland et al., 2012), communication problems (Pike et al., 2021), urinary incontinence (Rose et al., 2018), anxiety (Ryan et al., 2020), problems with medication compliance (Stara et al., 2021), and behavioral problems (Williams et al., 2013). For family caregivers being responsible for people living with dementia in the community, these technologies had the advantage to increase the feeling of being more present for the person with dementia (Fowler-Davis et al., 2020), increasing feelings of empowerment (Gross et al., 2021), slight improvement of sleep (Guisado-Fernandez et al., 2020), diminished caregiver burden (Mitchell et al., 2020), and reduced anxiety levels (Nijhof et al., 2013). In short, technologies proven to be effective demonstrate their benefits to address real life problems in dyads and act as facilitators of the family caregiver – care recipient interaction. Some disadvantages and adverse effects were experienced by some community-dwelling older adults living with dementia and their family caregivers. Participants reported difficulties with the quality of the Internet connection having a negative impact in the technology functioning (Bankole et al., 2020), difficulties identifying the purpose of the technology and tensions in the caregiver – care recipient relationship (Evans et al., 2021), difficulties understanding the technology and fatigue associated with "false alerts" (Fowler-Davis et al., 2020; Mitchell et al., 2020; Procter et al., 2018), perception of additional stress related to technology use and frustration (Gross et al., 2021; Stara et al., 2021), lack of interest in the technology (Inoue et al., 2021), negative comments regard-

ing the technology (Liang et al., 2017), technical problems (Malmgren Fänge et al., 2020; Megges et al., 2018), sensory difficulties interacting with the technology (Meiland et al., 2012), annoying noise and flickering lights (Nijhof et al., 2013), fear and disgust (Pike et al., 2021), agitation (Rose et al., 2018), stress when confronted with negative memories (Ryan et al., 2020), and confidentiality concerns (Williams et al., 2013).

Discussion

The current systematic review of the literature provides a comprehensive description of 20 studies describing 17 technologies for home support tested in community-dwelling older adults living with dementia and their family caregivers in a ten-year span (from 2012 to 2022). The study provides information about their efficacy and the advantages and disadvantages of their use in assisting people to age in place. The 20 studies were generally assessed as being of good quality, were mainly conducted in the UK and the US, with small sample sizes, included mostly individuals living with mild to moderate dementia, and used a mixed-methods research design.

These technologies included mostly sensors, but the studies also demonstrated the efficacy of robots, watches, cognitive agents, cameras, as well as mobile and tablet applications across the dementia continuum. Most of them included overlapping functionalities for behavioral or health monitoring of community-dwelling older adults living with dementia, caregiver education, communication, geographic location, help with medication compliance, social connections, support with daily activities, and emergency warnings. Overlapping functionalities are an advantage, particularly when technologies provide flexibility to be tailored to the dyad's needs. The heterogeneity of dementia can be addressed via this personalized approach to respond to specific individual challenges.

Technology implementation has been defined as a process of several planned and guided activities to launch, introduce and maintain technologies in a certain context to innovate or improve healthcare, which delivers the evidence for adoption and upscaling a technology in healthcare practices (van Gemert-Pijnen, 2022; Jutai et al., 2024). There is not a clear description of the process leading to the development process of these technologies and to our knowledge, none of the 17 technologies presented in this systematic review have moved to the implementation phase for home support at the local or national level. It has not prevented wide commercialization of technologies like PARO for institutional use despite challenges in implementation in care settings (Hung et al., 2019).

Once the data about their efficacy have been published, we are not aware of follow-up studies describing the process to refine the technologies once the difficulties with their use and the feedback from the end users have been identified. For that reason, it is not possible to see the iterations and later integration of end users' feedback in the latest versions of the technology. There are several reasons for this. Technology development is time-consuming and necessitates funding to proceed with the refinement of a product. Commonly, technology development requires multiple iterations to improve the final product and to make sure that it responds to the needs of the final users. Another reason is the time required for research with older adults living with dementia. Human research requires high standards with clearly established ethical procedures that can be even stricter and longer when trying to recruit individuals living with dementia for research purposes. Also, older adults living with moderate to severe stage dementia are a particularly hard-to-reach population (Tezcan-Güntekin et al., 2022; Wood et al., 2021). We must remember that family caregivers must deal with multiple responsibilities and psychological reactions including burden, anxiety, stress, and fatigue which limit their participation in peer-support groups (Lauritzen et al., 2015) or research (Hosie et al., 2022). Recruitment can be time-consuming, but community-dwelling older adults living with moderate to severe dementia and their family caregivers are probably those who most need and would benefit the most from different kinds of support, including gerontechnology.

Technological advancement moves very fast, and in their relentless quest for innovation, researchers can focus on cutting-edge technologies. However, as a person living with dementia moves through the different stages of severity, older and more familiar technologies can also be of value. In other words, both low-tech and high-tech interventions can be effective with specific problems that occur with dementia (Neubauer et al., 2018).

Participants in these studies experienced both benefits and inconveniences in the process of testing the technologies at home. It is normal to expect that there will be an amount of time (and effort) required before each member of the dyad feels comfortable using them. Integrating a technology into the daily routine at home involves a learning process, especially when the technology is not passive, and different levels of response are required from the family caregiver and the care recipient. When technical difficulties occur, there may be feelings of frustration that inhibit adoption even when the technology matches the dyads' needs and contributes to solving a dementia-related problem. It is

important to note that not all experiences are the same. For instance, the type of technology, user preferences, user demographics, attitudes towards technology, tech savviness, self-efficacy to use technology, and even familiarity play important factors in their adoption and the perception of their advantages and disadvantages.

In general, however, the technologies reviewed here have demonstrated their efficacy to support dyads with the management of behavioral and psychological symptoms of dementia (e.g., agitation, wandering, incontinence), cognitive difficulties having an impact on everyday life (e.g., forgetfulness, executive dysfunction), problems performing activities of daily living (e.g., medication management), and the reduction of negative emotional reactions experienced by family caregivers when assuming long-term care responsibilities (e.g., anxiety and hopelessness). In summary, the advantages are proven, but these technologies have to be carefully chosen to fit the needs of community-dwelling adults living with dementia and their family caregivers to avoid inconveniences.

A theoretical model of gerontechnology use by people living with dementia and their family caregivers

Figure 2 presents a theoretical model to be used in research and practice to develop, refine, introduce, and personalize gerontechnology for use by community-dwelling older adults living with dementia and their family caregivers at different stages of the disease process. The model helps to understand the complexity of the relationship between aging, dementia, and gerontechnology from the perspectives of family caregivers and older adults. This model helps to illustrate how technologies must adapt to the aging process, particularly in the context of different stages of dementia. It helps to make hypotheses about technology development for a specific dementia stage, and it helps to easily communicate to healthcare practitioners the stage at which a specific technology can be matched with a potential user. It helps to understand dementia progression in the context of the support provided by family caregivers. It also provides a temporal idea of the progression of dementia. Finally, it works as a transdisciplinary tool to help people from different backgrounds navigate the complexities of dementia and gerontechnology use (Moreno, 2024).

At the top of the model, the reader can find equivalent scores on two of the most widely used tests to screen cognition in older adults and individuals living with dementia: The Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination (MMSE). The MoCA is more difficult than the MMSE and the model provides the equivalent scores of these two widely used cognitive tests (Fasnacht et al., 2022). Starting with an MMSE/MoCA score of 30 exhibited by older adults with normal cognition, we can track the evolution of dementia severity from mild to severe.

Gerontechnology can address problems at any stage of the aging process from normal aging without cognitive difficulties to the severe stages of dementia. In older adults without dementia, these include the detection of medical emergencies, falls, and social isolation (Moreno et al., 2024). As presented in the model, among older adults with unimpaired cognition, individuals are actively involved in the decision process to choose the technology and they can manage it directly by themselves or together with the family caregiver. The involvement of family caregivers is discreet and minimal. Digital personal assistants alerting the older adult when they need to take their medication or calendars are a good example of this category. The older adult can program the assistant with or without the help of the family caregivers and be independent to make sure, for example, that the device is charged and operating.

However, the dyads' dynamics and needs change when the dementia process starts. To date, dementia is an incurable and irreversible process ranging from mild to severe cognitive impairment with a probability that increases with age (Reitz et al., 2023). The model represents the journey of individuals living with dementia and their family caregivers and the relationship with gerontechnology using two triangles, with the longest side representing the involvement needed with technologies in the dementia continuum (i.e., taking an active role using the technology) and the commitment with the care relationship (e.g., amount of time invested in care). As older adults move through the continuum from mild to severe dementia, they need more support from their family caregivers. For instance, individuals with mild dementia often experience memory problems, difficulties in learning new information, or minor language difficulties. The family caregiver may need to support the care recipient as they may forget steps in the process of learning to use the technology. As depicted in the model, the family caregiver will need to invest more time and resources to support the care recipient as the severity of dementia increases. For example, ADLife is an assistive system that monitors the behavior of people with mild stage dementia, sending an alert to family caregivers when there is unusual activity at home (Nijhof et al., 2013).

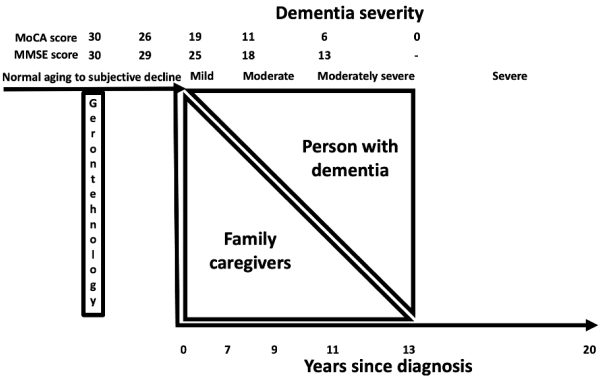

Figure 2. A theoretical model for the development and introduction of gerontechnology for use by dyads of older adults living with dementia and their family caregivers (Moreno, 2024).
Note: MoCA = Montreal Cognitive Assessment ; MMSE = Mini-Mental State Examination

In moderate stages of dementia and with the progression of the amnestic syndrome, individuals living with dementia may have difficulties remembering their personal history and daily events, be confused and disoriented, experience changes in their sleep patterns, and have occasional periods when they can get lost in new places or even in places that are familiar to them. In the moderate stage, technologies need to be more passive for the care recipient with the family caregiver taking more control of them (e.g., making sure the technology is working properly, responding to alerts, programming the reminders). The TECH@HOME technology would be a good example with smoke and water leak sensors to prevent accidents at home (Malmgren Fänge et al., 2020).

In the severe stages of dementia, people may be incontinent, agitated, wander, and have difficulties dressing and performing usual care routines, expressing themselves, and even recognizing family members or themselves in the mirror. As suggested in the model, at this stage, technologies must be passive as the care recipient will be unable to operate them independently and the family caregiver will need to have control of the technology and the responsibility to act when something unusual happens. TEMPO (Technology-Enabled Medical Precision Observation, Rose et al., 2018), as well as "Behavior Capture" and "Behavior Connect" (Williams et al., 2013) are technologies adapted to this stage to identify and find solutions to agitation provoking events. From the point when individuals with dementia cannot be tested using common screening tests such as the MMSE and the MoCA, dementia will continue to progress for several years as shown in the X-axis, with some older adults living as long as 20 years with dementia and 40% of that time in the severe dementia stage (Alzheimer's Association, 2022). After this point, individuals with dementia often require institutional care with professional caregivers to treat medical complications and chronic diseases. It is important to keep in mind that usually the disease has been progressing slowly long before it is formally diagnosed (i.e., preclinical dementia).

The early introduction of gerontechnology, at the right stage, and focusing on the problems experienced by the older adult can be a way to ensure their success. These technologies must be adapted according to the clinical evolution of the person with dementia. Technologies that were helpful in the early stages of the disease will need to be abandoned and replaced with other technologies. Personalization is necessary to respond to the dynamic nature of the disease process and to the specificities of each caregiver – care recipient relationship. Taking into account the model presented, gerontechnology should not be considered as a "one-size-fits-all" approach. Instead, they need to target a specific stage of the dementia process and be flexible enough to allow personalization to the needs and preferences of the end users.

Recommendations

Below we provide a set of recommendations for clinical practice, research, technological development, and public policy to promote the development and implementation of gerontechnology in the dementia spectrum.

Clinical

Professional education and training: Provide education and training to healthcare providers about existing empirically evaluated technologies, their characteristics, their benefits, and limitations. Training programs for rehabilitation professionals must include specific sections in the curriculum to familiarize them with gerontechnology, their possibilities, advantages, disadvantages, and potential for use. This will allow them to be able to give evidence-based professional advice to older adults living with dementia and their family caregivers.

Family caregiver education: Educate family caregivers to the possibilities of these technologies and the way in which they can be a game changer in the management of dementia and reduce caregiver burden and anxiety. Commu-

nity-dwelling older adults living with dementia and their family caregivers are already using many technologies and ask for professional advice about their use. Family caregivers are also looking for creative alternatives to alleviate their caregiving tasks and give them peace of mind. Some of the negative reactions to technologies for dementia are in response to "off the shelf" devices being rarely useful in a progressive condition like dementia (Sriram et al., 2019).

Early access to gerontechnology: Facilitate access to gerontechnology early in the process and at the right stage of the disease process. If we do not consider factors such as the diagnosis, stage of progression, severity of cognitive impairment, behavioral problems, and pre-morbid characteristics, there will be a mismatch between the technology and the dyads' needs. The consequence is that the technology will be rejected producing frustration in both the person with dementia and the family caregiver.

Family caregivers must be part of the decision process: Include family caregivers in the decision process to choose the appropriate gerontechnology. Individuals living with dementia may lack awareness of their deficits, one reason why it is important to work collaboratively with family caregivers (Leocadi et al., 2023). The progressive nature of symptoms of dementia and its evolution is another, which requires close collaboration with family members and significant others.

Research

Testing technologies at different stages of the dementia continuum: Include individuals with dementia of different severities when testing a technology that could be transversally useful in the disease process, or focus on a specific severity, considering the most frequent symptoms of that specific stage. If the technology was conceived to target mild memory problems in the early stages, it would probably be useless in people with severe dementia unable to respond to alarms or reminders. If the technology is conceived to target a specific problem such as wandering, it would probably not be necessary in individuals in the very mild stages where this problem is rare. Research participation of older adults living with dementia may be optimized through reducing risks and burdens, increasing benefits for participants, greater consumer input into study development, and shared and supported decision-making (Hosie et al., 2022). Interestingly, the very mild stages of the disease are not addressed by formal testing of these technologies. The results of a systematic review of technologies tested in both older adults with mild cognitive impairment and their family caregivers between 2012 and 2022 resulted in an empty review (Couve et al., 2023). In consequence, there is potential for technological development in predementia stages.

Recruitment strategies: Use multiple strategies to recruit community-dwelling older adults living with dementia. Field et al. (2019) found that successful recruitment of people with dementia, as one example of a hard-to-reach group, requires multiple strategies and necessitates close working between researchers and clinical services. Specific strategies include: a) direct referral by memory services clinicians, b) regular presence in memory services clinics by researchers, c) attendance at psychosocial intervention groups by researchers, d) 'pre' screening of clinical records by a research nurse, e) ad hoc mail outs targeting potentially eligible participants choosing to attend follow-up appointments offered at local GP practices, f) potential participants identified within multidisciplinary clinical meetings, g) professionals delivering the intervention identifying potential participants, h) attendance at clinical team business meetings by researchers, i) research team making contact with people who have participated in other studies previously and have agreed to be contacted about future studies, j) information displayed in GP practices associated with memory services, k) attendance at community groups by research staff, l) study promoted by researchers at local events, m) one mail out via non-statutory sector organization / sending non-statutory sector organization staff study information.

Transdisciplinary collaboration: Make sure to collaborate with clinicians who are knowledgeable of dementia and with family caregivers with lived experience. Not all clinicians are familiar with neurocognitive disorders or the clinical evolution of dementia. Professionals who are knowledgeable of dementia in their daily practice have a deep understanding of the heterogeneity of the disease and can easily anticipate difficulties using a specific technology. While family caregivers of persons with other diseases can share some experiences, family caregivers of older adults living with dementia experience particular difficulties and needs considering the progressive nature of the disease and the identity loss linked to this condition (Yu et al., 2023). Multidisciplinary collaboration among social scientists, engineers, healthcare experts, and different stakeholders is a must (Kleinman, 2021).

Using a variety of technologies: Consider that old and new technologies can be equally valid if they successfully target a specific problem related to dementia. Retrieval of recent events is disproportionately compromised relative to their remote counterparts (Irish, 2023). This means that indi-

viduals with dementia will probably be more at ease using old technologies as compared to new ones. This needs to be highlighted in research proposals so that the funding agencies understand that not using cutting-edge technology is also a valid approach to develop and test technologies for home support in individuals with dementia and their family caregivers.

Reporting cost, demographic, and clinical variables. Report the cost of each technology, as well as socio-demographic information (e.g., gender, education, income, living arrangement, time invested in the caregiving tasks, type of dementia, years since diagnosis, among others) to help users and other researchers to understand the profile of potential users of those technologies. When this information is missing as is the case in several articles analyzed in this systematic review, it is difficult to understand the reasons for the success of the technology or lack of it. Sometimes, the technology is not a good match to be tested with a specific population or dementia stage, which would be a good explanation for conflicting results using a well-conceived technological solution.

Technological development

Culture and attitudes: Be aware of cultural factors and attitudes mediating the use of technologies. Polychronic cultures, such as Asian, Arab, Latin American, and South European cultures, value interpersonal relations over schedules, they are described as past or present-oriented, and those differences in temporal orientation have an impact on health behaviors giving the impression that technologies and other compensatory interventions would not be required (Levine, 2013). For instance, the use of time management tools such as paper or whiteboard planners or calendars, and routine organizers are uncommon in India (Dsouza et al., 2022). Acceptability rates can be low when we consider also cultural expectations of recovery, attitudes, or stigma towards people with dementia, and concerns that the devices would make them look different, make their difficulties obvious to others, and attract questions regarding their diagnosis.

Accessibility: Make sure that the technology being developed meets accessibility requirements making their access possible to different social groups. Community-dwelling older adults living with dementia and their family caregivers prefer technologies that are low-cost, low-tech, simple to use even for people with limited education, portable, and easily available with access to support services. These products should permit customization to individual needs.

Focus on home support: Consider that the needs associated with home support are not the same as those related to institutional support. Gerontechnologies for home support place emphasis on maintaining the independence of the care recipient and promoting the peace of mind of the family caregiver. The availability of healthcare providers and professional caregivers in long-term care often leads to the control of dementia-associated problems from a case management perspective in institutional settings. But access to professional caregivers and healthcare providers is not available 24/7 in the community.

Personalization and customization: Personalization is a key element in the conception, development, refinement, and adoption of gerontechnology by dyads. For instance, a study to address attitudes towards socially assistive robots revealed the importance of customizing their appearance, services, and social capabilities (Pino et al., 2015). The study confirms that a mismatch between needs and solutions offered by the robot, usability factors, and lack of experience with technology are the most important barriers for socially assistive robots' adoption. Personal factors of the older adults and family caregivers including interest, the level of cognitive decline, and their experience with technology influence their attitudes towards technology positively or negatively (Van Assche et al., 2024).

Technical support: Provide technical support to quickly solve problems related with gerontechnology use. As technology can fail for different reasons, knowing when exactly how to easily find technical support can be reassuring for dyads. For instance, failing to identify a risk event could place an individual with dementia in a life and death situation. If the technology is not reliable, community-dwelling older adults living with dementia and their family caregivers will not be comfortable using it. If technology malfunctions frequently, it will be a source of frustration, leading to its rejection.

The creation of appealing technologies: Making technologies attractive to end users can contribute to their acceptance. It is important to make gerontechnology appealing because older adults and family caregivers show normal human reactions according to their preferences that influence their intention to use them. For instance, realistic, cute, and cuddly robots were preferred while artificial-looking, creepy, and toy-like robots were disliked by older adults, family caregivers, and individuals living with dementia (Dosso et al., 2022).

Public policy

Implementation: Promote collaboration with specific partners in the community to anticipate and facilitate implementation. For instance, technological implementation of wandering event monitors in older adults living with dementia requires the collaboration with the police services (Neubauer et al., 2021). It is important to have in mind the whole ecosystem and to anticipate the integration of these technologies from a wider perspective. Moreover, it is important that older adults with dementia, professional caregivers, and families are actively engaged in policy-making surrounding technology in dementia care (Robillard et al., 2019).

Cybersecurity: Make sure to prevent hacking and any other form of breach of security, making a particular system or technology vulnerable to cyberattacks. Data management, encompassing the processes of data acquisition, storage, processing, and sharing is a primary concern when using technologies for dementia (e.g., swiping behavior on mobile devices and associated apps, camera-recorded data from home surveillance systems, and self-tracked data from wearables that are not classified as medical devices) (Wangmo, 2019). The aim of gerontechnology for home support is to enhance the safety and security of people with dementia living in the community (Lorenz et al., 2019). Clearer privacy policies to protect users' data are strongly encouraged. For instance, only 46% of apps for dementia have a clear privacy policy and those that do exist lack clarity (Rosenfeld et al., 2017). Berridge et al. (2020) provide an exhaustive list of risks and ways to mitigate them including user education and restrictions, among others.

Commercialization: Avoid commercializing a technology without evidence of its efficacy. Technologies for people with dementia and their family caregivers have real positive and negative consequences in the disease process for users involved. As such, marketing without proof of efficacy is irresponsible and unethical. The results of a study raising important ethical considerations specifically focused on the design and development of new technologies for dementia reveal that the most discussed feature was the technology's quality and effectiveness, appearing in 77% of the sample (Robillard et al., 2019). When the technology has proven efficacy, it should be available through mainstream channels. As an example, most apps for dementia and other chronic illnesses described in the literature could not be located on the iOS or Android app stores (Singh et al., 2016).

Equitable access: Explore technological delivery strategies to ensure equitable access to gerontechnology. For instance, social policy agencies can be involved to ensure rapid accessibility to gerontechnology (e.g., insurance policy and housing policy agencies). The use of delivery approaches like those used to deliver assistive technologies, including socially disadvantaged groups as beneficiaries of technological solutions, is critical to offer equal access (Kleinman et al., 2021).

Other recommendations: A set of five recommendations for policymakers and funders is included in Genge et al. (2023): a) to recognize that technology must reflect and adapt to the heterogeneity of older adults who experience diverse and evolving needs through the lifespan, b) technology with real impact must solve a real problem respecting the needs and preferences of older adults, c) technology is not contrary to human interactions and should empower, enhance, or support existing health care services, d) co-creation and co-design require the development of authentic partnerships to inform and develop successful products, and e) policymakers and funders have an important role to play in enabling accelerated design, development, and testing to meet current and future needs.

General Conclusion

The current systematic review of the literature provided a comprehensive description of 20 empirical studies testing 17 technologies for home support in community-dwelling older adults living with dementia and their family caregivers from 2012 to 2022. The study presents detailed information about the quality of the studies, the efficacy of each gerontechnology, and the advantages and challenges of their use to age in place. After presenting a summary of each technology, we presented a theoretical model to conceptualize gerontechnology use in people living with dementia and their family caregivers. This model represents the variables involved in the development and the introduction of gerontechnology for aging and dementia in older adults living with dementia and their family caregivers. The article includes recommendations for clinical practice, research, technological development, and public policy to foster the development and implementation of gerontechnology in the dementia continuum.

Acknowledgements
This study was conducted with financial assistance provided by the Natural Sciences and Engineering Research Council of Canada (NSERC), and Gouvernement du Québec (Ministère de l'Économie, de l'Innovation et de l'Énergie) in Quebec, Canada. Dr. Moreno is supported by an AGE-WELL-EPIC-AT Fellowship and the Réseau Québécois de Recherche sur le Vieillissement (RQRV), a Research Network financed by Fonds de recherche du Québec. The authors would like to thank Marc-Olivier Croteau M. Sc., M.S.I. (Librarian at Université de Montréal) who helped to perform the literature review.

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Appendix

Appendix A
Description of technologies for home support tested simultaneously in community-dwelling older adults living with dementia and their family caregivers

Authors	Gerontechnology name and description	Function	Price (USD)	Intervention duration (weeks)	Diagnosis	Severity of dementia
Bankole et al. (2020)	Behavioral and Environmental Sensing and Intervention for Dementia Caregiver Empowerment (BESI) is a system of body-worn sensors, in-home sensors (acoustic, light, temperature, humidity, barometric pressure), and motion sensors developed to provide continuous, non-invasive agitation assessment and environmental context monitoring to detect early signs of agitation and its environmental triggers. It also includes smartwatch and tablet applications for caregivers to log activities of the person with dementia, agitation events, and caregiver data	Behavioral monitoring of agitation	ND	Phase 1: 1 Phase 2: 4	Dementia (not specified)	3MS (modified MMSE) = (55.5 = 18.1, range: 23-82). Mild Dementia (n = 5), Mild to Moderate Dementia (n = 2), Moderate Dementia (n = 3), and Moderately Severe Dementia (n = 2)
Boyd et al. (2017)	The Digital Prompter comprises an app on a tablet computer in Kiosk mode, to provide personalized prompts to guide a person with dementia through a multi-step task independently. Prompts were provided as text with matching audio messages plus photos. The person with dementia manually moves to the next prompt as required by touching an on-screen button. A manual providing guidance on how best to choose and break down tasks into suitable steps, and how to load them onto the prompter, was provided for the family caregiver.	Support in daily activities	ND	5	Dementia (not specified)	Mild to moderate
Evans et al. (2021)	The Digital Prompter includes an app on a tablet computer set in Kiosk mode that provides personalized prompts to guide older adults living with dementia through a multi-step task using verbal (e.g., with the family caregiver's voice), text, or pictures	Support in daily activities	ND	4	Alzheimer's Disease (n=18), Vascular Dementia (n=4), and Mixed Dementia (n=4)	Mean ACE-III score of 68.8 (SD = 8.9)
Fowler-Davis et al. (2020)	3Rings™ digital plug was installed with a routinely used electrical home appliance to report its use (e.g., electric kitchen kettle), where use of the appliance in this period is a significant indicator of the likelihood of the routine behavior taking place. With a digital monitoring application on the family caregiver's mobile phone, the family caregiver receives alerts when no activity occurred in a pre-set 'event- time' window	Behavioral monitoring of unusual activity	ND	16	Dementia (not specified)	ND
Gross, Byers, & Geiger (2021)	The Technology System included a handheld tablet, as well as a few connected devices: a wearable pedometer/activity monitor, a non-contact sleep monitor, a digital blood pressure monitor, and electronic weighing scales. Following their initial health assessment, a health portal was created that included past medical history and a care plan for the person with dementia to monitor their health	Health monitoring	ND	6.6	Mild dementia	A minimum of 17 for the MMSE
Guisado-Fernandez et al. (2020)	The Connected Health Platform (CH-platform) works on a tablet computer and is connected to a series of people with dementia monitoring devices for home use, including a blood pressure monitor, an electronic weighing scale, and an activity and sleeping tracker. The platform provides four features to the family caregivers: a) an educational section about dementia and advice about daily care, b) an assessment module with daily questionnaires for the family caregivers that collects health-related information about themselves and the person with dementia, c) surveys on mood, energy levels, sleep quality, and anxiety levels for family caregivers, and d) a diary for family caregivers to keep track of events. The encrypted platform securely connects all the key stakeholders involved in person with dementia's care (i.e., family caregiver, general practitioner public health nurse, and hospital geriatric services)	Health monitoring and caregiver education	ND	48	Vascular dementia (n = 4, 36%) or a non-specific type of dementia (n = 4, 36%), Alzheimer's Disease (n = 1, 9%), Parkinson's disease (n = 1, 9%), and Lewy Body Dementia (n = 1, 9%)	Mild dementia for all of them based on their MMSE score at the beginning of the study (mean MMSE: 24.1, SD = 3.7)
Harris et al. (2021)	The Digital Prompter comprises an app on a tablet computer in Kiosk mode, to provide personalized prompts to guide a person with dementia through a multi-step task independently. Prompts were provided as text with matching audio messages plus photos. The person with dementia manually moves to the next prompt as required by touching an on-screen button. A manual providing guidance on how best to choose and break down tasks into suitable steps, and how to load them onto the prompter, was provided for the family caregiver.	Support in daily activities	ND	4	Alzheimer's Disease (n=6), Vascular Dementia (n=3), and Mixed Dementia (n=2)	Mean ACE III score of 67.9 (SD = 9.98)
Inoue, Wada, & Shibata (2021)	PARO is a baby seal-shaped robot (ninth generation, about 57 cm, about 2.5 kg, antibacterial processed fur, and magnetic shielding function to be used in intensive care settings) developed to facilitate the users' psychological, physical, and social wellbeing. PARO can make an animal-like cry, moves its head and legs, and blinks. With artificial intelligence, it can remember the name of a person with dementia and endears itself to its owner with cute gestures and cries	Communication and interaction facilitator	ND	8 (range = 4 to 16)	Alzheimer's Disease (n = 6) and unspecified dementia (n = 1)	MMSE score of 12.6 (SD = 6)

Liang et al. (2017)	PARO looks like a stuffed animal shaped like a seal (ninth generation, about 57cm, about 2,5kg) and it was developed at the National Institute of Advanced Industrial Science and Technology (Japan). It's capable of making an animal-like cry, moves its head and legs, and blinks. It can remember the name of a person and endears itself to its owner with cute gesture and cries. PARO has a 4-senses sight, sound, balance, and touch-and is responsive to various stimuli	Communication and interaction facilitator	ND	6	Dementia	ND
Malmgren Fänge et al. (2020)	The TECH@HOME technology kit included home-leaving sensors, smoke and water leak sensors, door and window sensors, and motion-based bed sensors, and automatic lights. The sensors were connected to a router and in case of adverse events in the home, alerts, such as text messages or phone calls, were sent to the family members. Up to six family members could receive alarms. If the first family member did not confirm an alarm, the alarm was forwarded to the next family member on the list and so on	Behavioral monitoring of unusual activity	ND	Between 24 and 60	Alzheimer's Disease = 7 (78%); Vascular Dementia = 1 (11%) ; Unknown = 1 (11%)	MMSE = 19 (SD = 5, range 14-24) and GDS = 4 (range between 3 et 5)
Megges et al. (2018)	Two commercial German GPS watches: a) HIMATIC GPS Alpha watch, and b) ReSOS-2–the emergency watch, with a location and telephone function. Family caregivers also received a study-specific smartphone to be able to locate the person with dementia. By pressing a button in the watch, a call is sent out to the smartphone and the person with dementia can accept an incoming call by pressing this button. With both smartphone applications, family caregivers can view the last recognized position of the watch or on an online map	Tracking devices	ND	4	Dementia	Mild and moderate (n = 8 with MMSE scores between 20-25; n = 9 between 12-19). MMSE: 18.2 (SD = 4.3, range = 12–25)
Meiland et al. (2012)	The COGKNOW Day Navigator (CDN) prototype consists of a stationary in-home touchscreen, a mobile device, home-based sensors, and actuators. The stationary touch screen featured time and date, pop-up reminders remotely configurable, and a find mobile function in case the mobile device was lost. It supported picture dialing using existing phone or voice modem with handset, radio/lamp control, music player, and activity assistant. The technology also supported the help/emergency via personalized contact/help icon, pop-up safety warnings for doors and household appliances, and navigation when outdoors	Reminders, support in social contacts and daily activities, and emergency warnings	ND	Three intervention cycles: a) half a day, b) one week, and c) between 3 to 8 weeks	Alzheimer's disease	Mean MMSE score (20.5, SD = 1.8)
Mitchell et al. (2020)	The RAM (remote activity monitoring) system includes six unobtrusive motion sensors (e.g., door sensors, motion sensors, a toilet flush sensor, and a bed mattress sensor) placed in the home to detect daily activity, as well as an emergency call pendant. Family caregivers are alerted to abnormal activity patterns that may indicate a possible health condition (e.g., if sleep patterns change or the bathroom is used more frequently than usual)	Behavioral monitoring of unusual activity	ND	Three cohorts: 96 (n=30), 192 (n=21), and 288 (n=10)	Alzheimer's disease and related dementias	Moderate cognitive impairment
Nijhof et al. (2013)	ADLife is an assistive system that uses equipment installed in the home, comprising a gateway with an alarm button and several sensors which register the pattern of a person's behavior within the home. The gateway sends this information to a server through a conventional telephone line which can be accessed remotely by a professional caregiver to assist in clinical decision-making. The professional caregiver can contact the person with dementia or a family caregiver if changes in activity occur which might indicate the need for intervention	Behavioral monitoring of unusual activity	Purchase and installation (2856.81, one time cost) + (3141.71 monthly cost including troubleshooting service, professional caregivers' services, and technical services) which is cheaper as the nursing home fees	36	Unspecified dementia	Mean MMSE score = 23 (range 13 - 29)
Pike, Picking, & Cunningham (2021)	The "Ageless innovation" Robot cat is a product marketed specifically for older people and it focuses on improving the quality of life of aging loved ones. It is a cat that vocalizes with meows and purrs in reaction to light and touch, via on-board sensors. It can move its mouth, eyes, head, and roll over, in response to human interaction. It operates in mute or sound mode. In both modes, the cat's movements continue to function, and it is battery-powered	Communication and interaction facilitator	128	2 weeks (first interview) to 12 weeks (second interview)	Alzheimer's Disease (four of them without an official diagnosis)	ND
Procter, Wherton, & Greenhlagh (2018)	Two GPS tracking watches were used for the study. One with GPS tracking, fall detection, SOS functionality, plus a speaker, a microphone, and a wristband with fall detection, with or without a velocity direction. The second watch is a GPS device designed to have an appearance of a watch, with a stationary charging hub, which detects whether the device is in the house and disables the GPS to save battery power, without fall detection, but it has the 2-way communication and SOS functionality. The Ranger is a basic mobile phone with 4 speed dial buttons, SOS button, and GPS tracking. It includes geo-fence functionality and can be provided stand-alone or through a monitoring center	Tracking devices	ND	72	Vascular dementia (n=1), Alzheimer's type dementia (n=2), and Mixed-type dementia (n=2)	ND

Rose et al. (2018)	TEMPO (technology-enabled medical precision observation) is a battery-powered technology to measure agitation with wrist sensors/accelerometers placed on people with dementia at bedtime by their family caregivers. TEMPO captures wrist movements and has been validated with people with dementia as a measure of restlessness/physical agitation and serves as a proxy for sleep. It also includes bed sensors and audio sensors positioned next to the bed and a wetness sensor to detect urinary incontinence in participants with dementia	Behavioral monitoring of agitation	ND	One (5-7 nights)	Alzheimer's Disease (n=6), Mixed dementia (n=3), Dementia unspecified (n=2), Transient Ischemic Attack (n=1).	Based on scores of the 3MS: minimal impairment (n=1), Mild-moderate impairment (n=5), and Extreme impairment (n=6)
Ryan et al. (2020)	InspireD (Individual Specific Reminiscence in Dementia) is an app for iPad (IOS) designed to facilitate and promote reminiscence for people with dementia living at home. The app allows "photos", "videos", or "music" as examples to trigger memories. Family caregivers can import pictures of themselves, of the family, and friends of the person with dementia. With the pictures the family can record messages to listen to while looking at the pictures	Communication and interaction facilitator	ND	12	Dementia	Mild to moderate
Stara et al. (2021)	The Embodied Conversational Agent (ECA) Anne is a virtual character presented on a Surface Pro tablet under the Microsoft windows 10 operating system or by phone user interface. People with dementia can interact with the system through voice and by stimulating a more human-like interaction rather than just navigating with the touchscreen. Anne can support people living with dementia in all aspects of daily life: a) communication with the outside world, b) keeping track of items on the personal calendar, c) daily structure, d) medication, and e) reading the news and relaxation (games and music). It's also possible to make video calls to other persons in the repertoire. The news is on display, and they are matched to the person's interest. It's possible to listen to the radio, access an album photo section, an agenda, and receive medication reminders	Reminders, support in social contacts and daily activities, news, and hobbies	ND	4	Alzheimer's Disease	MMSE score of 25.2 (SD = 1.3)
Williams et al. (2013)	“Behavior Capture” and “Behavior Connect” technologies. Behavior Capture uses a “go-back-in time” digital system, which saves up to 30 minutes of video recording for review prior to the trigger activation with the intent of capturing events leading up to a behavior to inform behavior management care plans. Behavior Connect provides automatic HIPAA-secure transfer of video recordings to Internet storage for timely review	Caregiver support with behavioral problems	ND	12	Alzheimer's Disease	MMSE score of 11

Appendix B
Characteristics and main findings of the studies included in the systematic review

Authors and year	Type of study (Design)	Country	Study objectives	Measures	Results	User acceptance	Benefits	Difficulties using the technology	Adverse effects	Conclusion
Bankole et al. (2020)	Mixed Methods	USA	Phase 1: Confirm that the technology can accurately collect the data needed and develop a tablet-based application to document activities and agitation episodes in individuals with dementia. Phase 2: Validate the technology's capability to assess agitation and environmental events	Caregiver-reported agitation episodes, and severity level (tablet); physical, behavioral, and social activities of the person with dementia (tablet); Emotional states of the dyad (tablet); physical activity and agitation patterns of the person with dementia (TEMPO, Shimmer, Pebble); Room temperature (kelvin), light level (lux), air pressure, humidity, audio noise level, verbal agitation episodes (microphone), location with in-home movement	The results signal a valid relationship between the presence of agitation in individuals with dementia and environmental factors within the homes of the dyads	ND	The current system is robust and scalable to cover a variety of floor plans and an arbitrary number of rooms for any real-home deployment. The technology showed high potential to detect agitation early and so it could be helpful to reduce caregiver burden	Internet access and speed also proved to be a limitation in rural settings	ND	The study showed a relationship between the presence of dementia related agitation and environmental factors using BESI, which is effective in collecting the required data to detect agitation
Boyd et al. (2017)	Mixed Methods	UK	To provide preliminary evidence regarding the dyads' use of a prompter (both those living with dementia and their family caregivers) to achieve the goals they set, factors associated with its use, and potential outcomes	Log of prompter use and ratings of success to assess the use of the technology. Measures of cognitive functioning for people with dementia and measures of care knowledge and attitudes for family caregivers were also included	Most of the couples in this small trial were indeed able to use the prompter without training and 8/11 family caregivers also felt that their partner who was living with dementia was able to use the prompter independently, and all eight of these participants were able to achieve all of their goals, either fully or partially	Family caregivers rather than people living with dementia typically initiated use of the prompter	ND	Three dyads withdrew from the study without using it and two other dyads achieved only partial success with problems emerging when the person living with dementia came to use the prompter	ND	This study provides preliminary evidence that people living with dementia and their family caregivers can successfully use a touchscreen tablet and prompting software to complete tasks without additional support

Evans et al. (2021)	Qualitative	UK	To understand the experience of using a prototype electronic prompter at home from the perspective of people living with mild to moderate dementia and their family caregivers	Semi structured interviews to assess the individual experience of users with the technology	Participants' experience using the prompter are shaped by three core themes: their attitudes to technology, their judgements about its utility and the emotional impact of needing help.	Almost all the participants expressed concerns about using the prompter not just before doing so, but also after the trial, even if they had completed the tasks successfully	Most of the older adults saw the prompter as helping to support multi-stage everyday tasks	Some participants and family caregivers struggled to identify a clear purpose for the prompter that would be relevant to their lifestyle and routines. One family caregiver described technology as "trouble"	Some family caregivers reported that they had to use a lot of persuasion to get the person with dementia to try the prompter, which was often problematic and could cause tensions in their relationships	People living with dementia and their family caregivers can use a multimodal electronic prompter successfully. For all participants, successful use of the prompting package did not primarily rely on them mastering the operation of the prompter, but on their attitudes to using technology
Fowler-Davis et al. (2020)	Mixed Methods	UK	To investigate whether a family caregiver could check the daily routine of the person with dementia, and whether it reduced perceived burden felt by the family caregiver. It also sought to identify the effect on wellbeing of both parties	Wellbeing, frailty, caregiver burden, and subjective experience	Thirteen individuals with dementia and 10 family caregivers reported an improvement in wellbeing. Frailty improved or stayed the same in 17 individuals with dementia and 18 family caregivers reported a decrease in burden	Dyads found the technology acceptable and usefully demonstrated the relative stability of routine in individuals with dementia	The person with dementia liked to know that they were connected to their family caregiver through the device, and it was engaging for participants who were new users of technology	One family caregiver failed to understand the device and its alert management process, resulting in 19 alerts in the first month, while one person with dementia unplugged the device as part of their evening routine causing "false alerts"	ND	The use of this remote monitoring technology has the potential to reduce the stress and burden felt by family caregivers due to the behavioral feedback and regular patterns, which gives families "peace of mind"
Gross, Byers, & Geiger (2021)	Qualitative	Ireland	To explore if, and how, digital health technologies can achieve patient-centeredness through empowering family caregivers, and explore the way digital health technologies can facilitate the provision of better clinical care, which is focused on the person living with dementia	In-depth interviews and health data	Themes were identified from the qualitative interview data illustrating the factors influencing empowerment, patient-centered care, and integration of care through technology	The technology generated some anxiety and frustration for the dyads. The technology was not adapted to deal with more clinically complex needs. Many aspects of the technology were blind to the social and behavioral elements that accompany the reality of caring for someone	It helped the family caregivers feel empowered and better about themselves and more confident of how they were taking care of their care recipient. It helped have real-time connections with healthcare professionals which was important for family caregivers. It enhanced patient-centered care.	As it created additional responsibilities, it represented another stressor in the family caregivers' lives. It was also a lot to learn for the person with dementia. Technical limitations leading to frustration among family caregivers (e.g., loading speed, technological glitches, repetitive inputs, non-intuitive features)	Anxiety for the person with dementia, additional stressors, and frustrations for the family caregivers	While some family caregivers benefited from the real-time clinical supports, experienced empowerment, and found that their caring capacity improved, the system also created stress and responsibility
Guisado-Fernandez et al. (2000)	Quantitative	Ireland	To create a multidimensional profile for evaluating the progression of the well-being of people with dementia-family caregiver dyads during their use of the Connected Health platform at one year and long-term follow-up with different time-interval evaluations	Measured every three months: a) People with dementia-related functional status, cognitive status, quality of life; and b) Family caregiver's mood, sleep quality, and caregiver burden	In most measurement outcomes analyzed, there were no significant changes in the person with dementia or their caregivers' well-being over the year of follow-up when analyzed as a group	ND	Slight increase in the quality of sleep of family caregivers	ND	ND	No significant changes were reported during the time of use of the technology for the person with dementia or the family caregiver. Considering the high interindividual variability among dyads, these results support the potential value of individual-level monitoring

Harris et al. (2021)	Quantitative	UK	To provide preliminary evidence regarding the dyads' use of a prompter (both those living with dementia and their family caregivers) to achieve the goals they set, factors associated with its use, and potential outcomes	Log of prompter use and ratings of success to assess the use of the technology. Measures of cognitive functioning for people with dementia and measures of care knowledge and attitudes for family caregivers were also included	Most of the couples in this small trial were indeed able to use the prompter without training, eight family caregivers also felt that their partner who was living with dementia was able to use the prompter independently, and all eight of them were able to achieve all their goals, either fully or partially	Family caregivers rather than people living with dementia typically initiated use of the prompter	ND	Three dyads withdrew from the study without using it and two other dyads achieved only partial success with problems emerging when the person living with dementia came to use the prompter	ND	This study provides preliminary evidence that people living with dementia and their family caregivers can successfully use a touchscreen tablet and prompting software to complete tasks without additional support
Inoue, Wada, & Shibata (2021)	Mixed	Japan	To examine the potentiality of a PARO-mediated care provided by the family and to identify the problems when utilizing PARO in the home context	Mini-Mental State Examination-Japanese (MMSE-J); Nishimura's Activity of Daily Living Scale (N-ADL); Dementia Behavior Disturbance (DBD) Scale; Zarit Burden Interview (ZBI) ; Qualitative: A semi-structured interview	Despite no significant change in terms of the standardized tests, PARO positively impacted the participants' social and emotional health with participants maintaining a high level of interest (e.g., talking with PARO, looking at it, or smiling with a relaxed facial expression)	Most family caregivers reported that participants displayed a positive reaction and behavior toward PARO and others. Only two out of seven families discontinued the use of PARO but the reasons were not explored	PARO can help improve activity engagement, relaxation, a respite from supervision, and improve mood in people with dementia. It also provides a sense of comfort by serving as a companion, allows the participants time to interact with their families, provides a sense of connection and belongingness	Using PARO at home with an older person with dementia without any interest in it may yield limited results	ND	When PARO is used in-home care, individuals who displayed an active interest in PARO from the beginning would voluntarily increase the time spent with PARO, leading to a decrease in behavioral and psychological symptoms of dementia
Liang et al. (2017)	Quantitative	New Zealand	To investigate the psychosocial, behavioral, and physiological effects of PARO for people with dementia in both day care and home environments	People with dementia's cognitive level and blood pressure, cortisol levels, agitation, neuropsychiatric symptoms, depressive symptoms, medication use, and cognition. Interviews with family caregivers	Despite no differences in the variables of interest, family caregivers observed that people with dementia living at home responded positively to PARO and that it had a positive effect on their mood or behavior. Care recipients spent at least between 10 to 30 minutes a day interacting with PARO	Good as people with dementia interacted with PARO and responded positively at home	Family caregivers reported that PARO acted as a social stimulus, it was helpful in improving mood and reducing anxiety in people with dementia and that PARO	ND	A small number of care recipients directed negative verbal comments toward PARO, showed negative physical interactions, or chose not to interact with PARO at all	PARO elicited heterogeneous responses in care recipients with dementia, with individuals with greater cognitive functioning being more responsive to PARO
Malmgren Fänge et al., (2020)	Qualitative	Sweden	To explore experiences, needs, benefits and drawbacks with using sensor-based technology for safety and independence in the homes of people with dementia and their family members	Semistructured interviews about the experiences and needs related to the technology	Four categories emerged: a) understanding and accepting the technology and its purpose, b) the reliability of the technology, c) negotiating safety and privacy, and d) potential of sensor-based digital technology.	Individuals with dementia accepted to have it installed as a precaution to enhance life in the own home, and something that could support their families and friends. The family members expressed that the technology was in general very good	The technology provides support for people with dementia and their family caregivers, it's a silent technology, and mostly invisible. Possibility to remotely monitor the person with dementia, receive text messages, phone calls, or alarms when something unusual happens	Most of the times the bed sensors were not working correctly (plus size too small), sometimes people with dementia could not hear the alarm. The door sensors did not distinguish between different persons passing through the door, only if it was opened and/or then closed again	Some family members reported that the persons with dementia removed the entire technical kit, due to negative feelings of being monitored or due to general annoyance. Alarm tiredness regarding the routine morning message family caregivers received	Sensor-based technology has the potential to be a support to people with dementia and their family members in everyday life to make life easier and safer, with information about adverse behavior or changed behavior patterns being useful to detect early signs of deterioration or other health problems

Megges et al. (2018)	Quantitative	Germany	To perform an in-depth comparison of the user experience and clinical effectiveness of two similar commercial GPS watches in home dementia care	History of wandering events reports, caregiver burden, quality of life of people with dementia and family caregivers, orientation impairment and subjective burden of getting lost, and usability	Usability for both products was fair to good, and dyads rated product B better than product A. The examination of clinical effectiveness revealed no significant changes over the study duration. Family caregivers' frequency of use was moderate	Overall, dyads accepted the technology. Dropout rate of 10% because of product dissatisfaction associated with technical difficulties, with no other significant differences compared with nondropouts	Product A was able to assist in locating people with dementia in two wandering events. The telephone function and the localization function helped to locate the person with dementia	Nine dyads reported technical difficulties for each product (i.e., problems with the charging cable or dock, the software, and the telephone function). Family caregivers reported more difficulties than people with dementia	ND	GPS watches in home dementia care should contain few buttons, display a clear font with parsimonious text, and have a battery life of at least 24-hours
Meiland et al. (2012)	Mixed	Europe (Amsterdam, Belfast, and Luleä)	To evaluate an integrated digital prosthetic, the COGKNOW Day Navigator (CDN), to support persons with mild dementia in their daily lives, with memory, social contacts, daily activities, and safety	Usability was assessed using semi-structured interviews and standard questionnaires for both the person with dementia and the family caregiver, also direct observation, satisfaction with the system, the degree of difficulty learning how to use the system	Nearly all persons with dementia and family caregivers did not report changes on their quality of life or their way of functioning with the CDN	People with dementia and family caregivers were positive about the design, but the picture dialing function was considered not user-friendly. The radio and music functions were considered easy to use and learn, but the rest was less clear (e.g., the help button, agenda)	With the suggested adaptations, the CDN is expected to be a useful tool for supporting community-dwelling persons with mild dementia and their family caregivers	Audio quality and delays when hanging up with the size of the mobile device being too large and heavy. Also, the battery life was too short. People had difficulty recognizing the help button and the music button on the Mobile device. It remained difficult to understand some of the icons	ND	The CDN is generally valued as a user-friendly and useful device to support persons with mild dementia and their family caregivers, with some suggestions for improvement including the need for personalization
Mitchell et al. (2020)	Mixed	United-States	To determine whether family caregivers of persons with dementia perceived a remote activity monitoring (RAM) system as acceptable and useful for up to 1.5 years and to identify characteristics of family caregivers and persons with Alzheimer's disease and related dementias that are associated with acceptance of RAM	Caregiver distress, involuntary aspects of the caregiving role depression, self-efficacy, sense of competence, and the RAM system review checklist for acceptability	Two thirds of respondents agreed or strongly agreed that they would recommend RAM to other caregivers or care recipients in a similar situation, suggesting that RAM was viewed as useful by many participants, especially for those who did not live with the care recipient or who needed to be away for several hours during the day	A total of 24 participants noted that RAM was easy to use (62%), especially those who were already comfortable with technology and required little effort on the caregiver's part, while 54.2% of participants agreed or strongly agreed that the alerts provided by RAM were helpful	Caregivers who responded positively to RAM noted that the system provided useful information, promoted peace of mind, was easy to use, prevented health crises for the person with dementia, and promoted the person with dementia's independent living	Ten participants reported false alarms were a frequent problem requiring time and assistance to adjust, while 28% felt that parts of the RAM system were confusing and unclear	Some family caregivers mentioned having their sleep bothered by false alarms. Six family caregivers complained that the system was too disruptive and intrusive (e.g., false alarms). The system provided an overwhelming amount of information	RAM is an extra tool that appears to benefit people with dementia in the late-early to moderate stages of the disease and can, in some cases, help family caregivers by alleviating some of the challenges of care provision
Nijhof et al. (2013)	Mixed	Netherlands	To document the installation and introduction of a commercially available monitoring system into the homes of people with dementia and through the participating healthcare organization and to explore the perceptions of professional and family caregivers using the technology	Semi-structured interview to explore the implementation of the system, the usability of the technology, and the effect on care intervention and well-being, including a cost-analysis	ADLife was perceived as giving people with dementia a sense of freedom and autonomy because of the assistance, despite some problems (e.g., no alert leading to dehydration)	Family caregivers reported that most people with dementia became unaware of the sensors over time. They reported that the small size of the sensors ensured that they quickly became an acceptable feature of the home environment following installation	Saving money, alleviate anxiety of caregivers, help monitor older adults and help with autonomy loss	Family caregivers had misconceptions about what the system was designed to achieve, which affected levels of acceptability	Some clients appeared unsettled by noises and flickering lights from the equipment, seeing these as alarm indicators, raising levels of anxiety. One of the caregivers reported increased burden of care, if the sensors detected certain situations where additional care was required	The ADLife system enhanced the feelings of safety and security because of having it installed in the home. The system also appeared to reduce the burden of care on the family caregivers and provided the potential for supporting older people to live at home for longer

Pike, Picking, & Cunningham (2021)	Qualitative	UK	To explore the effects of robot pets in a home environment with the support of both family and/or professional caregivers	Interviews with each dyad (to know more about the acceptability of the robot cat and its effects on both members of the dyad)	Four themes were identified in the thematic analysis: a) acceptance and rejection, b) distraction, c) communication, and d) connecting with the cat and connecting with other	People who liked cats were most likely to accept the technology. Rejection more likely in early stages of dementia. Participants identified that conversations were stimulated as a response to the meow, purr, and movement of the cat, and that this promoted communication with family and others	The robot cat can stimulate communication for individuals and family caregivers alike. People can become less withdrawn. The cat's robotic behavior can act as a communication theme. It can improve family caregivers' wellbeing and the stability of the care recipient's behavior by reducing anxiety/moods	Three participants rejected the cat because they did not like cats, preferred their teddies, were not interested and/or resistant to support. One participant thought the cat looked 'spooky' and it had to be locked in the box	The robot cat had to be put away because one participant felt scared. It provoked disgust and a negative body language in two participants. The robot cat made a participant anxious when the cat meowed	Various factors influence the impact of a robot pet on people with dementia and their family caregivers, including acceptability of the pet. For individuals living at home, where assistance is accepted from others and where the robot cat is accepted, there are positive benefits
Procter, Wherton, & Greenhlagh (2018)	Qualitative	UK	a) To understand people with cognitive impairment's lived experience of global positioning system - GPS tracking, b) to facilitate the customization and adaptation of technologies and care services, and c) to explore the possibilities for a co-production methodology to shape these devices and services to meet their needs	Interviews to explore the perception of use of the technology, the needs, and opportunities to adapt and reconfigure the solution, as well as users' wishes	They identified four common themes: a) case management, b) matching technology options with clients' needs, c) locating and tracking as a collaborative activity, and d) dealing with false alerts and wandering	Most used it, one participant refused because he did not like it, and three other stopped	Reassurance from monitoring for some participants	Some family caregivers noticed a delay between the signal and his actual location, it was too big for one participant, it requires a lot of coordination and communication, and there are a lot of false alerts (but it's hard to find their causes)	It can be disruptive for the family caregiver to receive alert messages resulting in stress and confusion and unnecessary trips to the person with dementia's house for verification	This study emphasized the importance of healthcare services who are key to successful adoption of GPS technologies in people with dementia and their family caregivers
Rose et al. (2018)	Mixed	USA	To examine the feasibility and acceptability of the use of passive body sensors in community-dwelling individuals with Alzheimer's Disease by family caregivers	Baseline survey data, daily pain assessments, sleep diaries, and post study feedback. Semi-structured in-person interviews.	Family caregivers stated that they encountered no difficulty applying and maintaining the incontinence sensors, while people with dementia were consistent across the nights in the frequency and timing of wetness events	Instructions were easy to understand, and the graphics provided good reinforcement on the written directions	Passive technology, easy to use, helps evaluate nocturnal problems	One care recipient was resistant to wearing the incontinence pad and sensor and two care recipients removed the TEMPO wrist sensors at different times during the study (probably because of their sleeping position)	Agitation when the wrist band was placed in one participant	The use of body sensors to detect agitation, sleep, and urinary incontinence in individuals with dementia is a reliable and feasible means to gather valid data regarding these distressing symptoms
Ryan et al. (2020)	Qualitative	UK	To explore the impact of a home-based, personalized reminiscence program facilitated through an iPad app (InspireD) on People with dementia and their family caregivers	Semi structured interviews were used to collect data	Six key themes emerged from the thematic analysis: a) usability, b) revisiting the past, c) home use, d) impact on the person living with dementia, e) gains and abilities, and f) impact on relationships	The App was nice, easy, and simple to use which allowed the dyad to not lose interest. Some participants would bring it to family dinners to take pictures to add to the App. It became an everyday essential for a lot of them. It was also facilitated since the technology could be used at home in a familiar environment.	People with dementia became less anxious and more relaxed. Family caregivers reported they were 'finding' their loved one again (e.g., trans-generational impact), they developed a richer perspective of their loved one, and felt like they had more patience, respect, and understanding in their caregiving role	In some of the cases, participants struggled to use the App. Family caregivers acknowledged that they had not adapted well to this type of technology or felt this type of medium was not appropriate for their relatives. Some family caregivers find it difficult to interact with memories that did not include them	The reminiscence of more negative memories was a little distressing at the time. However, it was an essential process to reconnect the family caregivers with the person with dementia and it enabled them to address the feelings behind painful memories while preserving them on the App	A more individualized approach to reminiscence, facilitated using a tablet device and preceded by a period of reminiscence and IT training has the potential to generate a positive impact on people living with dementia living at home without negative consequences for family caregivers

Stara et al. (2021)	Mixed	Italy	To evaluate the usability and acceptance of the Embodied Conversational Agent (ECA) Anne by older adults living with dementia and to assess the ability of target users to utilize the system independently	Quality of life in older adults with cognitive impairment, the system usability scale, and unstructured interviews about the general impression of the system and the major discomfort issues perceived during the testing period. Telemetry data was collected during the 4 weeks to track every activity of the user on the tablet	People with dementia became less anxious during the 4 weeks of use, with positive changes (perceived enjoyment and social presence). The gaming functions and medication were the most successful services	Anne was perceived as a companion able to support memory and enjoyment needs, it served as a source of entertainment and to handle adherence to medication plans. None of the participants withdrew from the trial	After the 4-weeks, participants were less anxious in the usage, more skilled in the basic functionalities, they reported that Anna was seen to improve their well-being (70%), with touchscreen modality being positively used by people living with dementia	Some of the participants had difficulties using the speech recognition feature. These issues had a negative impact on the intention to use it, adaptiveness, usefulness, and trust	The speech command difficulties made some people feel insecure and frustrated	Overall, the sample shared a good engagement with the system providing evidence for the use of Embodied Conversational Agents as future E-Health systems able to address the basic and higher-level needs of people with dementia
Williams et al. (2013)	Mixed	United-States	To describe the adaptation and feasibility testing of a technology conceived for parent and teacher management for behavior problems of autistic children in home and school settings to support family caregivers of persons with dementia	Caregiver burden, memory and problematic behaviors, and caregiver efficacy	The interdisciplinary team overwhelmingly found that the recordings provided essential information for understanding the context of family caregiver's concerns and to provide advice on how to intervene. The family caregiver reported increased confidence in providing care and reduced caregiver burden	Family caregivers reported it was helpful	The professional feedback was helpful to improving caregiving skills and added new and more effective strategies	None reported by the dyad. Family caregivers denied added stress from using home monitoring but reported they may have modified their behavior due to awareness of being recorded	Potential issues related to protection of human subjects and privacy of protected health information	Home monitoring with professional feedback may expand interventions to support caregivers of persons with dementia at home, reducing some of the stress of caregiving, reducing premature nursing home placements, and health care costs while supporting families