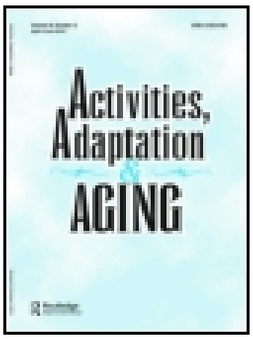

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Supporting Behavioral and Psychological Challenges in Alzheimer Using Technology: A Systematic Review

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ABSTRACT

The aging of the population is associated with an increase in the prevalence of neurodegenerative diseases such as dementia. Our research aim was to determine how technology can help to improve the support for behavioral and psychological challenges of dementia. A systematic review of the literature was performed following PRISMA guidelines. Papers meeting the inclusion criteria and reporting technological devices aimed to the management of these challenges. After screening 1085 papers, 18 studies were eligible for inclusion in the review. Technologies identified in this search (e.g., robots, mobile, apps, computer, software, GPS, wearables, assistive technology) suggest that this non-pharmacological approach may be useful in projects aimed to the management and control of behavioral and psychological manifestations in people living with Alzheimer. The manifestations that are most successfully supported by means of technological applications and devices are depression, sleep disorders, anxiety, apathy, motor activity, and agitation.

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KEYWORDS
Alzheimer; behavioral symptoms; psychological symptoms; non-pharmacological treatment; technology; dementia; systematic review

Introduction

Fifty million people suffer from dementia worldwide, a common term used by the Diagnostic and Statistical Manual, Fifth Edition (DSM-5) (American Psychiatric Association, 2013) for major neurocognitive disorders. Nowadays we are facing great challenges to which health systems should respond with innovative solutions. According to the World Health Organization (WHO) global data, it was estimated that Alzheimer and other dementias will affect 82 million people worldwide (about 5% of the world's older population) by 2030 and 152 million by 2050. Alzheimer may contribute to 60–70% of the cases so it is the most common form of dementia (World Health Organization, 2017, 2019). In fact, since the German scientist Alois Alzheimer published the results of a study carried out with Auguste Deter in 1906, research has not ceased to seek an effective treatment for this neurodegenerative disorder (Atri, 2019; Bash & Tanenbaum, 2022; Cummings, Tong,

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& Ballard, 2019; National Institute on Aging, n.d.-b; Reynolds, 2019; Yiannopoulou & Papageorgiou, 2020).

Definition of key concepts

Alzheimer: Dementia can have a variety of etiologies, but all of them are characterized by a functional impairment in one or more cognitive domains that affects the performance of daily activities, including basic, and intellectual activities (IADL) (Barrera López et al., 2018; Cloak & Al Khalili, 2020; Jia et al., 2021; Park & Cohen, 2019). **Alzheimer** is the most common form of dementia and it is characterized by deficits in cognition, function, and behavior (Zhang et al., 2021). As a matter of fact, a reduced quality of life has been reported in people experiencing cognitive changes since this disease has significant effects at physical, psychological, social, and economic levels, not only on people living with dementia but also on their relatives and loved-ones, and on the society in general. It has been suggested that clinical manifestations of Alzheimer may be associated between them. For example, cognitive deficits have been associated with reduced IADLs in the early stage of the disease and in the more advanced stages both variables have even been more closely related. In these stages, executive ability and personality changes may be independent risk factors for reduced IADLs (Jia et al., 2021). Furthermore, Jia et al. (2021) have recently proposed that IADLs can be a great help to identify and diagnose cognitive impairment.

Behavioral and psychological challenges of dementia: In 1996, the International Psychogeriatric Association (IPA) called a consensus conference and agreed on the term Behavioral and Psychological Symptoms of Dementia including "signs and symptoms of altered perception, thought content, mood, or behavior, which occur frequently in patients with dementia" (Mintzer, J, Mirski, D, & Hoernig, K, 2000). The prevalence of behavioral or psychological manifestations in people who have Alzheimer is very high, in fact up to 85–90% of this group experience behavioral and psychological challenges (Kolanowski et al., 2017). Behavioral and psychological challenges, also called neuropsychological symptoms, require attention because they are common manifestations of the disease and can significantly affect the prognosis and management of dementia. Updated reviews, such as that of Pérez Romero and González Garrido (2018) made it clear that psychological challenges include delusions, hallucinations, misidentification, depression, anxiety, or apathy being this one of the most common challenge, while behavioral symptoms cover a wide range of manifestations such as: wandering, agitation/aggression, resistance to care, inappropriate sexual behavior, and catastrophic reactions such as anger, verbal, and physical aggression. Other authors, like Cloak and Al Khalili (2020) classify them into five domains: cognitive/perceptual (delusions, hallucinations), emotional (e.g., euphoria, depression, apathy, anxiety,

and irritability), motor (e.g., pacing, wandering, repetitive movements, physical aggression), verbal (e.g., yelling, calling out, repetitive speech, verbal aggression), and vegetative (disturbances in sleep and appetite). Jia et al. (2021) recently suggested that a greater severity of the behavioral and psychological challenges may be associated with reduced ADLs. Furthermore, given that in people living with dementia difficulties in ADLs are frequently associated with dependence, the identification of these changes at an early stage seems to be necessary (Davalos, Teixeira, & Ikeda, 2022).

Technology: Digital technologies, include smartphones, wearables, sensors, biomarkers, robots, smart-home, telehealth, social media data, and assistive technology. Recently, it has been suggested that all these technologies may have a great potential in the early diagnostic and holistic management of symptoms in people living with dementia. It has also been proposed that technology-based interventions could be useful for assisting them to complete ADLs (Evans et al., 2020). From a few years ago until now there has been an exponential interest in focusing on how technology can contribute to the maintenance of different health conditions. There have been multiple potential applications of technological approaches in dementia, including diagnosis, assessment and monitoring, entertainment and engagement, care and management (Astell et al., 2019; Husebo et al., 2020; Shu & Woo, 2021).

Treatments of BPSD in people living with AD

At the present moment, the more usual paradigm for Alzheimer treatment involves a combined pharmacological and non-pharmacological approaches (Atri, 2019; Guzman-Martínez et al., 2021; Seok et al., 2022). However, with the aim of reducing symptoms accompanying the cognitive and functional decline observed along clinical progression in individuals who have dementia, as well as the burden on their loved ones, a more holistic outlook is required, which must be aimed to improve the quality of life both for persons living with dementia and their relatives (James et al., 2022; Yiannopoulou & Papageorgiou, 2020).

The presence and severity of behavioral and psychological challenges differ between people living with dementia. Some studies suggest a positive correlation between cognitive deficits indicating that with increased impairment there is an increase in the prevalence of these manifestations (Fernández, Gobartt, Balañá, Li, & Adams, 2010; Park & Cohen, 2019; Spalletta et al., 2010) whereas others claim that the relationship would be the opposite (Poletti, Nuti, Cipriani, & Bonuccelli, 2013). Therefore, the evaluation of these psychological changes through scales such as the Neuropsychiatric Inventory (NPI), the Behavioral Pathology Rating Scale in Alzheimer's Disease (BEHAVE-AD) or other questionnaires seems to be essential to identify which subjects require treatment for these symptoms (Fuju,

Yamagami, Ito, Naito, & Yamaguchi, 2021; Tible, Riese, Savaskan, & Von Gunten, 2017). According to clinical guidelines and reviews, the use of non-pharmacological approaches is recommended as the first option in the treatment of behavioral and psychological challenges (e.g. agitation, apathy, delusions, and disinhibition) (Bennett et al., 2021). It has been suggested that pharmacological therapy (e.g. hypnotics, antipsychotics, or antidepressants) should be only initiated in some situations, for example when the subject does not respond to the non-pharmacological approach, is very distressed or displays a behavior that possesses a significant safety risk (Atri, 2019; Bessey & Walaszek, 2019; Cummings et al., 2019; Kales, Lyketsos, Miller, & Ballard, 2019; Masopust, Protopopová, Vališ, Pavelek, & Klímová, 2018). Non-pharmacological approaches with the loved ones can also reduce the behavioral and psychological reactions (Meng et al., 2021). In this line, it is important to mention that the management of these challenges is difficult and that the lack of effective treatments has serious consequences for the individual. A rapid progression of the disease requires measures such as earlier assisted living environment that could promote a worse quality of life. Consequently, there are higher costs of care and greater distress for loved ones associated with this situation (Hung, Levine, Randhawa, & Park, 2022; Masopust et al., 2018; Pérez Romero & González Garrido, 2018; Tible et al., 2017).

The use of technology in the management of behavioral and psychological challenges in people living with Alzheimer

Different projects aimed to people living with Alzheimer have benefited from advances in new technological solutions, which have shown a significant increase in recent years (Astell et al., 2019). A growing number of studies indicate that digital technologies could have a great potential in diagnostic, support, and treatment of neuropsychological symptoms in people living with dementia (Alberdi et al., 2018; Chiberska, 2018; Coelho, 2022; Costanzo et al., 2020; Husebo et al., 2020; Klimova, Valis, & Kuca, 2018; Piau, Wild, Mattek, & Kaye, 2019; Sánchez-Gutiérrez, Ortega-Bastidas, & Cano-de-la-Cuerda, 2019; Stroud, Onnela, & Manji, 2019). Therefore, it has been proposed that the technology can be a promising solution that would meet current and future demands. However, there is a lack of information about the available options that technology can offer for people at advanced ages (Carrasco, Ortiz-Maqués, & Martínez-Rodríguez, 2020; Talmage et al., 2021; Tsertsidis, 2020). It is true that we are faced with limited research aimed to the management of main symptoms in individuals with neurodegenerative diseases through the use of technology, but systematic reviews such as the one recently published by Husebo et al. (2020) concluded that the success of health technology depends on the interdisciplinary cooperation and on the advances in the application of

ethical innovation. In addition, situations such as those that have arisen recently due to the outbreak of the COVID-19 pandemic have highlighted the lack of resources in nursing homes and especially for individuals experiencing cognitive changes, their loved ones, and professionals to alleviate unnecessary suffering (Behera, Condell, Dora, Gibson, & Leavey, 2021; Hoel, Feunou, & Wolf-Ostermann, 2021; Wang et al., 2020). This fact has shown us how a global pandemic demands global solutions. Thus, professionals need to innovate and develop devices, services, and other technological tools to improve the quality of care for people living with dementia taking into account the challenges and constraints that the pandemic period has imposed on us (Merrilees et al., 2022).

Some prior papers have addressed the use of technological solutions for Alzheimer and related dementias but there are clear differences with the present work. Recently, Cammisuli, Cipriani, and Castelnuovo (2022) have reviewed the role of technology for diagnosis management and treatment for Alzheimer, but their focus in not exclusively in behavioral and psychological challenges. In contrast, Bennett et al. (2021) centered their review in the implementation of strategies aimed to increase the application of non-pharmacological interventions to address these manifestations in people living with dementia, but in this paper no special attention is paid to technology. Other authors have focused their reviews in specific issues such as the use of technology for social communication (Anderson et al., 2022) or physical activity (Hung et al., 2022). Finally, Seok et al. (2022) reviewed non-pharmacological interventions for supporting people living with dementia comparing conventional care with solutions based on technology.

This review paper considers that in the coming decades the world's older population will increase dramatically and, consequently, the prevalence of dementia will also increase. Therefore, we present a synopsis of research studies whose objectives have been focused on evaluating how different types of technology could help improve the treatment and management of behavioral and psychological challenges in Alzheimer. Furthermore, the results obtained in this review could help to design future projects incorporating the implications and recommendations raised. These practical applications should also consider the special needs of this population and the types of technology that could contribute to a more efficient management of some of the manifestations, as summarized in the present review. In turn, unlike previous reviews conducted in this population, the present review pays special attention to technology aids, differentiating between behavioral and psychological challenges in Alzheimer.

Methods

In the present review, we have followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009; Page et al., 2021). Figure 1 shows the different phases defined in our methodology

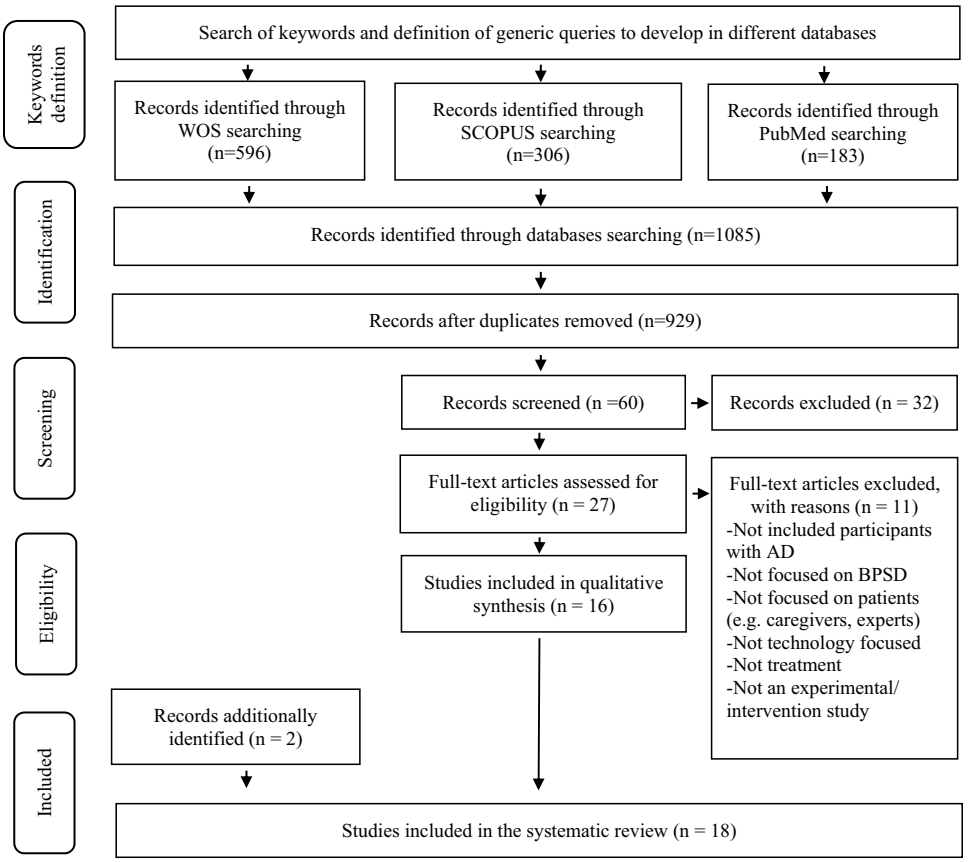

Figure 1. Study selection according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Keywords definition

In order to facilitate the process of identifying the keywords, we have defined three categories to work with:

- Alzheimer: Terms associated with the most common disease among this neurodegenerative disease in the older population.
- Behavioral and psychological challenges of dementia: Terms representing perceptual/cognitive, emotional, motor/behavioral, verbal, and vegetative symptoms, which are common in subjects with different types of dementia (e.g., delusions, hallucinations, mood disorders, wandering, physical/verbal aggression, sleep, and appetite disorders).
- Technology: Technical terms that usually appear in studies related to eHealth (e.g., wearable, smartphone, applications, assistive technology, and robots).

The complete list of categorized terms is provided in Table 1. We must also mention that we searched using Medical Subject Headings (MeSH) terms identified in the title, abstract, or keywords. Finally, keywords included MeSH terms, specific terms, synonyms, and keywords identified in other studies.

Identification

Studies were identified using computerized searches in three different scientific databases: Web of Science (WOS), Scopus, and PubMed. We searched for papers published in the last ten years until the 10th of April 2020. In each search, different terms were united with a logic OR operator and queries were linked between categories with a logic AND operator. Table 1 summarizes the query employed. In fact, we only considered English language. Papers included in the final selection have been published in the last 10 years (2010-April 2020). Finally, duplicated studies were removed.

Screening & eligibility

During the screening phase, the title and abstract of the articles were scanned. We followed the PICOTS reporting system, which describes the participants, interventions, comparisons, outcomes, timeframe and study design (Riva, Malik, Burnie, Endicott, & Busse, 2012):

- Participants had to be older adults over the age of 50 and diagnosed with Alzheimer. However, if the sample included both people living with Alzheimer and participants with other types of dementia for comparison (e.g. Vascular Dementia, Frontotemporal Dementia, Lewy-body dementia), the paper was not excluded if the information reported in the paper was sufficient for addressing how the effectiveness of the approaches have been evaluated for individuals living with dementia. Papers reporting technological devices or applications aimed only to the loved ones, without

Table 1. Indexed query formation process.

Index	Query	Category
1	("Alzheimer" OR "Alzheimer Disease")	*Alzheimer's Disease*
2	("Neuropsychiatric symptoms" OR "BPSD" OR "Behavioural symptoms" OR "Psychological symptoms" OR "Affective disorder" OR "Aggressiveness" OR "Agitation" OR "Depression" OR "Apathy")	*Behavioral and psychological symptoms of dementia (BPSD)*
3	("Technology Smartphone" OR "Applications" OR "Apps" OR "Mobile devices" OR "Wearable" OR "Telemedicine" "Geographic Information System" OR "GPS" OR "Smart-home" OR "Assistive technology" OR "eHealth" OR "mHealth" OR "Voice Assistant")	*Technology*
4	[1] AND [2] AND [3]	*Resultant query*

taking in account the management of behavioral and psychological challenges displayed by the subject, were also removed from the final selection.
- The approaches should be based on the evaluation of different types of technology addressed to the management of behavioral and psychological manifestations in persons with a supportive care.
- Comparisons between control/placebo and active interventions were taken into consideration.
- The Outcome must be referred to the effects of each type of technology supporting the management of the behavioral and psychological challenges.
- Timeframe included short- and long-term outcomes, and both have been considered.
- The Studies could be either randomized controlled trials (RCTs) or observational studies. Opinion papers, protocols, conference abstracts, systematic reviews, non-systematic reviews, case studies, technical notes, commentaries, and letters or editorials were excluded.

During the eligibility phase, all the identified papers were fully analyzed. The same exclusion criteria as in the screening phase were applied in this eligibility phase. The most common reasons for exclusion were as follows: paper not including participants diagnosed with Alzheimer, not focused on behavioral or psychological reactions, not focused on people living with dementia (e.g. loved ones, experts), not technology focused, not treatment, not an experimental/intervention study).

Included

The articles that were included can be classified according to two criteria: 1) Psychological symptoms (e.g., depressions, anxiety, apathy); and 2) Behavioral symptoms (e.g., sleep disturbances, agitations, wander). We selected those papers in which the use of different types of technology (e.g., robots, applications, and software) to control and manage the behavioral or psychological manifestations was reported. Participants had to include at least one group diagnosed with Alzheimer, although some studies compare them with other types of dementia. Two additional references were identified via cross-referencing.

Results

The systematic search generated 1085 English-language potential publications. The number of papers retrieved in each database was: from Web of Science (596), from Scopus (306) and from PubMed (183). From this total number of articles, after screening the abstracts and titles, 27 papers were identified as relevant for full-text evaluation. Of these, 11 papers were removed from the

following selection because they were not experimental studies and they did not focus on treatment of behavioral or psychological challenges with technology, or the sample did not include persons who have Alzheimer. The final selection were 16 studies, and two more were added after manual searching in Google Scholar. After screening and review following PRISMA 2020 guidelines (Page et al., 2021), 18 studies were eligible for inclusion in the review, by consensus among the coauthors (Figure 1).

Studies were published from 2011 to 2020 clustered in North America (6), Western Europe (9), Asia (2) and Australia (1) (Figure 2), with a large increase within the last year, indicating a steep pace of growth in the literature. Sample size ranged from 9 to 455 participants, most of them were diagnosed with Alzheimer but there were also participants with other diagnosis (e.g. Vascular Dementia, Lewy-Body Dementia, Frontotemporal Dementia). The average age of the participants ranged from 60 to 95 years old, whereas the percentage of women ranged from 6 to 74%. From all the studies reviewed, a total of 15 were considered experimental (9 non-randomized and 6 randomized controlled studies). Only three of the studies reviewed were observational descriptive. Regarding the duration of the studies, they cover a wide range, from 1 day to 5 years of follow-up (Table 2).

In terms of evaluation instruments included in the studies, the most widely used questionnaires were the Mini-Mental State Examination (MMSE) and the Neuropsychiatric Inventory (NPI). Table 3 shows four key categories that can be identified: 1) Neuropsychological questionnaires; 2) Psychological

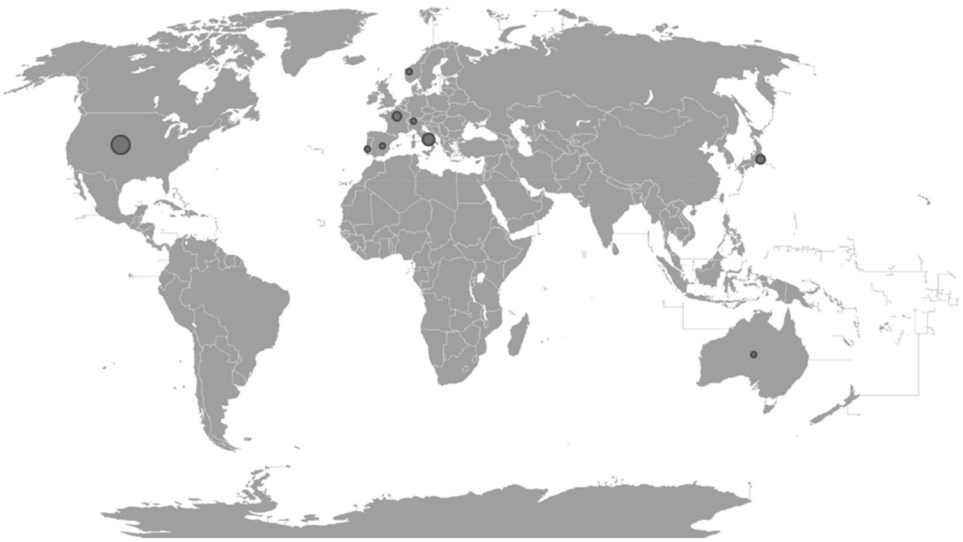

Figure 2. Geographical location and number of papers covered by this systematic review (2010-April 2020).

symptoms questionnaires; 3) Behavioral symptoms questionnaires; 4) Quality of life questionnaires.

We have summarized and classified these 18 studies that appear in Table 4, into two main groups: (1) psychological symptoms (depression, anxiety, apathy/indifference, mood, stress, delusions, psychosis, irritability/lability), and (2) behavioral symptoms (sleep, agitation/aggression, psychomotor activity, wander/ambulation, disinhibition, appetite and eating abnormalities). Usually, in every study, one type of technology (e.g. app, robot, assistive technology, wearable, GPS) is applied for different types of psychological and behavioral symptoms, and because of that we have focused on the results obtained about the effectiveness of the technology evaluated in each study for the management of the symptoms displayed by the participants (Table 4).

Psychological challenges

Table 5 shows the psychological and behavioral symptoms that have improved with various technological approaches. It also shows the type of technology identifying the published report by means of its first author and year of publication.

Nine of the reviewed studies suggest that depression is a psychological symptom that can be improved through the use of different technology-based solutions such as video conferencing (Weiner, Rossetti, & Harrah, 2011), music stimulation from the laptop with a microswitch (Lancioni et al., 2013), global positioning system (GPS) (Tung et al., 2014), a tailored lighting solution with a Daysimeter (Gfigueiro et al., 2014), the robotic seal-pet PARO (Jøranson, Pedersen, Rokstad, & Ihlebæk, 2015) and robot MARIO (D'Onofrio et al., 2019), the wearable camera Sensecam (Silva et al., 2017), the mobile application AlzhaTV (Varshney, Varshney, Tampi, McCall, & Varshney, 2018) or a digital therapeutic software ReminX (Filoteo et al., 2018). By contrast, results obtained in the study performed by Ohta et al. (2018) suggested that the telephone call system (Andes phone®) did not significantly improve depression levels.

Anxiety levels also improved with ReminX (Filoteo et al., 2018), AlzhaTV (Varshney et al., 2018) and in another study performed with the seal robot PARO (Petersen, Houston, Qin, Tague, & Studley, 2017). In contrast to the results obtained for depression, the automated telephone call system showed positive effects on anxiety (Ohta et al., 2018).

Apathy or indifference seems to be reduced by means of the Memory Motivation (MeMo) web application (Robert et al., 2020) probably because it improves attention and motivation through its regular use. Lancioni et al. (2013) showed how musical stimulation through songs on the laptop with a microswitch increases positive participation of people with moderate and severe Alzheimer. Along the same lines, the study by Tung et al. (2014) with

Table 2. Main characteristics of the included papers: first author (year), country, sample (size, mean age, gender), diagnosis, study design and duration, questionnaires, technology used, psychological, and behavioral symptoms managed, main outcome of the intervention.

First author (year), country	SAMPLE (size, mean age, gender)	Diagnosis	Study Duration	Questionnaires and assessment	Technology description	Symptoms	Main results
Robert et al. (2020), France	N = 46; $\bar{x}$=79.4 years; 22 ♂ 24 ♀	AD	Experimental, randomized controlled study/ 12 weeks	MMSE; IQCODE; FAB; FCSRT; TMT-A; STROOP Test; DSST; NPI; AI	MeMo (Memory Motivation) is a web application for the management of cognitive and behavioral symptoms in patients with neurocognitive disorders.	Apathy	Effectiveness depends on regular use. MeMo mainly improves attention and motivation.
Bromundt et al. (2019), Switzerland	N = 20; $\bar{x}$=85.6 years; 3 ♂ 17 ♀	AD; VD; LBD; KS; PS	Experimental, non-randomized study/ 17 weeks	S-MMSE; VAS; NOSGER; ADL; CADS; CMAI; QUALID	Prototype dawn-dusk simulator (DDS), a polychromatic white lighting from light emitting diodes gradually changed illuminance. Wrist actimetry (MotionWatch8) analyzed with Sleep Analysis Software v7.23.	Sleep Mood Agitation	DDS improves mood and QoL. Significant correlations between higher QoL and better mood, greater alertness and circadian rhythm stability.
D'Onofrio et al. (2019), Italy	N = 38; $\bar{x}$=77.1 years; 14 ♂ 24 ♀	AD	Experimental, non-randomized controlled study/ 3 months	OME; MMSE; NPI; CSDD; MSPSS; RS-14; QOL-AD; TBA; CGA; CDT; FAB	MARIO project aims to manage active and healthy aging with the use of caring service robots.	Depression	MARIO may be a useful tool in mitigating depression and loneliness, while enhancing social connectedness, resilience, and QoL.
Higami et al. (2019), Japan	N = 63; $\bar{x}$=77.6 years; 24 ♂ 39 ♀	AD	Cross-sectional descriptive study/ 1 week	MMSE; CDR; NPI-NH	Non-wearable actigraphy device placed under mattresses which measures different sleep parameters.	Sleep disturbances	Frequent bed leaving at night reflects severe sleep deprivation. Safety measures are required to prevent accidents related to sleep disturbances.
Filoteo et al. (2018), United States of America	N = 14; 60 years or older	Mild to moderate AD	Experimental, non-randomized controlled study/ 1 day	ET; STAI; HADS; NQOL; MDS	ReminX a digital therapeutic software based on Reminiscence Therapy (slide stories depicting important moments in the patient's life).	Anxiety Depression Distress Anger Apathy	Less anxiety and depression reported by patients. Less emotional distress reported by patients and caregivers.

(*Continued*)

Table 2. (Continued).

First author (year), country	SAMPLE (size, mean age, gender)	Diagnosis	Study Duration	Questionnaires and assessment	Technology description	Symptoms	Main results
Lancioni et al. (2018), Italy	N = 10; $\bar{x}$=81.4 years; 4 ♂ 6 ♀	Moderate to severe AD	Experimental, non-randomized controlled study/ 94–151 sessions	MMSE	Intervention program combined the use of a walker with assistive technology fostered supported ambulation.	Ambulation	Improvement of ambulation, attention/activity and mood.
Moyle et al. (2018), Australia	N = 455; $\bar{x}$ =85.3 years; 74.33% ♀	AD; VD; FTD; LBD	Experimental, randomized controlled study/ 3 weeks	RUDAS; CMAI-SF	PARO is a therapeutic pet-type robotic seal and SenseWear® is a wearable triaxial accelerometer.	Motor activity Sleep	Changes in day and nighttime motor activity and sleep (PARO induced a reduction in day and nighttime step count and physical activity). PARO may have some effect on motor activity in long-term care, but not on sleep patterns.
Varshney et al. (2018), United States of America	N = 9; between 61–95 years; 3 ♂ 6 ♀	AD; PD; MSA	Experimental, non-randomized controlled study/ 90 days	MMSE; NPI-NH; CAM; GDS	AlzhaTV is a smartphone app that enabled family to create and upload videos to the cloud and show them on the patient's TV.	Agitation Anxiety Depression Psychosis Delirious	AlzhaTV decreases BPSD, the use of antipsychotics or benzodiazepines and overall health-care cost.
Ohta et al. (2018), Japan	N = 104; $\bar{x}$=65.3 years; 38.2% ♂	ALS; SCD + MSA; PD; MS; AD	Experimental, non-randomized controlled study/ 3 months	MMSE; AS; GDS; STAI	Telephone call system (Andes phone®) that automatically called participants at their desired times.	Apathy Depression Anxiety	Positive effect on anxiety. Apathy and depression did not improve.
Petersen et al. (2017), United States of America	N = 61; $\bar{x}$=83.4 years; 14 ♂ 47 ♀	Mild to moderate AD	Experimental, randomized controlled study/ 3 months	MMSE; RAID; CSDD; GDS	The PARO robotic pet is a Food and Drug Administration (FDA) approved biofeedback device in treating dementia- related symptoms.	Anxiety Depression Sleep Behavioral	Decreased stress, anxiety and the use of psychoactive medications and pain medications.

(*Continued*)

Table 2. (Continued).

First author (year), country	SAMPLE (size, mean age, gender)	Diagnosis	Study Duration	Questionnaires and assessment	Technology description	Symptoms	Main results
Silva et al. (2017) Portugal	N = 51; between 60–80 years	Mild EA	Experimental, randomized controlled study/ 11 sessions	MMSE; ACE-R; TELPI; CDR; GDS; IAFAI; WHOQOL-OLD	SenseCam is a wearable camera used like a passive external memory aid. Control condition: Diary	Depression	Reduced depressive symptoms. Improved perceived functional. No effects on QoL. Immediate effects were not maintained at follow-up.
Krolak-Salmon et al. (2016) France	N = 424; $\bar{x}$=84 years; 165 ♂ 259 ♀	AD	Observational cohort study/ 1 year	NPI and six additional items	MTAD is a multidisciplinary mobile team dedicated to patients with AD and BPSD.	Sleep disorder Appetite and eating abnormalities	Reduced behavioral disorders (sleep and appetite disorders, endangered situation and caregiver burnout) and hospitalizations related to them.
Jøranson et al. (2015), Norway	N = 53; $\bar{x}$=84 years; 67% ♀	Moderate to severe AD	Experimental, randomized controlled study/ 1 year	MMSE; BARS; CSDD.	PARO is a highly advanced, adaptive robot with artificial intelligence software.	Depression Agitation	Reduced symptoms of agitation and depression.
Valentí Soler et al. (2015), Spain	N = 248; $\bar{x}$=81.6 years; 71.7% ♀	EA; mixed dementia; PD; LBD; FTD	Experimental, randomized controlled study/ 3 months	GDS; S-MMSE; MMSE; NPI; APADEM-NH; AI; QUALID	Social robots: a white humanoid robot (NAO) and a pet robot with the appearance, movement and sounds of a baby seal (PARO).	Delusions Hallucinations Apathy Disinhibition Irritability/ lability Nighttime behavioral disturbances	NAO helps to improve apathy (nursing home) and irritability/ lability and to reduce delusions (day care center). PARO helps to improve nighttime behavioral disturbances and to reduce irritability/lability (nursing home) and disinhibition (vs. the dog).
Gfigueiro et al. (2014), United States of America	N = 14; $\bar{x}$=86.9 years; 5 ♂ 9 ♀	Mild to moderate AD and related dementia	Experimental, non-randomized study/ 4 weeks	MMSE; PSQI; MDS-ADL; CSDD; CMAI	Tailored lighting intervention designed to deliver circadian stimulation during daytime. Daysimeter (small device that collect light-dark and rest-activity patterns, as sleep time and sleep efficiency).	Sleep Depression Agitation	Increased sleep quality. Reduced depression and agitation.

(*Continued*)

Table 2. (Continued).

First author (year), country	SAMPLE (size, mean age, gender)	Diagnosis	Study Duration	Questionnaires and assessment	Technology description	Symptoms	Main results
Tung et al. (2014), United States of America	N = 54; $\bar{x}$=72.2 years; 52% ♀	Mild to Moderate AD	Experimental, non-randomized controlled study/ 3 days	MMSE; DAD; GDS; AES	A global positioning system (GPS) provides quantitative measurements (area, perimeter, mean distance from home, and time away from home) of global movement for patients.	Motor activity Depression Apathy	Small area, perimeter and mean distance from home correlated with physical function (steps/ day, DAD, and gait velocity), apathy and depression. GPS have may be particularly valuable to monitor functional decline in AD.
Lancioni et al. (2013), Italy	N = 10; $\bar{x}$=80 years; 2 ♂ 8 ♀	Moderate to severe AD	Experimental, non-randomized study/ 3–7 sessions per day	MMSE; HDRS; GDS	Music stimulation (songs) using a microswitch and a laptop computer.	Motor activity Apathy Depression	Increase of positive participation (singing or music-related rhythmic movements of hands, feet, or body; positive verbal comments, and smiles)
Weiner et al. (2011), United States of America	N = 85; $\bar{x}$=69.6 years; 32 ♂ 53 ♀	AD; MDI; PD; VD	Observational and descriptive study/ 5 years	MMSE; CERAD-NB; CDR; GDS; NPI-NH; CDT; TMT-A; TMT-B; LM subtest of the WMS-III; CFT; DSMT; DSST	A videoconference (VC) technology to diagnosis and treat adult members with cognitive disorders.	Depression Psychomotor activity Rapid alternating movements Tremor	Feasible alternative and well accepted face -to-face communication technology for patients who live in remote areas.

Abbreviations:

MMSE: Mini-Mental State Examination; IQCODE: Informant Questionnaire on Cognitive Decline in the Elderly; FAB: Frontal Assessment Battery; FCSRT: Free and cue selective reminding task; TMT: Trail Making Test; DSST: Digital Symbol Substitution Test; NPI: Neuropsychiatric Inventory; AI: Apathy Inventory; FAST: Functional Assessment Staging Test of Alzheimer's Disease; CMAI: Cohen-Mansfield Agitation Inventory; QUALID: Quality of Life Scale for Severe Dementia; QOL-AD: Quality of Life Alzheimer's Disease; DEMQOL: Dementia Quality of Life; EQ-5D-5 L: EuroQol-5 Dimensions, five-level version; QUIS: Quality of Interactions Schedule; AD: Alzheimer's disease; VD: Vascular dementia; LBD; Lewy-body dementia; KS; Korsakoff Syndrome; PS: Parkinson Syndrome; S-MMSE: Severe Mini-Mental State Examination; VAS: Visual Analogue Scale; NOSGER: Nurses' Observation Scale for Geriatric Patients; ADL: Activities of Daily Living; CADS: Changes in Advanced Dementia Care Scale; OME: Observational Measurement of Engagement; CSDD: Cornell Scale for Depression in Dementia; MSPSS: Multidimensional Scale of Perceived Social Support; RS-14: 14-item Resilience Scale; TBA: Tinetti Balance Assessment; CGA: Comprehensive Geriatric Assessment; CDT: Clock Drawing Test; CDR; Clinical Dementia Rating; NPI-NH: Neuropsychiatric Inventory – Nursing Home Version; ET; Emotional Thermometer; STAI: State-Trait Anxiety Inventory; HADS: Hospital Anxiety and Depression Scale; NQOL: Neuro Quality of Life in Neurological Disorder; MDS: Modified Depression Scale; CQ: Caregiver Questionnaire; HDRS: Hamilton Depression Rating Scale; FTD: Frontotemporal Dementia; RUDAS; The Rowland Universal Dementia Assessment Scale; CMAI-SF: The Cohen-Mansfield Agitation Inventory-Short Form; PD: Parkinson's disease; MSA: Multiples System Atrophy; CAM: Confusion Assessment Method; GDS: Geriatric Depression Scale; ALS: Amyotrophic Lateral Sclerosis; SCD+MSA: Spinocerebeller Degeneration + Multiple System Atrophy; MS; Multiple Sclerosis; ADc: Alzheimer's disease-caregiver; AS: Apathy Score; RAID: Rating for Anxiety in Dementia; ACE-R: Addenbrooke cognitive examination-revised; TELPI: Test de Leitura de Palavras Irrgulares; IAFAI: Adults and Older Adults Functional Assessment Inventory; WHOQOL-OLD: World Health Organization Quality of Life – Older Adults module; BARS: Brief Agitation Rating Scale; APADEM-NH: Apathy Scale for Institutionalized Patients with Dementia Nursing Home version; PSQI: Pittsburgh Sleep Quality Index; MDS-ADL: Minimum Data Set Activities of Daily Living Scale; DAD: Disability Assessment for Dementia; AES: Apathy Evaluation Scale; MDI: Mild Cognitive Impairment; CERAD-NB: Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Battery; LM subtest of the WMS-III: Logical Memory of the Wechsler Memory Scale-III; CFT: Category Fluency Test; DSMT: Digital Span Memory Test.

Table 3. Questionnaires included in the reviewed papers and organized according to assessed functions and symptoms: neuropsychological, psychological symptoms, behavioral symptoms, quality of life.

Categories		Questionnaires
Neuropsychological questionnaires		- Frontal Assessment Battery (FAB) - Free and Cue Selective Reminding Task (FCSRT) - Trail Making Test (TMT) - Digital Symbol Substitution Test (DSST) - Digital Span Memory Test (DSMT) - Clock Drawing Test (CDT) - Logic Memory of the Wechsler Memory Scale (LM subtest of WMS-III) - Category Fluency Test (CFT) - Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) - Functional Assessment Staging Test of Alzheimer's Disease (FAST) - Nurses' Observation Scale for Geriatric Patients (NOSGER) - Activities of Daily Living (ADL) - Changes in Advanced Dementia Care Scale (CADS) - Clinical Dementia Rating (CDR) - The Rowland Universal Dementia Assessment Scale (RUDAS) - Addenbrooke cognitive examination-revised (ACE-R) - Test de Leitura de Palavras Irregulares (TELPI) - Adults and Older Adults Functional Assessment Inventory (IAFAI) - Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Battery (CERAD-NB)
Psychological symptoms questionnaires	*Depression*	- Cornell Scale for Depression in Dementia (CSDD) - Hamilton Depression Rating Scale (HDRS) - Geriatric Depression Scale (GDS) - Hospital Anxiety and Depression Scale (HADS) - Modified Depression Scale (MDS)
	Anxiety	- State-Trait Anxiety Inventory (STAI) - Rating for Anxiety in Dementia (RAID) - Hospital Anxiety and Depression Scale (HADS)
	Apathy	- Apathy Inventory (AI) - Apathy Score (AS) - Apathy Evaluation Scale (AES) - Apathy Scale for Institutionalized Patients with Dementia Nursing Home version (APADEM-NH)
Behavioral symptoms questionnaires	*Sleep*	- Pittsburgh Sleep Quality Index (PSQI)
	Agitation	- Cohen-Mansfield Agitation Inventory (CMAI) - Brief Agitation Rating Scale (BARS)
	Motor activity	- Tinetti Balance Assessment (TBA)
Quality of life questionnaires		- Quality of Life Scale for Severe Dementia (QUALID) - Quality of Life Alzheimer's Disease (QOL-AD) - Dementia Quality of Life (DEMQOL) - Neuro Quality of Life in Neurological Disorder (NQOL) - World Health Organization Quality of Life-Older Adults module (WHOQOL-OLD) - EuroQol-5 Dimensions (EQ-5D-5 L)

the use of GPS, which records the subject's global movements, and the Spanish study by Valentí Soler et al. (2015) with the white humanoid social robot (NAO) demonstrated the usefulness of these applications in managing apathy.

A recent study by Bromundt et al. (2019) confirmed the positive influence of a prototype dawn-dusk simulator (DDS) and a wrist actimetry (MotionWatch8) on subjects' mood and quality of life. This solution, combined with the use of a walker with assistive technology, also benefited subjects' mood (Lancioni et al., 2018).

Table 4. Psychological and behavioral symptoms that improve with each type of technology in the included studies.

		Psychological symptoms								Behavioral symptoms						
Technology		Depression	Anxiety	Apathy/ Indiference	Mood	Stress	Delusions	Psychosis	Irritability/ Lability	Sleep disturbances	Agitation/ Agression	Psychomotor activity	Wander/ Ambulation	Desinhibition	Appetite and eating abnormalities	First author (years)
APP	MeMo			X												Robert et al. (2020)
	AlzhaTV	X	X				X	X			X					Varshney et al. (2018)
	Mario	X														D'Onofrio et al. (2019)
ROBOT	PARO	X	X			X					X					Petersen et al. (2017) Jøranson et al. (2015)
	PARO + NAO			X			X		X	X				X		Valentí Soler et al. (2015)
	PARO + Wearable Sensewear				X					X X		X				Moyle et al. (2018) Bromundt et al. (2019)
LIGHT	Dawndusk simulator + Wrist actmetry	X								X	X					**Figuero (2014)**
	Lighting intervention + Device Daysimeter															
SOFTWARE	ReminX															Gfigueiro et al. (2014)
	ReminX	X	X			X						X				Weiner et al. (2011)
VC	Video-conference	X			X								X			Lancioni et al. (2018)
AT	Assistive-technology + walker									X					X	Krolak-Salmon et al. (2016)

(*Continued*)

Table 4. (Continued).

		Psychological symptoms								Behavioral symptoms						
Technology		Depression	Anxiety	Apathy/ Indiference	Mood	Stress	Delusions	Psychosis	Irritability/ Lability	Sleep disturbances	Agitation/ Agression	Psychomotor activity	Wander/ Ambulation	Desinhibition	Appetite and eating abnormalities	First author (years)
MOBILE/ TELEPHONE	Mobile Team		X													Ohta et al. (2018)
	Telephone call system	X		X								X				Tung et al. (2014)
GPS		X														**Silva (2017)**
WEARABLE/ NO WEARABLE	Sensecam									X						Higami et al. (2019)
	Acti-graphy	X		X								X				Lancioni et al. (2013)
COMPUTER	Laptop computer (songs) + Microwitch															

Principio del formulario

Table 5. Main conclusions, implications, and recommendations based on the systematic review. Lines of future research in the topic of technology applied to people living with AD.

Main conclusions	Implications and recommendations	Future research
1. Different technologies can help people living with AD: web applications, mobile applications, robots, light-based interventions, therapeutic software, videoconferences, assistive technologies, mobile-phone, GPS, wearables, sensors, laptop computers . . .	1. Some new information and communication technologies can be considered as a threat for some jobs. However, it can be better viewed as a support to other treatments, making it easier, for family members at home and experts in different care settings, to manage neuropsychiatric symptoms. 1.2. Technological innovations can benefit people living with AD both at early and advanced stages of the disease. 1.3. The importance of technological development has been clearly demonstrated from 2020 to the present due to the COVID-19 pandemic related outbreaks. 1.4. Technology has also contributed to offer tele-health support for people experiencing cognitive changes.	1. Future lines of research are being considered in areas such as big data or artificial intelligence.
2. These non-pharmacological approaches may be useful in interventions aimed to the management and control of BPSD in people living with AD.	2. Technology offers an interesting option that can revolutionize the health care field by facilitating the management of BPSD in individuals living with dementia. 2.1. The use of questionnaires can allow to verify the effectiveness of a type of technology on BPSD. 2.3. Technological solutions can help individuals living with AD, their relatives and professionals working with them to be connected. This communication channel can also contribute to the control of symptoms in some individuals.	2. Ethical and safety issues such as data protection or security related to the use of technology in the health field are also topics of great concern
3. The symptoms that are most successfully managed by means of technological applications and devices (e.g., robots, mobile, apps, computer, software, GPS, wearables, assistive technology) are depression, sleep disorders, anxiety, apathy, motor activity and agitation.	3.Questions related to practical applications of technology need to be considered: 3.1. Practical applications of these new technologies could be associated to lower costs for the health system, higher quality of life for affected individuals and their families, and better care provided by health professionals. 3. 2. The application of technology to different health questions can bring both quantitative and qualitative benefits in the field of dementia.	3. Need scientific studies of more quality in order to generalize the optimal use of different technological devices and applications evaluating their effects with measures and instruments more objective

Emotional stress in patients with mild-to-moderate Alzheimer was managed with ReminX software based on Reminiscence Therapy (Filoteo et al., 2018). Stress levels were significantly reduced in people in moderate and severe phases of Alzheimer by approaches based on interactions with the pet robot PARO. This is a device which has been approved by the Food and Drug Administration (FDA) as a biofeedback device in treating dementia and related changes (Petersen et al., 2017).

Other type of technological solutions can also influence other manifestations such as delusions. For example, delusions and irritability decreased in people who have been shown videos on TV created by family members through the AlzhaTV mobile application. In addition, this type of device could diminish the use of antipsychotics, benzodiazepines, and overall healthcare costs (Varshney et al., 2018). In day care centers, delusions have also been shown to be reduced by using the humanoid robot (NAO) (Valentí Soler et al., 2015).

Behavioral challenges

Table 5 also shows the behavioral manifestations that have improved with various technological approaches. It also shows the type of technology and its respective study with its first author and year of publication.

Regarding the management of sleep disturbances by means of technology we have identified six studies. Gfigueiro et al. (2014) showed that the use of a tailored approach designed to deliver circadian stimulation during daytime and a Daysimeter device that collect light-dark and rest activity patterns (as sleep time and sleep efficiency) increased sleep quality of people living with mild and moderate Alzheimer. Another more recent study reported by Bromundt et al. (2019) used a prototype of DDS, which is a polychromatic white light-emitting diode illumination that changes gradually, and a wrist actimetry as well, to demonstrate positive results in alertness and circadian rhythm, as well as improvements in quality of life. In addition, robots, specifically PARO, could reduce behavioral disturbances at night. This effect was confirmed both in the study by Valentí Soler et al. (2015) and in the results reported by Moyle et al. (2018) in which the triaxial accelerometer device was also used. Lastly, the multidisciplinary mobile team dedicated to people living with Alzheimer (Krolak-Salmon et al., 2016) and the non-wearable actigraphy device which can be placed under the mattress (Higami, Yamakawa, Shigenobu, Kamide, & Makimoto, 2019) suggest how important could technological devices be in order to control the quality of sleep, avoiding risks and symptoms related to sleep disorders.

Motor activity improves with technological video conferencing. This technology seems to be useful and well accepted, especially in remote areas without easy access to health services (Weiner et al., 2011). The study with the PARO

robot and the SenseWear® also points in the same direction (Moyle et al., 2018). Other types of technology, such as GPS recording (Tung et al., 2014) and music stimulation with the laptop (Lancioni et al., 2013), could be useful since they allow quantitatively and qualitatively record the subject's movements. The agitation or aggression of the person can be reduced with the tailored lighting solution (Gfigueiro et al., 2014), the robot PARO (Jøranson et al., 2015) or the mobile application AlzhaTV (Varshney et al., 2018).

Finally, we can mention that wandering or ambulation are better controlled with the assistive technology walker (Lancioni et al., 2018), disinhibition with the pet PARO (Valentí Soler et al., 2015) and eating disorders with the mobile multidisciplinary team (Krolak-Salmon et al., 2016). These are example of how the correct use of technology can help reduce behavioral disorders and related hospitalizations.

Discussion

Based on the scientific literature to date, our objective in the current review has been to conduct a systematic review that attempted to synthesize experimental studies evaluating technological approaches aimed to the management and treatment of these challenges in individuals living with Alzheimer. Some prior reviews evaluating the use of technology in people who have dementia have been published, although the main objectives differ from those pursued in our research. For example, Husebo et al. (2020) evaluated how technology can be applied to diagnosis and early detection of Alzheimer. In other previous studies, the optimization of quality of life both in people living with dementia and their loved-ones has been evaluated (Evans et al., 2020; Sanders & Scott, 2020). For that reason, after our systematic search in different databases, we have selected those papers addressed to evaluate the use of different types of technologies that can help in the management of behavioral and psychological manifestations and support the treatment in people who have dementia.

The main results of the systematic review and analysis we have performed on the total of papers selected for the current study (n = 18) led to some results. For example, it has become clear that very different technologies can be used in people living with dementia Alzheimer: web applications (Robert et al., 2020), mobile applications (Varshney et al., 2018), robots (D'Onofrio et al., 2019; Jøranson et al., 2015; Moyle et al., 2018; Petersen et al., 2017; Valentí Soler et al., 2015), light-based solution (Bromundt et al., 2019; Gfigueiro et al., 2014), digital therapeutic software (Filoteo et al., 2018), videoconferences (Weiner et al., 2011), assistive technologies (Lancioni et al., 2018), mobile-phone (Krolak-Salmon et al., 2016; Ohta et al., 2018), GPS (Tung et al., 2014), wearables (Higami et al., 2019; Silva et al., 2017) or laptop computer (Lancioni et al., 2013) (Table 4). The revised data also lead us to suggest that the application of technology to different health questions can bring both

quantitative and qualitative benefits in the field of dementia. Thus, the application of this technology could be associated to lower cost for the health system, higher quality of life for the persons who have Alzheimer and their families, and better care provided by health professionals. Although some authors have suggested that the new information and communication technologies can be considered as a threat for some jobs (Boyd & Holton, 2018; Cook & Cook, 2020; Zeng, Chen, & Lew, 2020), the present review and other currently published papers (Cammisuli et al., 2022; Stroud et al., 2019) suggest that it can be better viewed as a complement or support to other treatments, making it easier for family members at home and experts in care settings (day centers, nursing homes, hospitals, or clinics) to manage neuropsychiatric symptoms.

In the current review, studies evaluating technologies supporting cognitive training (Cheung & Peri, 2021; El Haj, Gallouj, & Antoine, 2017; Garlinghouse et al., 2018; Klaming, Robbemond, Lemmens, & Hart, 2022) or those that use technologies only for supporting caregivers or loved ones of people living with dementia (Shaw, Williams, Perkhounkova, Hein, & Coleman, 2020; Sikder et al., 2019) were not included, although interesting applications in these areas have also been published.

In Spain, for example, life expectancy is one of the highest in the world and the cost of dementia reaches 24 billion euros annually including the direct costs of medical and professional care and the indirect costs for loved ones and family members who have to modify their working life (Serrano Selva & Gatz, 2020). Therefore, an appropriate approach to this issue could contribute to avoid or reduce polypharmacy in this population allowing a more holistic and individualized program that integrates pharmacological and non-pharmacological treatments (Goodall, Taraldsen, & Serrano, 2021; Jia et al., 2021). Currently, technology offers an interesting option that can revolutionize the health field by facilitating the management of behavioral and psychological challenges in people living with Alzheimer. However, as some authors have recently suggested, we need higher quality scientific articles in order to generalize the optimal use of different technological devices and applications evaluating their effects with more objective measures and instruments (Sánchez-Gutiérrez et al., 2019), as well as more studies on the technology acceptance by older people and professionals (Özsungur, 2022).

Results of the search performed in different databases indicated that countries such as the United States, Italy, France, and Japan stand out for their exponential publication in the area of health-related technology, but only Japan is considered as a "super-aging" society. Moreover, this country is in a privileged position and could be an example to the rest of the world in terms of developing care pilot projects, policies, and the use of new technologies to support aging and dementia (Leroi, Kitagawa, Vatter, & Sugihara, 2018). Although the present review has been focused on Alzheimer, there are several

technologies such as the PARO robot (Jøranson et al., 2015; Moyle et al., 2018; Valentí Soler et al., 2015) and the AlzhaTV mobile application (Varshney et al., 2018) that may be useful in frontotemporal dementia to manage some typical behavioral manifestations such as disinhibition and agitation. In fact, behavioral and psychological challenges are more common in the more advanced stages of dementia, but the technology can benefit people with dementia both at early (Filoteo et al., 2018; Gfigueiro et al., 2014; Petersen et al., 2017; Silva et al., 2017; Tung et al., 2014) and at advanced stages (Lancioni et al., 2013, 2018). More studies are needed in order to extrapolate results obtained in people who have Alzheimer to other types of dementia.

Regarding the gender of the participants in the studies reviewed, many of them include both male and female participants, although the percentage of female was greater in a majority of studies. It is also important to note that gender comparisons regarding effectiveness of technology for managing Alzheimer challenges have not been carried out systematically. In the current scientific literature, there is still a gap in our understanding of the role of biological sex in neurodegenerative diseases (Alzheimer's Association, 2016). In addition, women live longer than men and that represents a risk factor for these diseases. It has been suggested that it is important to continue basic research on the biology of aging, because it will allow to face age-related diseases better (National Institute on Aging, n.d.-a). Alzheimer is often diagnosed at later stages because factors such as education or higher verbal memory, which is better in women, make early detection less likely in this group (Duarte-Guterman et al., 2019). Therefore, more studies with female samples are needed since research and clinical trials indicate that Alzheimer is more common in women.

The present review covers mainly experimental articles whose dependent variable is technology and the independent variables are neuropsychological symptoms. The use of questionnaires allowed to verify the effectiveness of a type of technology on subjects' behavioral changes. The comparison between data obtained from the studies reviewed here suggest that the most improved manifestations are depression (D'Onofrio et al., 2019; Gfigueiro et al., 2014; Jøranson et al., 2015; Lancioni et al., 2013; Silva et al., 2017; Tung et al., 2014; Varshney et al., 2018; Weiner et al., 2011), sleep disorders (Bromundt et al., 2019; Gfigueiro et al., 2014; Higami et al., 2019; Krolak-Salmon et al., 2016; Moyle et al., 2018; Valentí Soler et al., 2015), anxiety (Filoteo et al., 2018; Ohta et al., 2018; Petersen et al., 2017; Varshney et al., 2018), apathy (Lancioni et al., 2013; Robert et al., 2020; Tung et al., 2014; Valentí Soler et al., 2015), motor activity (Lancioni et al., 2013; Moyle et al., 2018; Tung et al., 2014; Weiner et al., 2011) and agitation (Gfigueiro et al., 2014; Jøranson et al., 2015; Varshney et al., 2018).

Our review helps to highlight new approaches that can be used supporting behavioral and psychological challenges in addition to other non-

pharmacological interventions previously described in the literature, such as patient-, caregiver-, or environment-centered interventions, structured activities or interventions aimed to identify and eliminate triggers of these symptoms (Mendez, 2022; Park & Cohen, 2019). Some of the recent approaches for supporting behavioral and psychological manifestations in people living with dementia include social interventions (Mabire, Gay, Charras, & Vernooij-Dassen, 2022), art-therapy (Shoesmith, Charura, & Surr, 2022) or participation in choirs (Thompson, Tamplin, Clark, & Baker, 2022).

The importance of technological development has been clearly demonstrated at the present year 2020 due to the COVID-19 pandemic. The interaction between humans and robots helped to manage the spread of COVID-19 in health-care environments (Zeng et al., 2020). Technology has also contributed to offer tele-health support to people who have dementia (Goodman-Casanova, Durá-Pérez, Guzmán-Parra, Cuesta-Vargas, & Mayoral-Cleries, 2020). Therefore, these are clear examples where technology helped persons living with dementia, family members, and experts to be connected and it has also contributed to the control of behavioral and psychological challenges in some persons (Bartmess et al., 2022).

Limitations

Our findings have some limitations and must be interpreted in that context. During the review process, we recognized that the MESH terms synonymous with "Alzheimer's disease," "Behavioural and psychological symptoms of dementia" and "Technology" probably did not cover the whole range of interesting topics for the systematic review. Furthermore, the present review covers a limited number of preliminary articles whose sample and duration are relatively reduced. This limited number of studies with technological approaches suggests that the grounds for innovation, validation and clinical transfer of technology in the management of psychological and behavioral challenges are promising (Husebo et al., 2020). For their use to be widespread, they must include security and privacy of data as well as ethical issues. Therefore, the present review points to a future perspective that needs to be worked on (Table 6). This type of studies can contribute to a better treatment of behavioral and psychological challenges, supporting the work performed by professionals in assisted living homes, caregivers, and clinicians (Davalos et al., 2022).

Conclusions

Overall, our systematic review shows that the technologies identified in the search performed in different databases suggest that this non-pharmacological approach may be useful in projects aimed to the management and control of behavioral and psychological challenges in people living with Alzheimer. The

Table 6. Main conclusions, implications, and recommendations based on the systematic review. Lines of future research in the topic of technology applied to people living with AD.

Main conclusions	Implications and recommendations	Future research
1. Different technologies can help people living with AD: web applications, mobile applications, robots, light-based interventions, therapeutic software, videoconferences, assistive technologies, mobile-phone, GPS, wearables, sensors, laptop computers . . .	1. Some new information and communication technologies can be considered as a threat for some jobs. However, it can be better viewed as a support to other treatments, making it easier, for family members at home and experts in different care settings, to manage neuropsychiatric symptoms. 1.2. Technological innovations can benefit people living with AD both at early and advanced stages of the disease. 1.3. The importance of technological development has been clearly demonstrated from 2020 to the present due to the COVID-19 pandemic related outbreaks. 1.4. Technology has also contributed to offer tele-health support for people experiencing cognitive changes.	1. Future lines of research are being considered in areas such as big data or artificial intelligence.
2. These non-pharmacological approaches may be useful in interventions aimed to the management and control of BPSD in people living with AD.	2. Technology offers an interesting option that can revolutionize the health care field by facilitating the management of BPSD in individuals living with dementia. 2.1. The use of questionnaires can allow to verify the effectiveness of a type of technology on BPSD. 2.3. Technological solutions can help individuals living with AD, their relatives and professionals working with them to be connected. This communication channel can also contribute to the control of symptoms in some individuals.	2. Ethical and safety issues such as data protection or security related to the use of technology in the health field are also topics of great concern
3. The symptoms that are most successfully managed by means of technological applications and devices (e.g., robots, mobile, apps, computer, software, GPS, wearables, assistive technology) are depression, sleep disorders, anxiety, apathy, motor activity and agitation.	3.Questions related to practical applications of technology need to be considered: 3.1. Practical applications of these new technologies could be associated to lower costs for the health system, higher quality of life for affected individuals and their families, and better care provided by health professionals. 3. 2. The application of technology to different health questions can bring both quantitative and qualitative benefits in the field of dementia.	3. Need of higher quality scientific studies in order to generalize the optimal use of different technological devices and applications evaluating their effects with measures and instruments more objective

(*Continued*)

Table 6. (Continued).

Main conclusions	Implications and recommendations	Future research
4. It is also important to note that gender comparisons regarding effectiveness of technology for managing AD symptoms have not been carried out systematically.	4. In the current scientific literature there is still a gap in our understanding how biological sex impact in neurodegenerative diseases and their consequences.	4. It is important to continue basic research on the biology of aging since it will allow us better to cope with age-related diseases such as dementia. More studies with female samples are needed since research and clinical trials indicate that AD is more common in women

challenges that are most successfully managed by means of technological applications and devices (e.g., robots, mobile, apps, computer, software, GPS, wearables, assistive technology) are depression, sleep disorders, anxiety, apathy, motor activity, and agitation. Future lines of research are being considered in areas such as big data or artificial intelligence. Ethical and safety issues, such as data protection, related to the use of technology in the health field are also topics of great concern.

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