

SYSTEMATIC REVIEW

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# Emerging technologies and vulnerabilities in older adults with cognitive impairments: a systematic review of qualitative evidence

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## Abstract

**Background** Recently, a vast amount of both theoretical and empirical literature has appeared, exploring the ethical implications of emerging technologies (ET) in the context of daily management and care of (frail) older adults. However, to the best of our knowledge, no comprehensive research has been carried out over the impact of ET on older adults' vulnerability, focusing on older adults with cognitive impairments, who are the main beneficiaries of ET.

**Research aim** This work aims to investigate the ethically-related impact of ET, in particular exploring the impact of ET on cognitively-impaired older adults' vulnerabilities.

**Methods** Using the PRISMA procedure, we conducted a systematic review of empirical (qualitative) evidence exploring the relationship between ET and older adults' vulnerabilities as perceived by older adults with cognitive impairments. Five major databases (Pubmed, Embase, Web of Science, CINAHL and Philosopher's Index) were queried, covering biomedical, philosophical, bioethical, and anthropological literature. 11.631 results were obtained. After duplicates were eliminated, titles, abstracts, and full texts of identified papers were screened for relevance. Eventually, 51 articles were included. Data analysis and synthesis followed the preparatory steps of the coding process detailed in the QUAGOL methodology.

**Results** ET seem to act in a twofold manner, taming some already existing vulnerabilities, and, at the same time, worsening already existing – or creating new – vulnerabilities. As an example, some Unconventional Monitoring Techniques (e.g., wearables) tame “physical vulnerability”, by providing a sense of safety and constant monitoring, but threat “psychological vulnerability”, causing frustration related to inherent technology's limitations and to a lack of familiarity with the technology itself.

**Conclusions** This systematic study significantly contributes to enriching the ethical debate on the use of technology for the care and assistance of older adults. It shows that, if properly implemented and used, ET can be helpful in taming some dimensions of older adults' vulnerability, thus contributing to active ageing and/or the containment of physical and psychological deterioration. However, technologies alone cannot mitigate vulnerability in all its dimensions. Indeed, some of these dimensions involve more complex and multi-layered phenomena, thus requiring authentic human intervention and, in some cases, socio-political measures.

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**Keywords** Aged care, Emerging technologies, Ethical issues, Older adults, Vulnerability

## Background

Aged care has become a critical priority for health and social systems worldwide, requiring innovative and sustainable solutions to address the growing complexity of care needs [1, 2]. Existing healthcare and assistance services must be adapted to meet evolving societal expectations regarding accessibility and delivery modalities [2]. This challenge has been further exacerbated by the financial crisis of recent years [3], which have led to a persistent shortage of economic resources, traditionally allocated to this sector. Given the growing number of older adults, particularly those with chronic conditions, and the socio-economic constraints societies are confronting with, it is imperative to identify models of aged care and assistance that are both economically viable and sustainable.

In response to these pressures, many stakeholders have increasingly turned to technology as a means of innovating conventional care systems and promoting healthy, independent ageing [3]. Technological solutions also offer the potential to shift the prevailing care paradigm from a “reactive” model, focused on disease management, to a “proactive” approach, emphasising chronic disease prevention [3]. This transition aligns with the principles of predictive, preventive and personalized medicine (PPPM – 3PM) in aged care [4].

Consequently, technological approaches have been introduced as tools to address the needs of ageing populations [5–9]. A wide array of technologies specifically designed for older adults have emerged on the market [10]. Most of these are classified as Emerging Technologies (ET). An emerging technology is defined as a “radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s)” [11]. These include Conventional Monitoring Techniques (CMT), which enable continuous observation of older adults physiological and physical conditions through traditional devices, such as the oximeter integrated within technological platforms [10, 12–14]; Unconventional Monitoring Techniques (UNMT), which employ pervasive body and environmental sensors, such as Ambient Intelligence systems [15, 16]; Virtual Reality Techniques (VRT), which use headsets to create 3D environments in which older adults are ‘immersed’ [17, 18]; and Socially Assistive Robots (SAR), designed to provide assistance to older people, primarily through social or physical interaction [19, 20].

Despite their differences, ET are introducing new forms of assistance, contributing to the construction of

innovative models of long-term care [9, 15, 16, 21]. These technologies have undoubtedly brought significant benefits to the care and assistance of older adults, widely emphasized by companies, research centres, and academics as well [10]. However, it is essential to consider potential threats, critical aspects and ethical challenges, associated with their implementation.

This issue becomes particularly relevant in case of older adults with cognitive impairments, who not only represent an extremely vulnerable population but also appear to be among the primary recipients of ET [22–24]. In the near future, neurological, neuropsychiatric and neurodegenerative diseases are expected to rank among the most socially and economically devastating disorders [4, p. 6], making older adults with cognitive impairments one of the largest patient cohorts. This scenario will predictably require targeted interventions in terms of care and assistance, as well as the integration of new technological tools.

Nevertheless, the presence of clinically significant cognitive impairments, which can affect memory, language, executive function, psychomotor speed, and other domains, creates extraordinary vulnerabilities that may be so pervasive to impact older adults in their entirety [25].

Insofar as older adults with cognitive impairments represent an extremely vulnerable population [26], ET devised for, and employed in contexts inhabited by, older adults with cognitive impairments may generate ethical challenges even more critical than those already affecting the older population in general. Commonly reported concerns include issues related to safety, (in)dependence, privacy, connectedness, cost and efficiency [10].

Within bioethics, at the academic level, these concerns are often discussed under the notion of “ethically-related impact” or “ethically-related contents”, in relation to ET [24, p. 5]. This expression refers to considerations framed within established ethical approaches (e.g., principlism, relational care ethics).

This paper aims to examine the ethical impact of ET, highlighting in particular the connection between these devices and the older adults’ vulnerability. Accordingly, the research question this work aims to provide an answer to is the following: what is the ethically-related impact of ET on older adults’ vulnerabilities, particularly among those with cognitive impairments?

## Working hypothesis and theoretical framework

Several studies have examined the impact of ET on older adults, both through quantitative and qualitative approaches, with particular attention to ethical

challenges [27–29]. Among them, some studies have explored the perspectives of older adults with cognitive impairments regarding ET and their ethical implications [30, 31], while others have investigated the impact of ET, especially SAR, on older adults with dementia or Alzheimer’s disease through quantitative methods (e.g., surveys or randomized control trials), indirectly addressing issues such as independence, trust in technology, affection and social responses [32–34].

To date, however, no study offers a systematic overview of qualitative evidence on the attitudes and experiences of older adults with cognitive impairments toward ET in its various forms, from robots to monitoring techniques, and their ethically-related impact, particularly in relation to vulnerability. This work addresses this gap, by mapping existing qualitative evidence and examining aspects *at the intersection of ET and older adults’ vulnerability*, a perspective largely undertheorized within the broader bioethical debate.

To assess the ethically-related impact of ET, despite not applying a unique pre-conceived ethical framework, we adopted a top-down approach grounded in relational care ethics, which emphasises the moral significance of (care) relationships and dependencies in human life. This approach was operationalised in a dignity enhancing model of care [25] where not only dignity but also vulnerability play a central role [26].

As to vulnerability, we adopted a taxonomy identifying six dimensions of older adults’ vulnerability: physical; psychological; relational/interpersonal; moral; sociocultural, political, and economic; and existential/spiritual [26]. *Physical vulnerability* refers to the physiological as well as pathological bodily deteriorations which tend to disproportionately affect older adults. *Psychological vulnerability* includes both psychological and experiential components, provided they influence mental well-being. *Relational/interpersonal vulnerability* concerns the ontological interdependence of the human nature, and the relationships of dependence characterizing the ageing condition in real-world settings. *Moral vulnerability* has a dual meaning: positively, it promotes care for older adults’ dignity, respect for their acquired wisdom, and attention to their moral preferences; negatively, it signals risks of infantilization, depersonalization, and stigmatization. *Sociocultural, political, and economic vulnerabilities* share the conviction that vulnerability should be mainly interpreted as a situational phenomenon, i.e., a condition deriving from unfair situational contingent (sociocultural, political, and economic) factors. Finally, *existential/spiritual vulnerability* relates to existential and/or spiritual conditions that quintessentially characterize human beings while appearing further increased in the ageing condition, e.g., older adults more vividly experience human finitude and disruption of everyday competences.

This taxonomy guided the presentation of ethically-related results, enabling a more analytical understanding of the relationship between existing or potential vulnerabilities and ET designed for older adults with cognitive impairments.

Additionally, a bottom-up approach was applied to capture themes emerging from the literature, such as usability, which recurrently appeared in our selected articles, while not belonging to any of the aforementioned approaches and/or dimensions.

Methods

In order to gain a comprehensive overview of the perceptions and experiences of older adults with cognitive impairments with respect to their vulnerabilities in the context of ET, we conducted a systematic review of qualitative evidence, the latter defined as methodologically rigorous reviews presenting an up-to-date comprehensive overview of qualitative studies (i.e., interviews, focus groups, observations).

Literature search

The research question reported in the Background section was formulated according to three groups of concepts we devised to organise our literature search (Table 1).

These structures progressively narrowed the selection to publications relevant to our research question. Group 1 concepts targeted papers involving the specific population under investigation, i.e., older adults with cognitive impairments. Group 2 concepts focused on the specific domain under investigation, namely, the use of ET. Group 3 restricted the search to papers addressing vulnerability and/or akin concepts, i.e., frailty; fragility; frailness; acceptance; attitude; concerns; discomfort; distress; ethical issues; ethics. As previously noted, the concept

Table 1 Groups of organising concepts for searching the literature and their associated database search terms

| Group 1:<br>Population                                                                                                                                                                  | Group 2: Technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Group 3:<br>Vulnerability                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Dementia;<br>aged; aging;<br>elder; elderly;<br>older people;<br>older adult;<br>older person*;<br>old people;<br>old adult;<br>aged care;<br>geriatrics;<br>older user;<br>Alzheimer’s | Assistive technologies; converging technologies; digital technologies; emerging technologies; health technologies; innovative technologies; new technologies; robotic technologies; telehealth technologies; robots; robotics; assistive robots; companion robots; domestic robots; social robots; social service robots; internet of things; domotics; smart home; wearables; wearable devices; ambient intelligence; information and communication technologies; care technologies; tracking devices; surveillance technologies; telecare; remote monitoring technologies; digital platforms; virtual reality | Vulnerability;<br>frailty; fragility; frailness;<br>acceptance;<br>attitude;<br>concerns;<br>discomfort;<br>distress;<br>ethical issues; ethics |

of vulnerability in the context of aging carries a specific meaning, reflected in the six dimensions we refer to as background paradigm. However, it also intercepts other facets of the condition and lifeworld of the older adults, such as physical and psychological-cognitive fragility, and problematic socio-economic situations. This means that, although some papers may refer, in the content of their reflections, to vulnerability, they may nonetheless use a different framing or different expressions to refer to it. Similarly, keywords ‘acceptance,’ ‘attitude,’ ‘concerns,’ were included because, in qualitative studies with older adults, ethical issues – and their connection with vulnerability – are rarely presented explicitly. Instead, they are often inferred from broad questions posed to participants, who are usually asked simpler questions concerning their adoption of ET, their concerns, perceived advantages and disadvantages, usability, and related aspects.

Each group of concepts was expressed in specific database search terms, in a suitable format for the different database queries (Additional File 1). Search strings were developed by the first author (VS) in consultation with the second and last authors (AF and CG).

Five major databases were queried: Pubmed®, Web of Science™, Embase®, CINAHL, and Philosopher’s Index. These databases, as a group, cover literature pertaining to the fields of biomedicine, bioethics, philosophy, and medical anthropology.

The database search was conducted on March 1st, 2022, using language filters to identify only articles published in English. No time filter was applied, as the intent was to identify all studies ever published since the emergence of ET. Additional File 1 presents the number of results returned using the search terms. We used End-Note™ (version X9, Clarivate Analytics, Philadelphia, PA, USA) reference library software to organise citations of the identified papers; duplicates were manually deleted.

**Inclusion and exclusion criteria**

The first (VS) and second (AF) author independently screened the titles, abstracts, and full texts of identified papers, according to a predefined set of inclusion and exclusion criteria (Table 2). To be included in our systematic review and appraisal, candidate publications had to meet all inclusion criteria and had to have no exclusionary ones. Screening of the publications was not limited by publication date.

Abstract screening was performed independently by the first (VS) and second (AF) author to assess whether selection criteria were applied consistently. For 87% of the abstracts (3.077 of 3.526), the authors agreed on the items to be included or excluded. For the questionable abstracts (13%, corresponding to 449 papers), the first two authors discussed the candidate abstract until agreement was reached. If the full text of an article was not

**Table 2** Inclusion and exclusion criteria

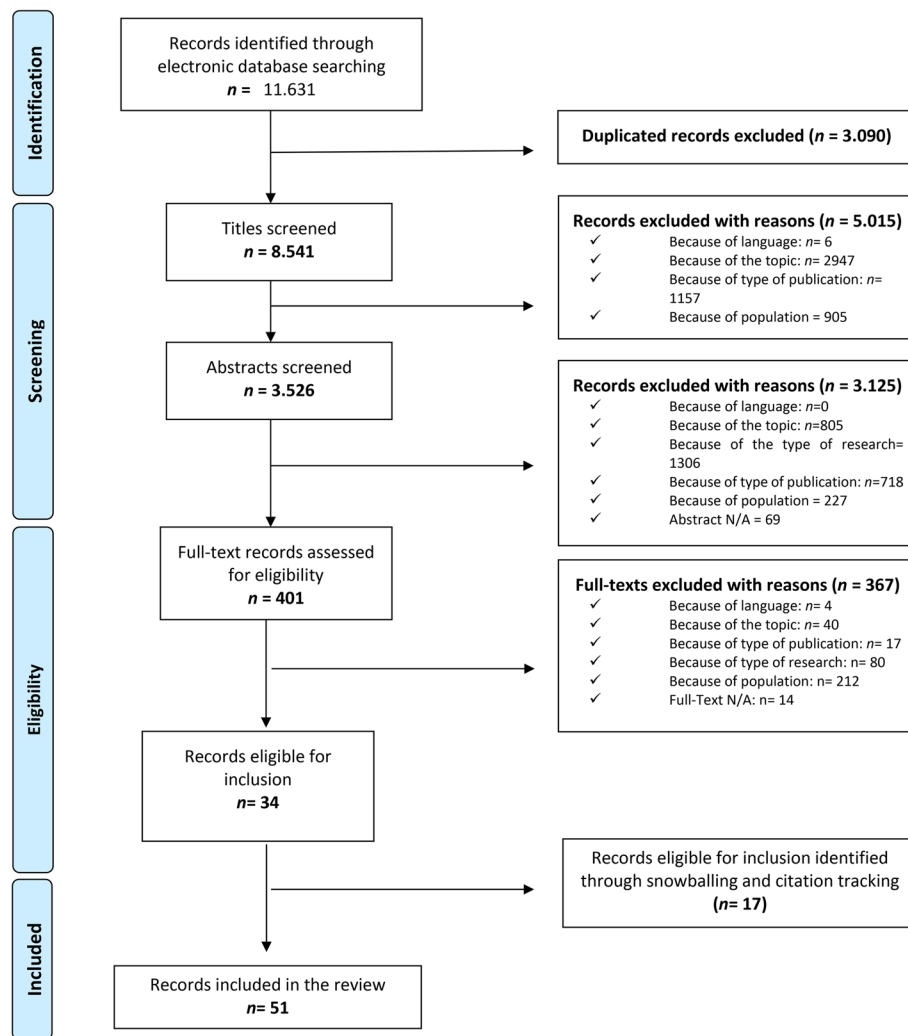
|                                | INCLUDED                                                                                                                                 | EXCLUDED                                                                                                                                                                                                                                                                                                    |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Types                          | Publication is considered to be a journal article reporting on primary, empirical research using a qualitative or mixed-method approach* | Editorials, book chapters, position papers, guidelines, reviews, protocols, ethics policies, and ethics codes, theoretical works of argument-based literature (i.e., an article using ethical concepts derived from current or traditional ethical theories in order to argue for a position or conclusion) |
| Topic                          | Use of the concept of vulnerability and/or related concepts (i.e., frailty, frailness, fragility), in relation to Emerging Technologies  | The concept of vulnerability and/or akin concepts is not significantly used and/or is not used in relation to Emerging Technologies, and/or it is used in a purely medical sense                                                                                                                            |
| Population and research domain | Application to the specific field of aged care (broadly understood), with specific focus on older adults with cognitive impairments      | Reference to fields other than aged care (e.g., research ethics), and/or target population not represented by older adults with cognitive impairments                                                                                                                                                       |
| Language                       | Publication must be in English                                                                                                           | Publications in languages other than English                                                                                                                                                                                                                                                                |

\* We chose to include qualitative studies featuring interviews and/or focus groups and/or observations. This choice reflects the intent to include all studies in which the older adults were given a voice, in a broad sense, i.e. through both direct (i.e., interviews and focus groups) and indirect methods (observations). The latter is in fact a fundamental method of data collection, used in ethnography, anthropology and health research, and it allows to collect qualitative data by observing subjects in their environment, revealing patterns of behavior and attitudes, especially informal and unspoken ones. This method has the advantage of circumventing a recurring problem: the fact that “we cannot be sure that what people say they do is what they actually do” [35, p. 67]. We excluded papers where older adults were not participating in

available, we emailed the first or corresponding author of that article to request a PDF copy. We also used the snowball technique and citation tracking to identify additional potentially relevant publications. Our search process was performed according to the statement and flowchart of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), as reported in Fig. 1, which shows electronic database search, publication identification, and selection process for the included articles.

**Quality appraisal**

The publications that met the inclusion criteria described above were assessed for their quality by using the CASP Qualitative Studies Checklist. The second (AF) and third (GB) author independently assessed the full-text publications and then compared their assessments. When disagreements arose, assessments were discussed until consensus was reached. With quality appraisal, the authors intended to identify studies of high, medium, and low methodological quality. No studies were excluded based on methodological quality.



**Fig. 1** PRISMA Flowchart of pre-screening and screening process

### Data extraction and synthesis

Data extraction and analysis adhered to the five preparatory steps detailed in the Qualitative Analysis Guide of Leuven (QUAGOL) [36, 37]. First, all the included publications were read and reread several times by the first author (VS), highlighting the relevant parts and the main perceptions described. Ethically-related content was identified based on themes and concepts present in a previously completed review of argument-based ethics literature [26] and those stemming from the relational care ethics approach as operationalized in the dignity-enhancing care model of bioethics [25, 38] (for a detailed explanation of this expression see Results, Section: “Ethics-Related Analysis”). Second, the first author (VS) together with the second author (AF) developed a narrative summary of these highlighted parts. Third, for each publication, a conceptual scheme was created. The conceptual scheme is a synthetic framework in

which different concepts deemed relevant to answer the research questions are presented. An example of a conceptual scheme is presented in Additional file 2. Each conceptual scheme was analysed separately by the first (VS), second (AF) and last (CG) author to verify that it accurately characterised each included publication. All the authors discussed conceptual schemes until they agreed on their adequate content. Fourth, these individual conceptual schemes were compared, with the aim of uncovering relationships that could produce an overall answer to our research question. This resulted in a comprehensive scheme that summarised the ethically-related impact of ET on older adults’ vulnerabilities, as gleaned from attitudes and experiences of the older adults. This scheme was iteratively evaluated and checked against previous QUAGOL steps to ensure that it adequately reflected the included papers. Finally, we synthesised a description of these results.



## Results

### General description of included publications

Fifty-one publications met our inclusion criteria and were therefore included in the review (Table 3). The description of the characteristics of included publications is reported in both Tables 3 and 4.

Publication dates range from 2007 to 2022, with seventeen articles published between 2020 and 2022.

Studies from the USA, Europe, Australia-Oceania and Asia are represented. However, the vast majority of papers results from studies conducted in Europe ( $N=35$ ).

Most papers ( $N=34$ ) focus on older adults with dementia, understood in a broad sense or with specific well-defined causes. The rest of the publications deal with older adults with Alzheimer's Disease and/or Mild Cognitive Impairment, and/or other types of cognitive impairment.

As to the type of ET, in our review, twenty-three papers focus on UNMT. In this review, UNMT mostly refer to sensors, especially environmental sensors [31, 47, 52–55, 66, 69] and wearable devices [39, 49, 51, 53, 54, 62, 65, 77, 79]. As to the former, these include motion sensors and contact sensors [47]; home-leaving sensors [31]; door and window sensors [31, 52, 54, 55, 66]; smoke and/or water leak sensors [31, 52, 55, 66, 69]; motion-based bed sensors [31, 54, 55, 69]. Such devices, such as the TECH@HOME technology kit [31], are used to detect bed occupancy, falls, entry and exit through doorways and to detect emergencies. As to wearables, the collected studies deal, for the most part, with fitness trackers, GPS trackers and smartwatches [39, 49, 62, 65, 66, 74, 77, 79]. These ET, e.g., GENEactiv Original [49], are useful to monitor physiological signs, measure steps, sleep and heart rate variability and respiration, and to detect physical activity and sedentary time.

SAR are also extensively employed, appearing in twenty-one papers. Within the SAR group, the most studied robot is PARO [44, 58, 59, 71, 73, 80, 81], the robot seal, which can communicate and/or act as a companion. Humanoid robots [30, 70, 83, 86], e.g., Pepper [30], are often represented in our review as well. These are endowed with different functionalities, including face-recognition, emotion-recognition, speech recognition, dialogue abilities and capability of interacting. Other robots, e.g., BOMY [50], give reminders of daily activities and deliver cognitive stimulation games.

In fourteen papers, the technology studied belongs to the CMT category. Here we mainly refer to ICT technologies (e.g., computers, smart phones, tablets) [14, 39, 41, 62, 63, 68, 79]. These ET are used in association with health care, in order to provide mobile self-care systems, which enable older adults to monitor their health data and to communicate and interact remotely. In the

collected studies, these technologies are often called “assistive” or “everyday” technologies.

Finally, only one study focuses on VRT [67]. Here the specific VRT, the “Virtual Reality Forest”, employs video game technology, involving vivid graphics and motion sensors, to create an interactive and immersive environment.

### Methodological quality

Table 5 addresses the quality of the included studies and reports the results of the evaluation performed. For thirty-four studies, the quality was deemed high; as for the remaining seventeen studies, the quality was deemed moderate.

Regarding the methodologies adopted, all the included studies were conducted by following an appropriate methodology. Every publication contained a clear statement of the aims, and the findings were also clearly reported.

The ethical issues have been taken into consideration in the majority of papers; ethical approval from ethics committees and informed consent from participants were obtained.

The recruitment strategies were appropriate in forty studies; the data analysis was rigorous in forty studies as well.

Nevertheless, in only seven studies researchers made some considerations on their own role, potential biases, and reactions to events, as well as on the implications of possible changes in the study design.

### Ethics-related analysis

As reported above (see Background), in presenting our ethics-related results we have adopted a two-fold strategy, both top-down and bottom-up, where a taxonomy constituted of six dimensions of older adults' vulnerability plays as fundamental conceptual framework.

In what follows, we will first analyse the impact of ET for each specific dimension of older adults' vulnerability, starting from the most recurrent to the less recurrent ones. Then, we will report an additional element that have shown to have an influence on vulnerability, which nonetheless did not appear in the original conceptual framework. A summary of ethics-related results is reported in Tables 6 and 7.

### Psychological vulnerability

Psychological vulnerability (PV) appears in 43 out of the 51 publications included in the review, therefore being the most recurrent vulnerability identified by older adults with cognitive impairments. In our taxonomy of older adults' vulnerabilities, PV was defined as an umbrella term, referring to both cognitive and emotional components impacting on older adults' psychological sphere.

**Table 3** List of included publications

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                    | Design/methodology                                                                                | Participants                                                                                                                                                                                                                                                                       | Emerging Technologies                                                                                                                                                                                             |
|----|-----------------------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Albers Elizabeth A. (2022) [39]   | USA                    | To investigate how and why some people with memory concerns and their caregivers living in the community changed their mainstream and assistive technology use to adapt to isolation during the COVID-19 pandemic in the United States | Explorative qualitative approach using semi-structured interviews. Qualitative thematic analysis. | 20 older adults (OAs) and their caregivers<br>OAs' age: 57–88 (median = 74.75)<br>OAs are people with memory concerns i.e., individuals diagnosed with cognitive impairment or Alzheimer disease or related dementia                                                               | UNMT: mainstream technologies and assistive technologies, such as fitness trackers, smartwatches, GPS trackers, pill dispensers<br>CMT: mainstream technologies such as smartphones, tablets, computers, smart TV |
| 40 | Bäckman Charlotte (2020) [40]     | Sweden                 | To explore expectations and user experiences of older adults and caregivers regarding a robotic shower                                                                                                                                 | Explorative qualitative approach using interviews.                                                | 7 OAs and 7 personnel.<br>OAs' age: age range 58–82<br>OAs are people with cognitive impairments (e.g., dementia)                                                                                                                                                                  | UNMT: Poseidon<br>A robotic shower with emergency alarm                                                                                                                                                           |
| 30 | Betrian Feni (2021) [30]          | Japan                  | To explore the interactions between healthcare robots and older adults in two institutions                                                                                                                                             | Qualitative descriptive analysis study using simultaneous observations. Content analysis.         | 23 OAs<br>OAs' age is not defined, but they are always labelled as "older people"<br>OAs are people with "dementia", defined through Hasegawa's Dementia Scale-Revised (HDS-R) (20–15 points: Mild; 14–10 points: Moderate, 9–5 points: Moderately Severe; below 5 points: Severe) | SAR: Pepper<br>A humanoid social robot, that can recognize faces and basic human emotions It can engage with people through conversation, and it is able to inform and entertain people                           |
| 41 | Block Marije (2020) [41]          | The Netherlands        | To explore OAs' use of Information and Communication Technologies (ICTs) from a social and emotional perspective, analysing barriers and benefits in ICT use                                                                           | Explorative qualitative approach using semi-structured interviews.                                | 11 OAs, 11 informal caregivers, 8 third persons and 5 professional caregivers<br>OAs' age: 58–93<br>OAs are people with cognitive impairments due to vascular dementia, Alzheimer's disease, Lewy Body dementia, and Mild Cognitive Impairment                                     | CMT: ICTs, such as telephone, smart TV and tablet, desktops and laptops                                                                                                                                           |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                                                   | Design/methodology                                                                                                                                       | Participants                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                      |
|----|-----------------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 42 | Cahill Suzanne Mary (2007) [42]   | Ireland                | To evaluate the use and usefulness of assistive technologies                                                                                                                                                                                                          | Mixed methods approach: a quantitative approach using comprehensive semi-structured questionnaires and a qualitative approach using in-depth interviews. | 20 OAs and 20 caregivers<br>OAs' age: 60+ (mean age 72 (M) 74 (F))<br>OAs have Alzheimer's disease, vascular dementia and mixed dementia (Alzheimer and vascular dementia)                                                                                                                                                                                                                                                                                                                            | CMT: assistive technologies<br>The automatic Night and Day Calendar, which is useful to promote night-time day-time orientation and prevent wandering or calling caregivers at night<br>The Lost Item Locator<br>The Automatic Night Lamp<br>The Gas Cooker Device, which regulates the heat of the cooker by turning off the appliance if pans overheated<br>The Picture Button Telephone |
| 43 | Casey Dympna (2020) [43]          | Ireland                | To explore the perceptions and experiences of users as regards the use of a social robot                                                                                                                                                                              | Descriptive qualitative approach using semi-structured interviews. Qualitative content analysis.                                                         | 38 OAs, 28 relatives/carers, 28 formal cares, 13 managers OAs' age: 60+.<br>OAs are people with "dementia", defined as progressive neurocognitive disorder that has a profound effect on a person's personality, memory, social skills, ability to communicate and make decisions as well as on mood and emotional reactions                                                                                                                                                                          | SAR: MARIO<br>A companion robot, that has the capability of interacting with people in a socially acceptable way                                                                                                                                                                                                                                                                           |
| 44 | Chen Shu-Chuan (2022) [44]        | Taiwan                 | To explore OAs' experiences and perspectives about relationship with the PARO companion, investigating how the OAs view the robot through their interactions and to what extent the relationship can constitute a meaningful companionship or an unexpected encounter | Qualitative research using semi-structured interviews. Thematic analysis.                                                                                | 26 OAs<br>OAs' age: 65 +<br>OAs are people with "dementia", defined as mild cognitive impairment as determined by Mini-Mental State Examination (MMSE) (The cut-off point of the MMSE was based on a study by Zhang et al., in which the level of cognitive impairment in Chinese OAs was shown to vary according to educational level: 17/18 for older people without formal education, 20/21 for those with 1–6 years of education, and 24/25 for participants with more than 6 years of education) | SAR: PARO<br>A baby harp seal, a companion-type social robot with which older adults can communicate<br>It has five sensors for touch, sound, light, posture, and temperature<br>It can show humanlike emotional reactions and has a diurnal rhythm                                                                                                                                        |



**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                         | Design/methodology                                                                                                                | Participants                                                                                                                                                                                                                                                                                                                   | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----|-----------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 45 | Christiansen Line (2020) [45]     | Sweden                 | To explore subjective effects of mHealth on Health-related Quality of Life and perceptions of OAs with mild cognitive impairments           | Qualitative design with a phenomenographic approach using semi-structured interviews.                                             | 18 OAs<br>OA' age: 65 +<br>OAs are people with "dementia", defined as a multifactorial disorder characterized by a progressive deterioration in memory and other cognitive domains; actually, in the study they specify that they enrolled participants with mild dementia and mild cognitive impairments (MMSE score = 20–26) | CMT and UNMT: Mobile Health Technologies (mHealth)<br>Mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices, used for health-related interventions and for mobile self-care                                                                                                                                                                                                                |
| 46 | Darragh Margot (2017) [46]        | New Zealand            | To explore how a robot in the home could assist the mildly cognitively impaired                                                             | Observational requirements gathering study using semi-structured interviews.                                                      | 9 OAs, 8 caregivers and 16 experts<br>OAs' age: age range 54–78<br>OAs are participants with memory difficulties, Mild Cognitive Impairment, or Mild Dementia                                                                                                                                                                  | SAR: Homecare robot<br>The robot can provide functional support, track physical and psychological well-being, and deliver therapeutic intervention specifically for people with mild cognitive impairment                                                                                                                                                                                                                                                       |
| 47 | Epstein Iris (2016) [47]          | Canada                 | To explore the perspectives of OAs with early dementia and compare them to caregivers' perspectives on the experience of in-home monitoring | Mixed-method approach: a quantitative approach using questionnaires and a qualitative approach using focus groups and interviews. | 37 participants: OAs and their caregivers<br>OAs' age: age range 55–84<br>OAs are participants with "dementia" (no further specified)                                                                                                                                                                                          | UNMT: In-home monitoring technology<br>A monitoring system that included the use of motion sensors, contact sensors and Internet connections with one-way communication capabilities<br>Motion sensors detect movement; contact sensors detect opening and closing of doors on fridges or medicine cabinet; smart light bulbs receive wireless on/off commands from remotes or other sensors; remote controls transmit on/off commands to the smart light bulbs |
| 48 | Fæø Stein Erik (2020) [48]        | Norway                 | To explore the perceptions of persons with dementia on assistive technology                                                                 | Qualitative, exploratory design, based upon hermeneutical methodology, using semi-structured interviews.                          | 12 home-dwelling OAs.<br>OAs' age: 65 + (age range 69–89)<br>OAs are people with "dementia", diagnosed in relation to ICD-10 criteria (World Health Organization. ICD-10—The ICD-10 classification of mental and behavioural disorders)                                                                                        | UNMT: Assistive Technologies<br>Stove guards, safety alarms, electronic pill dispensers                                                                                                                                                                                                                                                                                                                                                                         |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                              | Design/methodology                                                                                                           | Participants                                                                                                                                                                                                                                                                                                                                 | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----|-----------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 31 | Fänge Agneta Malmgren (2020) [31] | Sweden                 | To explore experiences, needs and benefits of people with dementia and their family members concerning sensor-based technology, for safety and independence                                      | Inductive, qualitative design with semi-structured interviews.<br>Manifest content analysis.                                 | 9 OAs and 21 informal caregivers<br>OAs' age: 64–92<br>OAs are people with "dementia", defined through MMSE score 14–24 and caused by Alzheimer disease or vascular dementia or unknown causes                                                                                                                                               | UNMT: sensor-based technology<br>The TECH@HOME technology kit includes home-leaving sensors, smoke and water leak sensors, door and window sensors and motion-based bed sensors and automatic lights                                                                                                                                                                                                                                             |
| 49 | Farina Nicolas (2019) [49]        | UK                     | To understand how people with dementia view wearing activity monitors and what aspects of the device effect wear time<br>To understand the acceptability and feasibility of wearing such devices | Quantitative questionnaires and qualitative interviews.                                                                      | 26 OAs and 26 caregivers<br>OAs' age: 65+<br>OAs are people with dementia of various causes (Alzheimer's disease, vascular dementia, mixed dementia, Lewy body dementia, not specified)                                                                                                                                                      | UNMT: GENEactiv Original<br>It is a wrist-worn acceleration sensor, which is small, lightweight and water-proof. The device is black, with a black plastic sports strap. There are no other prominent design features, displays, or interactive elements.<br>The device can record up to 45 days without charging or downloading the data.<br>The device has previously been shown to be a valid measure of physical activity and sedentary time |
| 50 | Gasteiger Norina (2021) [50]      | New Zealand            | To explore the usefulness of the robot and OAs' perceptions and experiences of using it                                                                                                          | Qualitative, descriptive design, conducting semi-structured interviews.<br>Thematic data analysis through inductive process. | 6 OAs<br>OAs' age: 65 + (72–83 YO)<br>OAs are five participants presenting normal cognitive functioning and one participant scoring as having a mild cognitive impairment (MMSE score < 25)<br>Participants have various health needs, including vision impairment, tinnitus, memory and hearing concerns and requiring multiple medications | SAR: Bomy<br>It is a daily care robot, which reminds OAs of daily activities and delivers cognitive stimulation games.<br>It can provide social, non-physical assistance with daily functioning, including reminders                                                                                                                                                                                                                             |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                             | Design/methodology                                                                                                                                                                                                 | Participants                                                                                                                                                                                                                                                                                                                                                        | Emerging Technologies                                                                                                                                                                                                                                                                                                                            |
|----|-----------------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 51 | Gelonch Olga (2019) [51]          | Spain                  | To understand the acceptance of a wearable lifelogging camera in older adults with mild cognitive impairment (MCI)                                                                                              | Mixed-method design, consisting of a self-report questionnaire, numerous images taken by users, and a series of focus group discussion.<br>Thematic qualitative analysis, from a socio-constructivist perspective. | 9 OAs adults and 9 caregivers<br>OAs' age: 65 +<br>OAs are people with "mild cognitive impairment", defined as a condition affecting people who suffer from memory impairment beyond what would be expected for their age, but who maintain relatively normal levels of general cognitive functions and are able to carry out activities associated with daily life | UNMT: Narrative Clip - Assistive Technology Device (ATD)<br>It is a small lifelogging camera, worn around the neck.<br>It automatically takes hundreds of pictures per day from a first-person perspective                                                                                                                                       |
| 52 | Godwin Beatrice (2012) [52]       | UK                     | To examine whether assistive technology contributes to person-centred care<br>To understand whether users can participate in research<br>To explore ethical dilemmas with users, family and professional carers | Qualitative study, using semi-structured interviews and vignettes.<br>Content analysis.                                                                                                                            | 9 OAs, 9 families, and 9 professionals<br>OAs' age: not defined, but they are labelled as "older people".<br>"They were all in their pension age except for Rosemary, who was in her 50s. The oldest was Nellie, who was in her 90s" (p.126)<br>OAs are people with "dementia" (no further defined)                                                                 | CMT and UNMT: Assistive Technology Technologies are a personal building exit sensor; a pressure mat and a pager/buzzer; a door sensor; a bedside light with pressure mat; an auto-dial smoke detector; an automatic kettle; a visual calendar; an automatic pill dispenser; a lost object indicator                                              |
| 53 | Hall Alex (2017) [53]             | UK                     | To understand the facilitators and barriers to the implementation of monitoring technologies in care homes                                                                                                      | Embedded multiple-case study with qualitative methods, using semi-structured interviews.<br>Framework Analysis approach.                                                                                           | 9 OAs, 24 staff, 9 relatives<br>OAs' age: 65+ (age range: 72–95)<br>OAs are people with "dementia" (considered as an umbrella term referring to different cognitive impairments)                                                                                                                                                                                    | UNMT: monitoring technologies<br>Cognitive aids: prospective memory aids; retrospective memory aids<br>Physiological sensors: vital signs and metabolic parameters; fall detectors<br>Environmental sensors<br>Advanced integrated sensor systems<br>Wearable radiofrequency transmitters<br>Satellite-enabled technology<br>Video-based systems |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                                                                                                                                                | Design/methodology                                                                                                                                                                     | Participants                                                                                                                                                                                                           | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| 54 | As above (2019) [54]              | UK                     | To understand the influence of the ethical debate upon the implementation of monitoring technologies in care homes<br>To explore the extent to which remote monitoring of care home staff, and equality of access to technologies, were seen to influence the use of monitoring technologies within routine practice<br>To discuss subsequent ethical implications | Embedded multiple-case study design, conducting observations and semi-structured interviews. Framework Analysis approach.                                                              | 24 Staff, 3 residents of three dementia-specialist care homes, and 9 relatives<br>OAs' age: 65+ (age range: 72–95)<br>OAs are people with "dementia" (no further defined)                                              | UNMT: Assistive Technologies -Monitoring Technologies<br>Technologies are integrated systems that incorporate wearable sensors and/or environmental sensors to detect bed occupancy, falls, entry and exit through doorways<br>Technologies provide continuous monitoring of location, activity, and/or physiological signs<br>The devices alert staff when assistance is required, and generate data for post-hoc analysis<br>Video technology is used to tackle fears of malpractice, but also to illuminate unwitnessed incidents such as altercations between residents |
| 55 | Hamblin Kate (2017) [55]          | UK                     | To understand whether an American model of 'obtrusiveness' is applicable to the UK context by examining what factors influence older adults' acceptance and use of telecare                                                                                                                                                                                        | Qualitative, multi-method, longitudinal research study, using ethnographic observations and qualitative interviews supplemented by creative methods including photography and diaries. | 60 OAs<br>OAs' age: 65+<br>OAs are people with cognitive impairment and/or memory problems (no further specification), susceptible to falls                                                                            | UNMT: telecare<br>Technologies are equipment and detectors that provide continuous, automatic and remote monitoring of care needs emergencies and lifestyle changes, using information and communication technologies (ICT) to trigger human responses, or shut down equipment to prevent hazards<br>Devices included in telecare packages, linked to monitoring centres, are GPS devices; bed, door and chair exit sensors; carbon monoxide, smoke, flood and temperature extreme sensors; reminder systems; medication dispensers                                         |
| 56 | Hebesberger Denise (2017) [56]    | UK                     | To evaluate a long-term autonomous robot deployed in a real-world scenario at a care facility for older adults with severe multimorbidity and dementia<br>To study social acceptance and user experience                                                                                                                                                           | Concurrent mixed methods multistrand research design, combining qualitative (interviews, observations) and quantitative (online questionnaires) methods.                               | 350 OAs and 465 hospital staff<br>OAs' age not defined, but they are labelled as "older adults"<br>OAs are people with "dementia" or cognitive impairments;<br>Results related to older adults may be easily extracted | SAR: STRANDS robot - SCITOS Robotic Platform<br>It is a long-term autonomous robot, capable of autonomous navigation and patrolling, greeting task and reciprocity                                                                                                                                                                                                                                                                                                                                                                                                          |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                         | Design/methodology                                                                                                                                                                                                   | Participants                                                                                                                                                                                                                                                                                                                                                                                           | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----|-----------------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 57 | Hedman Annicka (2016) [57]        | Sweden                 | To understand how people with mild cognitive impairment relate to technology as part of and as potential support in everyday life – both present and future | Qualitative study, conducting in-depth interviews. Analysis with Grounded Theory Approach.                                                                                                                           | 6 OAs<br>Age: age range 61–86<br>OAs are people with MCI (fulfilling or having fulfilled within the past 2 years the Petersen MCI criteria, i.e. subjectively perceived cognitive decline, which is objectively verified in clinical assessment, no dementia, and overall intact Activities of Daily Living (ADL)/ Instrumental Activities of Daily Living (IADL); one person with Alzheimer's Disease | CMT and UNMT: Everyday Technologies<br>Ambient Assisted Living (AAL)<br>One example of CMT is Google calendar for reminders<br>As for AAL, it refers to integrated assisted living technologies based on ambient intelligence, i.e. digital environments that are sensitive, adaptive, and responsive to human needs Applications potentially relevant for OAs with cognitive impairments include systems monitoring and providing reminders during activities of daily living (ADL) |
| 58 | Hung Lilian (2021) [58]           | Canada                 | To explore the perceptions about the experiences with PARO robot in a hospital setting                                                                      | Video-ethnographic methods, including conversational interviews and observations with video recording (with OAs) and semi-structured individual interviews and focus groups (with nursing staff). Thematic analysis. | 10 OAs and nursing staff<br>OAs' age: 60+<br>OAs are people with different kinds of dementia, dissimilar functional disabilities, various ethnic backgrounds, both sexes                                                                                                                                                                                                                               | SAR: PARO robot<br>It is a robotic seal pet designed to provide emotional and social support for older people with dementia<br>It behaves like a domestic pet and responds to touch, light, sound, motion and temperature<br>Its artificial intelligence enables machine learning to support the social and emotional needs of those who interact with it                                                                                                                            |
| 59 | Inoue Kaoru (2021) [59]           | Japan                  | To examine the potentiality of using the robot PARO to mediate care provided by the family<br>To identify problems when utilizing PARO in the home context  | Exploratory study, conducting standardized assessments, observations of OAs' interactions with robot and family interviews.<br>Descriptive statistics and inductive thematic content analysis.                       | 7 OAs<br>Age: 65+<br>OAs are people with "dementia", defined through MMSE Japanese (score lower than 23/30) and "Alzheimer's dementia" (no specific definition)                                                                                                                                                                                                                                        | SAR: PARO robot<br>It is a robotic seal pet developed to facilitate users' psychological, physical, and social wellbeing<br>PARO is capable of making an animal-like cry, moves its head and legs, and blinks<br>With artificial intelligence, it can remember the name of a person and endears itself to its owner with cute gestures and cries                                                                                                                                     |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                               | Design/methodology                                                                                                                     | Participants                                                                                                                                                        | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| 14 | Jakobsson Elin (2019) [14]        | Sweden                 | To study the experiences of using eHealth in contact with health care among older adults with cognitive impairment                                                                | Qualitative study, conducting individual, semi-structured interviews. Constructivist Grounded Theory approach.                         | 9 OAs<br>Age range: 65–84<br>OAs are people with cognitive impairments of varying origins (stroke, dementia, mild cognitive impairment)                             | CMT: eHealth<br>Services provided through technologies<br>Central to the use of eHealth services such as online health guides and e-prescriptions are technological artifacts such as computers and mobile phones and services through Internet<br>eHealth is defined as the use of Everyday Technologies (e.g. stationary phones, smartphones, and computers) and ET services (e.g. health information on the Internet, online booking and answering machines) in contact with health care<br>Examples of ET and ET services relevant to individuals' health management include patient portals, tele-health systems and support systems                                                                                                                                                                                                                                            |
| 60 | Karlsson Eva (2011) [60]          | Sweden                 | To explore the complex issues involved in the process from a user driven development to the acceptance and usage of a new digital assistive device for persons with mild dementia | Qualitative case study, conducting participant observations and semi-structured interviews. Qualitative content analysis.              | 2 OAs with mild dementia and their partners<br>Age of the 2 people with mild dementia: Alice: about 60 years old, Sven about 80 years old                           | CMT: a digital assistive device<br>The device consists of two parts: one is stationary, and the other is mobile. The mobile part integrates functions to support memory, social contact, daily activities, and intended to enhance the feeling of safety<br>The devices can also be adjusted to meet the needs of the individuals using them                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 61 | Khosla Rajiv (2021) [61]          | Australia              | To study the engagement and robot experience of older people with dementia while interacting with a social robot in the context of home-based care                                | Mixed-method approach in design, including qualitative (observations) and quantitative (survey questionnaire) methods. Video analysis. | 5 OAs<br>Age: 65+ (age range 75–85)<br>OAs are people with "dementia", interpreted as loss of mental and physical functions and variability of cognitive impairment | SAR: Betty<br>The social robot is 39 cm tall and weighs 6.5 kg. The upper part contains two light sensors, two microphones for speech recognition, and voice localization in the front<br>Its head has two axes of movement, nodding/panning $\pm 180$ degrees and tilting $\pm 45$ degrees<br>The embodiment of interactional environment in the robot involves modelling of human characteristics like gesture, emotional expressions, voice, and motion Betty is deployed in each home with human attributes including baby face like appearance, voice vocalization, face recognition, face registration and tracking, facial expressions, gestures, body motion sensors, dance movements, touch sensors, emotion recognition and speech acoustics recognition<br>Features: singing and dancing; phone calls; weather forecast; news; book reader; reminder; quiz; date and time |



**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                                         | Design/methodology                                                                                                                      | Participants                                                                                                                                                                                                                                                                                                                                                                               | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----|-----------------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 62 | Lindqvist Eva (2013) [62]         | Sweden                 | To describe how persons in the early stages of Alzheimer's disease (AD) became users of assistive technology (AT)<br>To understand what the use of AT came to mean to these users and, when relevant, their significant others                              | Intervention study conducting semi-structured interviews.<br>Analysis with constant comparative approach, derived from grounded theory. | OAs<br>Age: 54–79<br>OAs are people with Alzheimer's Disease                                                                                                                                                                                                                                                                                                                               | CMT and UNMT: Assistive Technologies<br>Abilia Reminder gives a reminder when the door opens<br>C. STATUS Info Panel Key Tag shows status of appliances and doors at home/outside home<br>Doro Handleplus Mobile Phone enables simplified calls outside home<br>FOFA Item Locator<br>Forget-me-not Electronic calendar<br>Handi Hitta Mobile phone/GPS<br>MEDOS Alarm Watch gives regular reminders<br>MEMO day-planner<br>MEMO messenger talking clock<br>Olympus VN 3500pc note taker records audio<br>Skeeper Mobile phone/GPS is a wrist mobile phone with buttons for pre-programmed phone numbers, equipped with auto-answer and GPS<br>Smart Finder Item Locator Tentaculus support system gives (also repeated) reminders or warnings under preprogrammed terms software program for computer, hardware for communication with, e.g., sensors |
| 63 | Lindqvist Eva (2018) [63]         | Sweden                 | To investigate the areas of concern where persons with cognitive deficits meet challenges in everyday life, in what environments these challenges appear and how technology might be involved as part of the challenge and/or the solution to the challenge | Qualitative study conducting focus groups interviews.                                                                                   | Different groups of individuals (professionals at memory investigation clinic; researchers; members of volunteer health organizations) of various age (age range 35–70).<br>OAs' age: age range 51–60 ( <i>N</i> =2) and 61–70 ( <i>N</i> =8).<br>OAs are people with "mild cognitive deficits" (defined as deficits due to minor stroke), early stage dementia, Mild Cognitive Impairment | CMT: everyday technologies<br>Mobile phone and smart phone with GPS, computers, tablets, Personal Digital Assistants (PDA)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 64 | Masoud Sara S. (2021) [64]        | USA                    | To understand the experiences of individuals living with dementia and family care partners who regularly attend Memory Cafés<br>To study how these gatherings affect perceptions of social connectedness                                                    | Qualitative descriptive design, conducting semi-structured interviews.<br>Analysis using a combined inductive and deductive approach.   | 5 people with dementia and 12 family care partners<br>Age of persons with dementia is not defined, but "older adults" appear in relation to the study                                                                                                                                                                                                                                      | CMT: Virtual Memory Cafés<br>A widely implemented program that provide individuals living with dementia and their care partners an opportunity to socialize with others<br>These spaces, whether virtual or in-person, provide individuals living with dementia a place to socialize without fear of stigma or judgment due to behavioral symptoms of their diagnosis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                     | Design/methodology                                                                                                                            | Participants                                                                                                                                                                                  | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
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| 65 | McCabe Louise (2013) [65]         | UK                     | To explore the ideas and opinions of people with dementia and their carers about a GPS tracking device                                                                                                                                  | Qualitative study, conducting focus groups. Analysis using a qualitative, thematic approach.                                                  | 17 OAs and 3 caregivers<br>Age: 60+<br>OAs are 12 people with dementia and 5 healthy people                                                                                                   | UNMT: GPS tracking device<br>A device to support safe walking                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 66 | Mehrbian Shima (2015) [66]        | France                 | To assess perceptions of the usefulness of different functionalities of the telecare system<br>To evaluate perceived advantages and disadvantages of the telecare system and the degree of willingness to adopt such technology at home | Quantitative approach, using questionnaires, and qualitative approach, conducting semi-structured interviews.<br>Inductive thematic analysis. | 62 OAs and 30 caregivers<br>Older adults' age: 65+ (age range 69–75)<br>OAs are people with "mild cognitive impairment" (age range 74.8+/-5.9) and Alzheimer's disease (age range 77.1+/-7.2) | UNMT: Home telecare/smart home<br>It involves the application of telecommunications and computer technologies to the provision of effective at-home health care<br>It makes use of Internet technology, broadband communication, smart house technology, and a free in-home software module<br>The services are devoted to lifestyle monitoring and aim to improve patient well-being through enhancing the patient's safety and security; providing a cognitive prosthesis to the patient through medications, tasks, and appointments; training cognitive functions; monitoring health with teleconsultation between patients and health care professionals; and enhancing valuable social links<br>It is easy to use and displays interfaces tailored to the needs and preferences of cognitively impaired persons<br>Services include detecting some emergencies, providing cognitive stimulation exercises, enabling teleconsultation with professionals and videoconferencing with family and friends, and providing medicines and tasks reminders through an easy-to-use computer that encompasses a touch screen as well as some sensors (front door, fire and water, fall sensors) at home |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                        | Design/methodology                                                                                                           | Participants                                                                                                                                                                                                                                                                                              | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
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| 67 | Moyle Wendy (2018) [67]           | Australia              | To measure and describe the effectiveness of a Virtual Reality Forest (VRF) on engagement, apathy, and mood states of people with dementia<br>To explore the experiences of staff, people with dementia and their families | Mixed-method study, conducting observations and semi-structured interviews.<br>Quantitative analysis and thematic analysis.  | 10 OAs, 10 family members, and 9 staff members<br>OAs' age: 60+<br>OAs' are people with "dementia" (defined through the Psychogeriatric Assessment Scale/PAS Score, a higher score represents a higher level of cognitive impairment/decline<br>OAs scores ranged from 7.35 to 20, average score = 13.21) | VRT: Virtual Reality Forest<br>It is a sensory experience, utilizing a large interactive screen, and designed to immerse the user in the virtual environment<br>The aim is to improve quality of life for the person living with dementia.<br>It uses video game technology, involving vivid graphics and motion sensors, to create an interactive and immersive environment.<br>Its imagery includes a river spanned by a bridge winding through trees and flowers, which is accompanied by a background soundtrack incorporating peaceful white noise and forest sounds, such as bird calls.<br>The seasons and various animated objects can be manipulated through Microsoft Kinect® motion sensors allowing participants to interact with the scene through hand and arm movements |
| 68 | Nygård Louise (2007) [68]         | Sweden                 | To understand the difficulties with and hindrances to using everyday technology for persons with early-stage dementia                                                                                                      | Qualitative, exploratory study, conducting observations and interviews.<br>Analysis through a constant comparative approach. | 8 OAs<br>Age: 57–82<br>Older adults are people with "dementia" and different cognitive deficits (no further specification)                                                                                                                                                                                | CMT: everyday technology<br>It may include both newly developed and common, well-known, technological artefacts and services                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 69 | Orpwood Roger (2008) [69]         | UK                     | To evaluate a complete autonomous smart home installation in an apartment in a care home<br>To understand the impact it had on the behaviour and independence of someone with quite severe dementia                        | Quantitative approach, using questionnaire and a qualitative approach, conducting interviews.                                | 1 person with vascular dementia (older adult), his daughter, and his care staff<br>OA' age: 82-year-old                                                                                                                                                                                                   | UNMT: Gloucester Smart Home<br>It is a smart home, a technology different from telecare<br>It does not rely on outside individuals or call centres to provide support to the user<br>The house provides this support autonomously<br>In this way such installations can respond immediately to any problems that might arise, and they are much more empowering to the user<br>It includes sensors (e.g. bed occupancy, light switches, smoke alarms, etc.) and support devices (e.g. lighting, tap control, messaging system, etc.)                                                                                                                                                                                                                                                   |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                      | Design/methodology                                                                                                                                                                                      | Participants                                                                                                                                                                                                                          | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| 70 | Pino Mari-bel (2015) [70]         | France                 | To investigate questions about the robot and the user characteristics, potential applications, feelings about technology, ethical issues, and barriers and facilitators for SAR adoption | Mixed-method approach, including a short, self-administered questionnaire and a series of focus groups. Content analysis using principles described by Strauss and Corbin (1998).                       | 18 OAs and 7 caregivers<br>OAs' age: 65+<br>OAs are people with Mild Cognitive Impairment and healthy older adults                                                                                                                    | SAR: Different types of SAR<br>Human-like robots (e.g. Telenoid; Nexi); androids or very realistic human-like robot (e.g. Geminoid); mechanical human-like robots (Kompai, Pearl, Mamoru-kun, Eve); animal-like robots (e.g. Paro); and mechanical animal-like robots (e.g. iCat)<br>SAR can help by: (a) supporting user's cognitive and functional abilities (e.g. tasks reminding and monitoring, navigation aids); (b) offering the user opportunities to enhance social participation and psychological well-being (e.g. communication and social applications, telepresence, companionship); (c) providing remote and continuous monitoring of user's health status (e.g. blood pressure or fall detection sensors); and (d) coaching the user to facilitate promotion of healthy behaviour and achievement of health-related goals (e.g. improving nutrition, physical activity) |
| 71 | Pu Lihui (2019) [71]              | USA                    | To explore how people with mild to moderate dementia and chronic pain perceive PARO as an alternative intervention to manage their pain and mood                                         | Qualitative study conducting semi-structured interviews. Thematic analysis.                                                                                                                             | 11 OAs<br>Age: age range 65–94<br>OAs are people with dementia (Alzheimer's dementia, vascular dementia)                                                                                                                              | SAR: PARO<br>It is a robotic harp seal, which can learn users' preference for its behaviour<br>It can open and close its eyes, moves its neck, front a rear flipper as well as respond to users by making a sound when it is being stroked, patted or called<br>It can also show negative emotions on undesired stimulation, such as being hit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 72 | Riikonen Merja (2013) [72]        | Finland                | To explore the factors that facilitate the use of technology in the daily life of home-living people with dementia                                                                       | Ethnographic approach with open interviews, participant observation, field notes, a structured questionnaire for family members and four batteries of tests. Inductive or data-driven content analysis. | 25 OAs and their caregivers<br>OAs' age: age range 54–90 years old (median age = 79)<br>Participants are people with mild, moderate or severe Alzheimer disease (1 participant had mixed dementia combining AD and vascular dementia) | CMT and UNMT: Assistive technologies<br>GSM Camera with motion detector; electronic medication reminder; photo memory telephone                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 73 | Robinson Hayley (2016) [73]       | New Zealand            | To study the interactions between older adults and a SAR<br>To understand the engagement, how residents treated the robot and if the robot acted as a social catalyst                    | Qualitative study, conducting interviews.                                                                                                                                                               | OAs in a nursing home (only some are affected by dementia) and staff<br>OAs' age: 84.4 as median age                                                                                                                                  | SAR: PARO<br>It is a 2.7-kg fluffy white seal robot<br>It responds to touch, light, movement and sound                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                                                         | Design/methodology                                                                                                                                                                                                                                                                                                               | Participants                                                                                                                                                                                                            | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----|-----------------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 74 | Robinson Louise (2007) [74]       | UK                     | To explore the perspectives of different stakeholders in the management of wandering in dementia<br>To understand the ways in which these stakeholders assess and balance rights against risks to older persons in relation to different assistive technology interventions | Systematic review and a qualitative study conducting Focus Groups.<br>Thematic framework approach (Ritchie and Spencer 1994), which is both deductive (a 'top-down' approach informed by the aims of the research and the study questions) and inductive (a 'bottom-up' approach grounded in the responses of the participants). | 6 OAs, 3 family carers, 10 health and social care professionals and nursing home staff members<br>OAs' age: not defined, but they are labelled as "older adults"<br>OAs are people with "dementia" (no further defined) | UNMT: Assistive technologies<br>Alarms, electronic tagging and tracking devices<br>They are hard technologies and technical devices that are intended to assist the older person in living safely and independently                                                                                                                                                                                                                                                            |
| 75 | As above (2009) [75]              | UK                     | To design acceptable and effective prototype technologies to facilitate independence for people with dementia through a user-centered design process involving them and their carers                                                                                        | Three-stage participatory design process: scoping stage (five focus groups); participatory design stage (five workshops) and prototype development stage (four meetings).<br>Inductive approach to data collection, using the constant comparative method (Glaser, 1965) and deviant case analysis.                              | OAs and their caregivers<br>OAs' age: not defined, but they are labelled as "older adults"<br>OAs are people with "dementia" (no further defined)                                                                       | UNMT: Assistive technologies<br>Armband and electronic notepad                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 76 | Stara Vera (2021) [76]            | Italy                  | To evaluate the usability and acceptability of the virtual agent Anne by people living with dementia<br>To assess the ability of target users to use the system independently and receive valuable information from it                                                      | Mixed methods approach, balancing quantitative (questionnaires) and qualitative instruments (unstructured short questions).                                                                                                                                                                                                      | 20 OAs and 14 caregivers. OAs' age: 65+<br>OAs are people with dementia                                                                                                                                                 | UNMT: Embodied Conversational Agent Anna<br>Embodied conversational agents (ECAs) are screen-based entities designed to stimulate human face-to-face conversation skills, allowing for natural human-machine interaction<br>Anne can support people with dementia in all aspects of daily life, such as communication with the outside world, keeping track of items on the personal calendar, daily structure, medication, reading the news, and relaxation (games and music) |

**Table 3** (continued)

| N° | First Author and Publication Year  | Country of Affiliation | Aim                                                                                                                                                                                                          | Design/methodology                                                                                                                                                                                                                                                             | Participants                                                                                                                                                                                                                                                  | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----|------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 77 | Stavropoulos Thanos G. (2021) [77] | Greece                 | To understand the preferences, priorities and concerns of people with dementia and their caregivers for using monitoring wearables                                                                           | Study including a structured voting session and close questions (with voting cards) and general and open discussion/focus group with face-to-face interviews.                                                                                                                  | 11 OAs and 10 caregivers<br>OAs' age: not defined, but they are labelled as "older adults"<br>OAs are people with mild/moderate "dementia" (mainly Alzheimer's dementia, one person with frontotemporal, one person with vascular dementia)                   | UNMT: Internet of Things (IoT)<br>Bracelet 1 measures steps, sleep and heart rate (HR), high accuracy, light, high comfort, 7-day battery life, monochrome touchscreen, and waterproof<br>Bracelet 2 measures steps, sleep, HR and 3D movement (XYZ accelerometer), high accuracy, bulkier, soft, 2-day battery life, and color touchscreen<br>Bracelet 3 measures steps and sleep, average accuracy, the lightest (is a wristband), 7-day battery life, and no screen<br>Bracelet 4 measures steps, sleep, HR, heart rate variability and perspiration (Galvanic Skin Response—GSR), high accuracy, large and heavy, 1-day battery life, and no screen<br>SAR: James<br>Assistive robot by Zora Robotics PLC |
| 78 | Van Assche Maaïke (2021) [78]      | Belgium                | To explore the experiences of older adults with mild cognitive impairment with a SAR during the first lockdown in Belgium                                                                                    | Qualitative study, conducting semi-structured interviews.<br>Quantitative data collected through questionnaires and logbooks (the authors don't use "mixed-method approach" definition).<br>Thematic analysis according to the guidelines designed by Braun and Clarke (2006). | 4 OAs<br>Age: range 70–90<br>OAs are people with mild cognitive impairment                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 79 | Verloo Henk (2020) [79]            | Switzerland            | To understand the perceptions of community-dwelling OAs and their informal caregivers and professional caregivers about technologies that can help keep OAs at home                                          | Multicenter study using a qualitative design with one-to-one interviews, focus groups, and photo-elicitation interviews.<br>Qualitative content analysis approach described by Graneheim and Lundman (2004).                                                                   | 68 OAs 21 informal caregivers, and 32 professional caregivers<br>OAs' age: age range 64–95<br>OAs are healthy OAs, physically impaired OAs, and cognitively impaired OAs<br>OAs with cognitive impairments are affected by mild/moderate cognitive impairment | CMT, UNMT, SAR: Gerontechnologies<br>10 technologies: light path; fall detector; electronic pillbox; robot vacuum cleaner; service robot; GPS bracelet; touchscreen tablet; social network; brain training technology<br>These devices can provide support and solutions, monitoring health status to optimize autonomy, and improving the quality of life of community dwelling OAs, regardless of their level of dependency                                                                                                                                                                                                                                                                                 |
| 80 | Wada Kazuyoshi (2007) [80]         | Japan                  | To explore the psychophysiological influences on human-robot interaction, including long-term interaction<br>To develop a design theory for therapeutic robots<br>To develop a methodology for robot therapy | Experiment, using interviews, video-recordings of interactions with PARO and urinary tests.                                                                                                                                                                                    | 12 OAs<br>OAs' age: 65+ (age range: 67–89)<br>OAs are participants with "dementia" defined through MMS: OAs score ranged from 15 to 29 (less than 21 corresponds to dementia)                                                                                 | SAR: PARO<br>It is a mental commit robot It is a baby harp seal and it is covered with pure white fur<br>PARO has a behaviour generation system consisting of two hierarchical process layers: proactive and reactive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                        | Design/methodology                                                                                                                                                                                    | Participants                                                                                                                          | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------------------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 81 | As above (2008) [81]              | Japan                  | To understand how people interact with PARO under the freely accessible condition and its socio-psychological and physiological effects on the residents                   | Experiment, using interviews, video-recordings of interactions with PARO and urinary tests.                                                                                                           | 12 OAs<br>Age: 70–84<br>OAs have MMSE scores between 15 to 29 (those with a score of above 23 were diagnosed as mentally healthy)     | SAR: PARO<br>It is a seal-type mental commit robot for robot therapy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 82 | Wang Rosalie (2017) [82]          | Canada                 | To study the perspectives of OAs with Alzheimer's disease (AD) and their caregivers on robots that provide stepwise prompting to complete activities in the home           | Descriptive mixed methods study, combining questionnaires (not included in this paper) and semi-structured interviews.<br>Qualitative, thematic analysis.                                             | 10 OAs and 10 caregivers<br>OAs' age: 59–88<br>OAs are participants diagnosed as having mild-to-moderate Alzheimer's Disease          | SAR: Ed<br>It is a tele-operated assistive robot that provides step-by-step assistance for daily activities<br>Its functions are movement, communication and prompting; assistance in hand washing in the bathroom and in tea making in the kitchen                                                                                                                                                                                                                                                                                                 |
| 83 | Wu Ya-Huei (2012) [83]            | France                 | To give some recommendations to engineers in charge of the design of the robot's appearance<br>To explore how the elderly perceived robots with regard to robot appearance | Study using Focus Groups.<br>Thematic analysis and inductive approach (Braun and Clarke, 2006).                                                                                                       | 15 Older adults<br>Age: 65+<br>OAs are healthy (N=8)<br>OAs and OAs with cognitive impairments (N=7) (no further definition)          | SAR: Assistive robots (companion type and service type)<br>R2D2, robuLAB 10, Aibo, Amiet, Anybot Monty, Asimo, Nexi-MDS, Care-o-bot13, Care-o-bot11I, Eve from WALL-E of Pixar, HRP4C, iRobiQ, Robot Housekeeper, Kobian, Mamoru, Mechadroid type c3, uBOT-5, Motoman SDA10, Nao, Paro, Pomi, My Spoon, Ri-Man, SmartPal, Toyota i-foot, Twendy-One and others (not specified)                                                                                                                                                                      |
| 84 | As above (2014) [84]              | France                 | To study robot-acceptance in OAs                                                                                                                                           | Mixed-method study comprising a robot-acceptance questionnaire, semi-structured interviews, usability-performance measures, and a focus group.<br>Inductive thematic analysis (Braun & Clarke, 2006). | 11 OAs<br>Age: 65+ (age range 76–85)<br>OAs are healthy (N=5)<br>OAs and OAs with cognitive impairments (N=6) (no further definition) | SAR: Kompai<br>It is an indoor mobile platform with two propulsive wheels used as a generic platform<br>It is designed to ease the development of advanced robotics solutions<br>It can recognize and synthesize voices, and navigate in unknown environments<br>It also remembers appointments, manages shopping lists, plays music, and can be used as a video conference system<br>Users interact with it via touch screen and voice<br>Kompai can recognize and respond to simple phrases and orders, such as 'Hello', 'What date is it today?' |



**Table 3** (continued)

| N° | First Author and Publication Year | Country of Affiliation | Aim                                                                                                                                                                                                                                                                                                                                                                                                                            | Design/methodology                                                                                                                                                                                     | Participants                                                                                                                                                                                                                                                                                                                                                                                                    | Emerging Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----|-----------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 85 | As above (2016) [85]              | France                 | To understand difficulties and needs of OAs with mild cognitive impairment and their attitudes toward an assistive robot to develop appropriate robot functionalities                                                                                                                                                                                                                                                          | Qualitative approach with two data collection methods, focus group discussions and semi-structured interviews. Inductive thematic analysis (Braun & Clarke, 2006).                                     | 20 OAs<br>Age range: 63–88<br>OAs are participants with cognitive impairments (defined in line with five criteria: i) cognitive complaint; ii) performance at least 1.5 standard deviations (SD) below age normative values on a cognitive test, iii) normal general cognitive function, iv) no significant limitation of functional independence due to their cognitive deficits, and v) no dementia criteria) | SAR: Assistive robot (not specified)<br>Its functionalities are event and appointment reminder, object-finding, cognitive stimulation, video conferencing, remote surveillance, and companionship                                                                                                                                                                                                                                                                                                                                                                                             |
| 86 | Yamazaki Ryuji (2014) [86]        | Japan                  | To explore how a teleoperated android robot affects people in the real world when it is employed to express telepresence and a sense of 'being there'<br>To explore OAs' reactions to, and acceptability of, the robot<br>To explore and compare the reactions towards the robot as a communication medium by OAs, and verify whether its design technology is acceptable across cultures for supporting their quality of life | Exploratory study using a qualitative method with dialogue recording data, collection of narrative and behavioral data of the OAs during the conversations, and observations through video recordings. | 2 OAs<br>Age: 65+ (1 participant 75-year-old and 1 participant 92-year-old)<br>OAs are 2 participants: one healthy (92), one with Alzheimer's disease (75)                                                                                                                                                                                                                                                      | SAR: Telenoid R2<br>It is a teleoperated robot designed as a minimalistic human<br>It is designed to resemble and suggest human presence that can be perceived as either male or female, young or old<br>It has a minimal human representation/embodiment that allows any person to transfer her own presence to a distant location by mediation<br>Key feature include: (1) an omni-human likeness that enables the robot to represent any person, (2) holdability that facilitates physical interaction, and (3) mobility that encourages people to use Telenoid in a variety of situations |

Articles included in this review refer to both these components, with a majority of papers ( $N = 23$ ) focusing only on the relationship between ET and the older adults' emotional sphere [14, 30, 40, 42, 44, 46–48, 50, 55, 56, 59–62, 67–69, 74, 77, 79, 80, 83], four papers discussing only the impact of ET on their cognitive abilities and skills [57, 63, 76, 82], and sixteen papers discussing both the emotional and cognitive implications of ET on older adults PV [31, 39, 41, 43, 45, 51, 55, 62, 66, 70, 71, 73, 78, 84–86].

As first general result, it is important to notice that, *no matter the specific type of technology considered*, with the exception of one publication [57], the broad family of ET employed in aged care has a positive influence on older adults' PV in *its cognitive dimension*, indisputably helping in taming already existing vulnerabilities related to ageing, such as physiological cognitive decline, as well as additional vulnerabilities related to the presence of serious cognitive impairments, such as memory loss and non-physiological cognitive decline.

**Table 4** Detailed characteristics of included publications (*N* = 51)  
**Analysed features (Number of Publications)/Paper No. as listed in Table 3**

|                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Year</i>                                                                                                                                                                                                                                                  |
| 2020–2022 ( <i>N</i> = 17): 30, 31, 39, 40, 41, 43, 44, 45, 48, 50, 59, 61, 64, 76, 77, 78, 79                                                                                                                                                               |
| 2015–2019 ( <i>N</i> = 19): 14, 46, 47, 49, 51, 53, 54, 55, 56, 57, 58, 63, 66, 67, 70, 71, 73, 82, 85                                                                                                                                                       |
| 2010–2014 ( <i>N</i> = 8): 52, 60, 62, 65, 72, 83, 84, 86                                                                                                                                                                                                    |
| 2005–2009 ( <i>N</i> = 7): 42, 68, 69, 74, 75, 80, 81                                                                                                                                                                                                        |
| <i>Country affiliation of the first author</i>                                                                                                                                                                                                               |
| UK (49, 52, 53, 54, 55, 56, 65, 69, 74, 75): <i>N</i> = 10                                                                                                                                                                                                   |
| Sweden (14, 31, 40, 45, 57, 60, 62, 63, 68): <i>N</i> = 9                                                                                                                                                                                                    |
| France (66, 70, 83, 84, 85) & Japan (30, 59, 80, 81, 86): <i>N</i> = 5 each                                                                                                                                                                                  |
| New Zealand (46, 50, 73), USA (39, 64, 71) & Canada (47, 58, 82): <i>N</i> = 3 each                                                                                                                                                                          |
| Australia (61, 67), Ireland (42, 43) & Norway (48, 69): <i>N</i> = 2 each                                                                                                                                                                                    |
| Belgium (78), Finland (72), Greece (77), Italy (76), The Netherlands (41), Spain (51), Switzerland (79), Taiwan (44): <i>N</i> = 1 each                                                                                                                      |
| <i>Data collection tools<sup>a</sup></i>                                                                                                                                                                                                                     |
| Semi-structured interviews (or interviews in general) ( <i>N</i> = 38): 14, 31, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 55, 57, 58, 59, 60, 62, 64, 66, 67, 68, 69, 71, 72, 73, 76, 78, 79, 80, 81, 82, 81, 82                               |
| Focus groups ( <i>N</i> = 13): 47, 51, 58, 60, 63, 65, 70, 74, 75, 77, 79, 83, 85                                                                                                                                                                            |
| Observations ( <i>N</i> = 13): 30, 47, 54, 55, 56, 59, 61, 67, 68, 72, 73, 81, 86                                                                                                                                                                            |
| <i>Type of cognitive impairment<sup>a</sup></i>                                                                                                                                                                                                              |
| Dementia (not defined/various causes e.g. Lewy Body, vascular, etc. except for Alzheimer's disease) ( <i>N</i> = 34): 30, 31, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 52, 53, 54, 56, 58, 59, 60, 61, 63, 64, 65, 67, 68, 69, 71, 72, 74, 75, 76, 77, 80 |
| Alzheimer's Disease ( <i>N</i> = 11): 31, 39, 41, 42, 49, 59, 62, 66, 77, 82, 86                                                                                                                                                                             |
| Mild Cognitive Impairment ( <i>N</i> = 9): 41, 46, 50, 51, 57, 63, 66, 70, 78                                                                                                                                                                                |
| Cognitive Impairment in general (memory problems, mild cognitive deficits and synonyms) ( <i>N</i> = 13): 14, 39, 40, 55, 56, 63, 68, 73, 79, 81, 83, 84, 85                                                                                                 |
| <i>Type of ET<sup>a</sup></i>                                                                                                                                                                                                                                |
| CMT ( <i>N</i> = 14): 14, 39, 41, 42, 45, 52, 57, 61, 64, 63, 64, 68, 72, 79                                                                                                                                                                                 |
| UNMT ( <i>N</i> = 23): 31, 39, 40, 45, 47, 48, 49, 51, 52, 53, 54, 55, 57, 62, 65, 66, 69, 72, 74, 75, 76, 77, 79                                                                                                                                            |
| SAR ( <i>N</i> = 21): 30, 43, 44, 46, 50, 56, 58, 59, 61, 70, 71, 73, 78, 79, 80, 81, 82, 83, 84, 85, 86                                                                                                                                                     |
| VRT ( <i>N</i> = 1): 67                                                                                                                                                                                                                                      |

<sup>a</sup> Some papers may appear several times, under different classification

In particular, UNMT systems made up of different elements (e.g., fitness trackers, tablets, smart TVs, etc.), enabling older adults to attend online classes [39], play memory games [43, 45, 57], exercise to workout videos [39], or search for information [39, 41], allow older adults to perceive themselves as “more actively engaged” [39, p. 6]. ICT technologies as well, by helping older adults to gain and/or share information, and communicate with others, enable them to stay involved in their hobbies and passions, make them feel “more engaged in their life” [41, p. 6]. Such an ‘active cognitive engagement’ resulted in a positive influence on older adults’ quality of life [43, p. 9]. Other CMT, such as pill dispensers, and UNMT, such

as home-sensors, reminding older adults with mild cognitive impairments about their daily commitments (e.g., being adherent to treatments, ventilate rooms, making showers, walk more) increased older adults’ self-confidence [39, 45, 51, 62], improving their perception of control and capacity [62, pp. 392–393]. SAR also appear to have a positive influence on PV in its cognitive dimension: PARO robot, for instance, was seen by older adults participating in one study as an occasion for positive cognitive stimulation [58, p. 495].

In the only publication stressing the negative impact of ET on older adults’ cognitive function, interviewed older adults reported that simplifying technology may be considered as “potentially risky for the preservation of one’s abilities” [57, p.6]. In other words, while technologies acting as reminders may first appear as facilitators of daily activities, trade-offs should be made between their advantages and potential negative impact on one’s own cognitive capacities.

More complexity is found when analysing the emotional component of older adults’ PV, namely the impact of ET on older adults’ PV in its emotional dimension. Indeed, in this context, ET appear both as facilitators and barriers to older adults’ emotional wellbeing. Included publications refer to ET emotional impact by using positive expressions such as warmth [30, 58], emotional satisfaction [41], confidence [43], enjoyment [56], but also negative expressions, e.g., awe [39], insecurity [40], embarrassment [41], emotional distress [44].

Interestingly, such a differential outcome seems to be also correlated to the specific type of technology considered. More precisely, in our included articles, studies employing SAR mainly report a positive emotional response to the technology: of the 18 publications defining ET as facilitators to the emotional wellbeing of older adults with cognitive impairments, the vast majority (*N* = 13) used a SAR. On the other hand, studies employing CMT and/or UNMT, mainly report a negative emotional response to the technology: of the 14 publications defining ET as barriers to the emotional wellbeing of older adults with cognitive impairments, nearly all of them (*N* = 12) used a CMT, a UNMT, or a combination of the two. Such a difference into this emotional response may be partially explained by considering what is reported by older adults themselves, as this may help understanding what is emotionally impacting by their side.

One of the most important issues pointed out by participants in our selected studies which shows to positively impact on PV in its emotional component is that interacting with SAR, both humanoid (e.g., MARIO) and non-humanoid robots (e.g., PARO), helps older adults forgetting about their dementia [43, 44]. By “distracting their attention from illness” [44, p. 134], older adults

Table 5 Quality assessment of included articles (CASP<sup>a</sup>)

| First Author and Publication Year    | (1) Was there a clear statement of the aims of the research? | (2) Is a qualitative methodology appropriate? | (3) Was the research design appropriate to address the aims of the research? | (4) Was the recruitment strategy appropriate to the aims of the research? | (5) Was the data collected in a way that addressed the research issue? | (6) Has the relationship between researcher and participants been adequately considered? | (7) Have ethical issues been taken into consideration? | (8) Was the data analysis sufficiently rigorous? | (9) Is there a clear statement of findings? | (10) How valuable is the research? | Overall Assessment |
|--------------------------------------|--------------------------------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------|---------------------------------------------|------------------------------------|--------------------|
| Included qualitative publications    |                                                              |                                               |                                                                              |                                                                           |                                                                        |                                                                                          |                                                        |                                                  |                                             |                                    |                    |
| 1 Albers Elizabeth A. (2022) [39]    | Y <sup>b</sup>                                               | Y                                             | N <sup>c</sup>                                                               | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 2 Baccman Charlotte (2020) [40]      | Y                                                            | Y                                             | N                                                                            | U <sup>d</sup>                                                            | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 3 Betriana Feni (2021) [30]          | Y                                                            | Y                                             | N                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 4 Block Marije (2020) [41]           | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 5 Casey Dymona (2020) [43]           | Y                                                            | Y                                             | Y                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 6 Chen Shu-Chuan (2022) [44]         | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 7 Christiansen Line (2020) [45]      | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 8 Darragh Margot (2017) [46]         | Y                                                            | Y                                             | N                                                                            | Y                                                                         | U                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 9 Faxø Stein Erik (2020) [48]        | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 10 Fänge Agneta Malmgren (2020) [49] | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 11 Gasteiger Norina (2021) [50]      | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 12 Godwin Beatrice (2012) [52]       | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 13 Hall Alex (2017) [53]             | Y                                                            | Y                                             | U                                                                            | Y                                                                         | Y                                                                      | U                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 14 Hall Alex (2019) [54]             | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 15 Hamblin Kate (2017) [55]          | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 16 Hedman Annicka (2016) [57]        | Y                                                            | Y                                             | U                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 17 Hung Lillian (2021) [58]          | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 18 Jakobsson Elin (2019) [14]        | Y                                                            | Y                                             | U                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 19 Karlsson Eva (2011) [25]          | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 20 Lindqvist Eva (2013) [62]         | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 21 Lindqvist Eva (2018) [63]         | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 22 Masoud Sara S. (2021) [64]        | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 23 McCabe Louise (2013) [65]         | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 24 Nygård Louise (2007) [68]         | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 25 Pu Lihui (2019) [71]              | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 26 Robinson Hayley (2016) [73]       | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | Y                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 27 Robinson Louise (2007) [74]       | Y                                                            | Y                                             | Y                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 28 Robinson Louise (2009) [75]       | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 29 Verloo Henk (2020) [79]           | Y                                                            | Y                                             | U                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 30 Wu Ya-Huei (2012) [83]            | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | N                                                      | Y                                                | Y                                           | Y                                  | High               |
| 31 Wu Ya-Huei (2016) [85]            | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 32 Yamazaki Ryuji (2014) [86]        | Y                                                            | Y                                             | N                                                                            | U                                                                         | Y                                                                      | U                                                                                        | Y                                                      | N                                                | Y                                           | Y                                  | Moderate           |
| Included mixed-method publications   |                                                              |                                               |                                                                              |                                                                           |                                                                        |                                                                                          |                                                        |                                                  |                                             |                                    |                    |
| 1 Cahill Suzanne Mary (2007) [42]    | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 2 Epstein Iris (2016) [47]           | Y                                                            | Y                                             | N                                                                            | N                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 3 Farina Nicolas (2019) [49]         | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | N                                                | Y                                           | Y                                  | Moderate           |
| 4 Gelonch Olga (2019) [51]           | Y                                                            | Y                                             | U                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | U                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 5 Hebesberger Denise (2017) [56]     | Y                                                            | Y                                             | U                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | Moderate           |
| 6 Inoue Kaoru (2021) [59]            | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 7 Khosla Rajiv (2021) [61]           | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |

**Table 5** (continued)

| First Author and Publication Year     | (1) Was there a clear statement of the aims of the research? | (2) Is a qualitative methodology appropriate? | (3) Was the research design appropriate to address the aims of the research? | (4) Was the recruitment strategy appropriate to the aims of the research? | (5) Was the data collected in a way that addressed the research issue? | (6) Has the relationship between researcher and participants been adequately considered? | (7) Have ethical issues been taken into consideration? | (8) Was the data analysis sufficiently rigorous? | (9) Is there a clear statement of findings? | (10) How valuable is the research? | Overall Assessment |
|---------------------------------------|--------------------------------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------|---------------------------------------------|------------------------------------|--------------------|
| 8 Mehtrabian Shima (2015) [66]        | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 9 Moyle Wendy (2018) [67]             | Y                                                            | Y                                             | N                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 10 Orwood Roger (2008) [69]           | Y                                                            | Y                                             | U                                                                            | N                                                                         | Y                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 11 Pino Maribel (2015) [70]           | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 12 Rikonen Merja (2013) [72]          | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 13 Stara Vera (2021) [76]             | Y                                                            | Y                                             | U                                                                            | Y                                                                         | U                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | Y                                  | Moderate           |
| 14 Stavropoulos Thanos G. (2021) [77] | Y                                                            | Y                                             | N                                                                            | Y                                                                         | U                                                                      | N                                                                                        | Y                                                      | N                                                | Y                                           | Y                                  | Moderate           |
| 15 Van Assche Maaike (2021) [78]      | Y                                                            | Y                                             | U                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 16 Wada Kazuyoshi (2007) [80]         | Y                                                            | Y                                             | N                                                                            | U                                                                         | Y                                                                      | U                                                                                        | Y                                                      | U                                                | Y                                           | N                                  | Moderate           |
| 17 Wada Kazuyoshi (2008) [81]         | Y                                                            | Y                                             | N                                                                            | U                                                                         | Y                                                                      | N                                                                                        | Y                                                      | U                                                | Y                                           | N                                  | Moderate           |
| 18 Wang Rosalie (2017) [82]           | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |
| 19 Wu Ya-Huei (2014) [84]             | Y                                                            | Y                                             | Y                                                                            | Y                                                                         | Y                                                                      | N                                                                                        | Y                                                      | Y                                                | Y                                           | Y                                  | High               |

<sup>a</sup> Critical Appraisal Skills Programme (2018). CASP Qualitative Checklist. [online] Available at: <https://casp-uk.net/images/checklist/documents/CASP-Qualitative-Studies-Checklist-2018.pdf>. Accessed: 17/08/2023; <sup>b</sup>Y, yes; <sup>c</sup>N, no; <sup>d</sup>U, unclear

declared this has improved their moods, positively ameliorating their QoL [43, p. 9]. Companion-types social robots, e.g., PARO, are also defined as “calming” [58, p. 494] and “reassuring presences” [44, 46] capable of reducing stress, anxiety, fear, worry for future uncertainties [78]. In a few studies, SAR are also defined as “funny”, “enjoyable”, and “entertaining” [50, 56, 61, 70, 71, 73], and their presence as potentially capable of creating a “positive atmosphere” both in house [80] and within nursing homes [56, 59].

However, in four publications [44, 56, 61, 71], SAR are also considered as potential sources of negative emotions. Such negative impact is sometimes the consequence of older adults getting bored by the invariant program and functionalities of the robot, which, over time, offered the same familiar contents [56, p. 424]. More common is, however, the emotional distress generated by a twofold scenario. Some older adults felt deeply “upset” when the robot was withdrawn [44, p. 135], as they already developed some attachment to the robot, enjoying its positive outcomes. This mainly occurs with non-humanoid robots, e.g., PARO. On the other hand, with humanoid robots (e.g., Betty robot), older adults declared to have experienced “disillusion”, because of a mismatch between original expectations related to the robot and the way in which the robot corresponded to them, for instance for having failed to reply in a proper manner to the older adult’s question [61]. This has also a relational connotation, as we are going to discuss below (see Relational/interpersonal vulnerability section).

As to the negative emotional impact created by ET, mainly CMT and UNMT, older adults generally declare that the novelty of the situation may create insecurity [40], but in some cases even confusion [67]. Confusion and agitation may also be the result of some specific functionalities of the technology which, despite being originally created to help older adults in their daily activities, may lead to a negative outcome. For instance, the beep alarm installed on the UNMT device to indicate the time for medicines, confused and further agitated the older woman enrolled in one study, who declared she was not able to downsize her antipathy towards the device even when the explanation of its functionalities was provided [48, p. 995]. In another case, the pressure provided by the technology was so high that older adults adapted their behaviours to be compliant with it: the awareness of the presence of bed sensors, which may have sent an alarm to their caregivers, pushed some older adults to “rush to get back to bed before an alert was triggered” [55, p. 7]. In other cases, the awareness of not being able to be fully compliant with the technology demands created embarrassment [42], and even feelings of stupidity [14].

**Table 6** Ethically-related impact of ET on older adults' vulnerabilities, as gleaned from perceptions and experiences of the older adults<sup>a</sup>

| Dimensions of Vulnerability                                                           |                                                                                                                                                            | TOT |
|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>1. Physical Dimension</b>                                                          |                                                                                                                                                            | 34  |
| 1.1 Non-pathological physical/physiological bodily deterioration related to ageing    | 14, 30, 44, 47, 48, 49, 50, 53, 55, 56, 57, 65, 66, 70, 71, 77, 78, 82, 83, 84, 85                                                                         | 21  |
| 1.2 Pathological physical/physiological conditions related to ageing                  | 14, 42, 43, 44, 45, 46, 47, 48, 50, 51, 52, 55, 57, 58, 60, 62, 63, 65, 66, 69, 70, 71, 72, 77, 79, 82, 84, 85                                             | 28  |
| <b>2. Psychological Dimension</b>                                                     |                                                                                                                                                            | 43  |
| 2.1 Cognitive                                                                         | 31, 34, 41, 43, 45, 51, 57, 58, 62, 63, 66, 70, 71, 73, 76, 78, 82, 84, 85, 86                                                                             | 20  |
| 2.1 Emotional                                                                         | 14, 30, 31, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 50, 51, 55, 56, 58, 59, 60, 61, 62, 66, 67, 68, 69, 70, 71, 72, 73, 74, 77, 78, 79, 80, 83, 84, 85, 86 | 39  |
| <b>3. Relational/interpersonal dimension</b>                                          |                                                                                                                                                            | 35  |
| 3.1 Ontological interdependence of the human condition                                | 41                                                                                                                                                         | 1   |
| 3.2 (Inter)dependence in real-world settings                                          |                                                                                                                                                            |     |
| 3.2.1 Relationships between older adults, caregivers, personnel and/or family members | 14, 30, 31, 39, 40, 41, 42, 43, 33, 45, 46, 50, 51, 55, 57, 58, 60, 64, 65, 66, 70, 71, 74, 73, 76, 77, 78, 79, 80, 82, 83, 84, 85                         | 33  |
| 3.2.2 Human-robot interaction                                                         | 30, 43, 45, 56, 57, 58, 70, 79, 80, 81, 82, 83, 84, 85                                                                                                     | 14  |
| <b>4. Socio-cultural, economic and political dimension</b>                            |                                                                                                                                                            | 14  |
| 4.1 Socio-cultural dimension                                                          |                                                                                                                                                            |     |
| 4.1.2 Broadly understood                                                              | 56, 83                                                                                                                                                     | 2   |
| 4.1.3 Isolation/exclusion from social life                                            | 64, 71                                                                                                                                                     | 2   |
| 4.1.4 Marginalisation (also related to racism)                                        |                                                                                                                                                            |     |
| 4.1.5 Stigmatisation (i.e. ageism)                                                    |                                                                                                                                                            |     |
| 4.1.6 Related to gender                                                               |                                                                                                                                                            |     |
| 4.1.7 Low education level attained                                                    |                                                                                                                                                            |     |
| 4.2 Economic dimension                                                                | 45, 54, 55, 56, 57, 66, 70, 78, 79, 82, 83, 85                                                                                                             | 12  |
| 4.3 Political dimension                                                               | 56, 83                                                                                                                                                     | 2   |
| <b>5. Moral dimension</b>                                                             |                                                                                                                                                            | 28  |
| 5.1 Decisional autonomy/self-determination                                            | 39, 40, 43, 52, 55, 57, 62, 67, 75, 77, 78, 79                                                                                                             | 12  |
| 5.2 Privacy/confidentiality                                                           | 45, 47, 51, 66                                                                                                                                             | 4   |
| 5.3 Privacy/Control and surveillance                                                  | 31, 47, 52, 55, 66, 70, 74, 75                                                                                                                             | 8   |
| 5.4 Privacy/Integrity and identity                                                    | 47, 55, 57, 84                                                                                                                                             | 4   |
| 5.5 Stigmatisation and Infantilisation                                                | 41, 42, 44, 51, 55, 57, 60, 63, 65, 70, 74, 75, 83, 84, 85                                                                                                 | 15  |
| <b>6. Existential/spiritual dimension</b>                                             |                                                                                                                                                            | 3   |
| 6.1 Trait of human existence                                                          |                                                                                                                                                            |     |
| 6.2 Experience of human finitude                                                      | 85                                                                                                                                                         | 1   |
| 6.3 Acquisition of new meaning(s)                                                     | 44, 57                                                                                                                                                     | 2   |
| 6.4 Loss of meaning                                                                   |                                                                                                                                                            |     |

<sup>a</sup> Some papers may appear several times, under different classification

### Relational/Interpersonal vulnerability

Relational/Interpersonal Vulnerability (RV) appears in 35 out of the 51 publications included in the review, being, therefore, the second most recurrent vulnerability identified by older adults with cognitive impairments, after PV. In our taxonomy of older adults' vulnerabilities, RV referred to both "ontological interdependence", namely vulnerability arising from the recognition of human beings as intrinsic relational creatures, and "interdependence in real-world settings", that is, vulnerability deriving from daily relationships, in particular among older adults, and between older adults and their caregivers.

While the first meaning of RV was almost absent from our selected articles being reported only in one paper [41], all the 35 publications referred to the second meaning, thus exploring the impact of ET on the older adults' current and/or future relationships. Within this broad relational domain, we identified two emerging themes: most publications ( $N = 21$ ) focused on what we defined as "Relationships between older adults, caregivers, personnel and/or family members" [14, 31, 39–42, 44, 47, 50, 51, 55, 60, 64–66, 71–75, 77, 78], two papers looked at the RV only through the angle of the "human-robot interaction" [56, 81], while twelve publications analysed ET's

**Table 7** Ethically-related impact of ET on older adults' vulnerabilities, as gleaned from perceptions and experiences of the older adults<sup>a</sup>

| <b>PSYCHOLOGICAL VULNERABILITY</b><br><b>(N = 43/51)</b>                                                                                                                                                              |                                                                                                                                                            |                                                                                                                                               |                                                                                                                                                                                              |                                                                                                                                                                      |                                                                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>Cognitive</b><br><b>(N = 20/43)</b>                                                                                                                                                                                |                                                                                                                                                            |                                                                                                                                               | <b>Emotional</b><br><b>(N = 39/43)</b>                                                                                                                                                       |                                                                                                                                                                      |                                                                                    |
| Positive impact, i.e. facilitator<br>(Technology type)                                                                                                                                                                | Negative impact, i.e., barrier<br>(Technology type)                                                                                                        | Both                                                                                                                                          | Positive impact, i.e. facilitator<br>(Technology type)                                                                                                                                       | Negative impact, i.e., barrier<br>(Technology type)                                                                                                                  | Both                                                                               |
| N = 19                                                                                                                                                                                                                | N = 1                                                                                                                                                      | NA                                                                                                                                            | N = 18                                                                                                                                                                                       | N = 14                                                                                                                                                               | N = 7                                                                              |
| 31 (UNMT), 39 (CMT & UNMT), 41 (CMT), 43 (SAR), 45 (CMT & UNMT), 51 (UNMT), 58 (SAR), 62 (CMT & UNMT), 63 (CMT), 66 (UNMT), 70 (SAR), 71 (SAR), 73 (SAR), 76 (UNMT), 78 (SAR), 82 (SAR), 84 (SAR), 85 (SAR), 86 (SAR) | 57 (CMT & UNMT)                                                                                                                                            |                                                                                                                                               | 30 (SAR), 31 (UNMT), 41 (CMT), 43 (SAR), 46 (SAR), 47 (UNMT), 50 (SAR), 58 (SAR), 59 (SAR), 62 (CMT & UNMT), 69 (UNMT), 70 (SAR), 73 (SAR), 78 (SAR), 80 (SAR), 83 (SAR), 84 (SAR), 86 (SAR) | 14 (CMT), 39 (CMT & UNMT), 40 (UNMT), 41 (CMT), 48 (UNMT), 51 (UNMT), 55 (UNMT), 60 (CMT), 66 (UNMT), 68 (CMT), 74 (UNMT), 77 (UNMT), 79 (CMT, UNMT & SAR), 85 (SAR) | 44 (SAR), 45 (CMT & UNMT), 56 (SAR), 61 (SAR), 67 (VRT), 71 (SAR), 72 (CMT & UNMT) |
| <b>RELATIONAL VULNERABILITY</b><br><b>(N = 35/51)</b>                                                                                                                                                                 |                                                                                                                                                            |                                                                                                                                               |                                                                                                                                                                                              |                                                                                                                                                                      |                                                                                    |
| <b>Ontological interdependence</b><br><b>(N = 1/35)</b>                                                                                                                                                               | <b>Relationships between older adults and other individuals</b><br><b>(N = 33/35)</b>                                                                      |                                                                                                                                               |                                                                                                                                                                                              | <b>Human-robot interaction</b><br><b>(N = 14/35)</b>                                                                                                                 |                                                                                    |
|                                                                                                                                                                                                                       | Positive impact, i.e. facilitator<br>(Technology type)                                                                                                     | Negative impact, i.e., barrier<br>(Technology type)                                                                                           | Both                                                                                                                                                                                         | Positive impact, i.e. facilitator<br>(Technology type)                                                                                                               | Negative impact, i.e., barrier<br>(Technology type)                                |
|                                                                                                                                                                                                                       | N = 14                                                                                                                                                     | N = 12                                                                                                                                        | N = 7                                                                                                                                                                                        | N = 2                                                                                                                                                                | N = 3                                                                              |
|                                                                                                                                                                                                                       | 31 (UNMT), 42 (CMT), 43 (SAR), 44 (SAR), 45 (CMT & UNMT), 58 (SAR), 65 (CMT), 70 (SAR), 71 (SAR), 72 (CMT & UNMT), 73 (SAR), 76 (UNMT), 78 (SAR), 80 (SAR) | 14 (CMT), 30 (SAR), 47 (UNMT), 50 (SAR), 51 (UNMT), 57 (CMT & UNMT), 60 (CMT), 64 (CMT), 66 (UNMT), 77 (UNMT), 79 (CMT, UNMT & SAR), 83 (SAR) | 39 (CMT & UNMT), 40 (UNMT), 41 (CMT), 55 (UNMT), 82 (SAR), 84 (SAR), 85 (SAR)                                                                                                                | 43 (SAR), 56 (SAR)                                                                                                                                                   | 30 (SAR), 84 (SAR), 85 (SAR)                                                       |
| <b>PHYSICAL VULNERABILITY</b><br><b>(N = 34/51)</b>                                                                                                                                                                   |                                                                                                                                                            |                                                                                                                                               |                                                                                                                                                                                              |                                                                                                                                                                      |                                                                                    |
| <b>Non-pathological physical/physiological deterioration related to ageing</b><br><b>(N = 21/34)</b>                                                                                                                  |                                                                                                                                                            |                                                                                                                                               | <b>Pathological physical/physiological conditions related to ageing</b><br><b>(N = 28/34)</b>                                                                                                |                                                                                                                                                                      |                                                                                    |
| Positive impact, i.e. facilitator<br>(technology type)                                                                                                                                                                | Negative impact, i.e., barrier<br>(technology type)                                                                                                        | Both                                                                                                                                          | Positive impact, i.e. facilitator<br>(technology type)                                                                                                                                       | Negative impact, i.e., barrier<br>(technology type)                                                                                                                  | Both                                                                               |
| N = 11                                                                                                                                                                                                                | N = 6                                                                                                                                                      | N = 4                                                                                                                                         | N = 26                                                                                                                                                                                       | NA                                                                                                                                                                   | N = 3                                                                              |

**Table 7** (continued)**PHYSICAL VULNERABILITY****(N = 34/51)**

| <b>Non-pathological physical/physiological deterioration related to ageing<br/>(N = 21/34)</b>                     |                                                            |                                                | <b>Pathological physical/physiological conditions related to ageing<br/>(N = 28/34)</b>                                                                                                                                                                                                                          |                                      |  |
|--------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|--|
| 47 (UNMT), 48 (UNMT), 49 (UNMT), 53 (UNMT), 65 (CMT), 66 (UNMT), 70 (SAR), 77 (UNMT), 82 (SAR), 84 (SAR), 85 (SAR) | 24 (CMT), 30 (SAR), 50 (SAR), 56 (SAR), 71 (SAR), 83 (SAR) | 44 (SAR), 55 (UNMT), 57 (CMT & UNMT), 78 (SAR) | 24 (CMT), 41 (CMT), 42 (SAR), 44 (SAR), 45 (CMT & UNMT), 46 (SAR), 47 (UNMT), 48 (UNMT), 50 (SAR), 51 (UNMT), 52 (CMT & UNMT), 58 (SAR), 60 (CMT), 62 (CMT & UNMT), 63 (CMT), 65 (CMT), 66 (UNMT), 69 (UNMT), 70 (SAR), 71 (SAR), 72 (CMT & UNMT), 77 (UNMT), 79 (CMT, UNMT & SAR), 82 (SAR), 84 (SAR), 85 (SAR) | 44 (SAR), 55 (UNMT), 57 (CMT & UNMT) |  |

**MORAL VULNERABILITY****(N = 28/51)**

| <b>Decisional autonomy/self-determination<br/>(N = 12/28)</b>              |                                                           |                                            | <b>Privacy/confidentiality<br/>(N = 4/28)</b>             |                                                           |            |
|----------------------------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|------------|
| Positive impact, i.e. facilitator (technology type)<br>N = 6               | Negative impact, i.e., barrier (technology type)<br>N = 3 | Both<br>N = 3                              | Positive impact, i.e. facilitator (technology type)<br>NA | Negative impact, i.e., barrier (technology type)<br>N = 4 | Both<br>NA |
| 39 (CMT & UNMT), 40 (UNMT), 43 (SAR), 52 (CMT & UNMT), 77 (UNMT), 78 (SAR) | 55 (UNMT), 75 (UNMT), 79 (CMT & UNMT & SAR)               | 57 (CMT & UNMT), 62 (CMT & UNMT), 67 (VRT) |                                                           | 45 (CMT & UNMT), 47 (UNMT), 51 (UNMT), 66 (UNMT)          |            |

**SOCIO-CULTURAL, ECONOMIC AND POLITICAL VULNERABILITY****(N = 15/51)****Socio-cultural****(N = 4/15)**

| <b>Broadly understood<br/>(N = 2)</b>                     |                                                                                 |            | <b>Isolation/exclusion from social life<br/>(N = 2)</b>                  |                                                                       |            |
|-----------------------------------------------------------|---------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------|------------|
| Positive impact, i.e. facilitator (technology type)<br>NA | Negative impact, i.e., barrier (technology type)<br>N = 2<br>56 (SAR), 83 (SAR) | Both<br>NA | Positive impact, i.e. facilitator (technology type)<br>N = 1<br>71 (SAR) | Negative impact, i.e., barrier (technology type)<br>N = 1<br>64 (CMT) | Both<br>NA |

**EXISTENTIAL/SPIRITUAL VULNERABILITY****(N = 3/51)**

| <b>Experience of human finitude<br/>(N = 1/3)</b>         |                                                                       |            | <b>Acquisition of new meaning(s)<br/>(N = 2/3)</b>                                        |                                                        |            |
|-----------------------------------------------------------|-----------------------------------------------------------------------|------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------|------------|
| Positive impact, i.e. facilitator (technology type)<br>NA | Negative impact, i.e., barrier (technology type)<br>N = 1<br>85 (SAR) | Both<br>NA | Positive impact, i.e. facilitator (technology type)<br>N = 2<br>44 (SAR), 57 (CMT & UNMT) | Negative impact, i.e., barrier (technology type)<br>NA | Both<br>NA |

**USABILITY****(N = 28/51)**

| <b>Usability issues<br/>(N = 27/28)</b>             |                                                  |      | <b>Usability as a means to address vulnerability<br/>(N = 4/28)</b> |                      |  |
|-----------------------------------------------------|--------------------------------------------------|------|---------------------------------------------------------------------|----------------------|--|
| Positive impact, i.e. facilitator (technology type) | Negative impact, i.e., barrier (technology type) | Both |                                                                     | To improve usability |  |



**Table 7** (continued)

| USABILITY<br>(N=28/51)        |                                                                                                                                                                                                                                                                    |                                         |                                                           |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-----------------------------------------------------------|
| Usability issues<br>(N=27/28) |                                                                                                                                                                                                                                                                    |                                         | Usability as a means to address vulnerability<br>(N=4/28) |
| N=2                           | N=21                                                                                                                                                                                                                                                               | N=4                                     | N=4                                                       |
| 51 (UNMT), 69 (UNMT)          | 14 (CMT), 39 (CMT & UNMT), 45 (CMT & UNMT), 46 (UNMT), 47 (UNMT), 49 (UNMT), 50 (SAR), 55 (UNMT), 56 (SAR), 57 (CMT & UNMT), 62 (CMT & UNMT), 63 (CMT), 66 (UNMT), 68 (CMT), 74 (UNMT), 75 (UNMT), 76 (UNMT), 77 (UNMT), 79 (CMT & UNMT & SAR), 82 (SAR), 85 (SAR) | 42 (CMT), 60 (CMT), 78 (SAR), 84 (SAR), | 42 (CMT), 47 (UNMT), 75 (UNMT), 78 (SAR)                  |

<sup>a</sup> Some papers may appear several times, under different classifications

impact on both these aspects [41, 43, 45, 57, 58, 70, 79, 80, 82–85].

If we start considering ET implications on the “relationships between older adults and other individuals”, two main results may be reported.

*First*, ET have both a positive and a negative impact on this specific type of RV, being the advantages and disadvantages almost homogeneously distributed in our selected studies: fourteen publications consider ET as facilitators of RV [31, 42–45, 58, 65, 70–73, 76, 78, 80], while twelve publications consider ET as barriers to RV as interpreted upon [14, 30, 47, 50, 51, 57, 60, 64, 65, 77, 79, 83], and seven studies define them as both facilitators and barriers [39–41, 55, 82, 84, 85].

*Second*, both positive and negative aspects may be broadly referred to ET in general, or at least to the most recurrent technologies included in the studies, UNMT and SAR, therefore allowing more general considerations on the impact of ET on RV.

As to the positive impact of ET on RV, interviewed older adults reported that both ICT technologies and SAR with communication interfaces sustain social connection [39, 44, 72] and/or promote a feeling of connectedness [42], thus helping reducing isolation and loneliness [39, 43, 44, 70, 76, 78, 80, 82]. In one case, the impact of the ET was so important that it “compensated the lack of caregivers” [85, p. 11]. ET appear as facilitators of social connections and “enhancers of socializing opportunities” [44] in three main respects, among older adults [43], between older adults and their caregivers [71], and, within nursing homes, between older adults, visitors, and staff [44, 58, 73]. For instance, PARO was considered by one participant as “a conversation piece” able to make you feel at home and whose presence stimulates conversation [58, p. 495]. The same robot was also used as a welcoming way for the staff to know their patients [58, pp. 495–496], in a way that was perceived as calming and respectful of older adults’ emotions [58, p. 494]. Only one paper referred to these ET in a less enthusiastic manner, defining them as useful tools for older

adults who may feel the presence of other human beings as particularly intrusive, while considering their implementation in other contexts as a last resort option [81].

Besides providing companionship, thus alleviating feelings of isolation, ET, in providing older adults with support for daily activities, were also positively considered as tools for increased independence, self-management, and control [40–42, 55, 65]. One participant affected by dementia declared, for instance, that, thanks to her CMT, she does no longer have to ask her caregiver what day it is, improving her sense of independence [42, p. 137]. The same feeling is reported by older adults with dementia enrolled in another study testing a UNMT with a GPS tracking device, supporting safe walking. In this case, the participants declared that being able to walk safely and going out the safe zone, gave them a sense of independence, capable to partially re-balance the already delicate relationship with their caregivers [65, p. 8].

These advantages do not prevent older adults enrolled in our studies from identifying also potential challenges posed by ET to RV. As first consideration, several older adults have claimed that, although ideally promoters of independency and self-control, in practice these tools are difficult to use, *de facto* obliging them to be ever more dependent on their caregivers to use them properly [39, 41, 50, 51, 57, 60]. In other words, in spite of their intention, ET risk creating a new obligation, namely, a duty to rely on others, which is regarded with suspect by many [14]. However, this is not always considered as a real disadvantage: for instance, participants using the UNMT Poseidon, i.e., a robotic shower with an emergency alarm, reported that the fact that they may need some help in using the robotic shower is the positive sign that ET cannot fully replace human relationships and interaction [40, p. 9]. On more serious grounds, the most important concern raised by study participants is that the ever-increasing presence of ET, both assistive technologies, UNMT like environmental sensors, and SAR may lead to “poorer interactions” [79, p. 12], even end up losing personal contact, replacing caregivers and personal love with



the anonymous presence of technologies [14, 47, 66, 77, 79, 82, 83]. The same was reported by other older adults when raising their concerns that technology may lead to dehumanization of care relationships. In this respect some participants declared, for instance, that also communicating personal medical needs is easier and more effective in presence of a health care provider, rather than through a “yes or no” machine [14, p. 6].

A complementary perspective concerns the second theme identified in our publications in relation to RV, what we labelled “human-robot interaction”, referring specifically to interactions between older adults with cognitive impairments and SAR. Many of the considerations are already embedded in this topic. However, several studies in this review focus exclusively on it, offering valuable insights into RV. Participants report that interacting with SAR fosters a new form of relationality between older adults and machines. In settings where the humanoid robot MARIO was used, some even began referring to it as a friend, asking questions about its wellbeing [43, p. 7], interacting with it as a long-standing embodied presence. However, beyond initial enthusiasm, acceptance of the robot stemmed from a process of ‘humanisation’ of the robot itself: instead of recognising it as a machine, participants tended to attribute to it human traits, e.g., reciprocity, care, trust, and to refer to the robot as ‘he’ or ‘she’ [43, p. 7]. This may also help clarifying why in some cases participants used a negative frame to refer to the ‘human-robot interaction’. When participants realized that the SAR is incapable of reciprocity [40], lacks spontaneity [84], and above all authenticity [85] – in other words, it is not a human being – participants appeared relationally wounded, disillusioned and disappointed.

### **Physical vulnerability**

Physical Vulnerability (PHV) is addressed in 34 out of the 51 publications reviewed, making it the third most frequently identified vulnerability among older adults with cognitive impairments. In our taxonomy, PHV encompasses both physiological conditions (e.g., instability, reduced mobility, loss of power, problems with vision and hearing) and pathological deteriorations (e.g., disability), which tend to disproportionately affect this population. While all the studies considered in this review involve older adults with cognitive impairments, some participants also experience additional physical vulnerabilities. The impact of ET on PHV may or may not be related to the existing cognitive impairment. As a result, a small number of studies present findings applicable to cognitively healthy older adults as well – for instance, those specifying the minimum safe distance between a robot and an older adult. In details, of the 34 studies exploring PHV, thirteen publications explore the impact of ET on a

pathological condition, i.e. the specific cognitive impairment affecting the older adult population enrolled in the study, such as dementia [42, 43, 45, 46, 51, 52, 58, 60, 62, 63, 69, 72, 79]; fifteen publications investigate ET impact on both pathological and physiological bodily deteriorations related to ageing [14, 44, 47, 48, 50, 55, 57, 65, 66, 70, 71, 77, 82, 84, 85]; and six publications focus on the effect of ET on the physiological deterioration of older adults [41, 49, 53, 56, 78, 83].

Looking at the results (see Table 7), in general, ET included in our review have a positive impact on older adults’ PHV, as reported in 28 out of 34 studies included [14, 42–53, 58, 60, 62–64, 66, 69–72, 77, 79, 82, 84, 85]; in 4 studies ET are framed as both facilitators and barriers to PHV [44, 55, 57, 78]; only 6 studies report potential concerns related to the use of ET with regard to PHV [14, 30, 50, 56, 71, 83].

As to the positive impact of ET on PHV, some recurrent themes emerge, among which *safety and security* are paramount. Different types of CMT and UNMT tame PHV as they improve older adults’ security [42, 53, 55, 58, 63, 69] and create a feeling of safety [47, 50, 51], thus reducing both actual and perceived risks [72, 77, 79]. Some CMT developed to promote night-time day-time orientation and to indicate the correct day/time have shown to have an impact on older adults’ orientation, thus providing them with a sense of reassurance [42, p. 37]. The same are also defined as fall prevention tools, thus having a positive impact on older adults’ safety. Other ET, e.g., homecare robots [46] and environmental sensors [47], can help with personal safety [46] by measuring vital signs for comorbid conditions (e.g., blood pressure for hypertensives). Some UNMT, endowed with telecameras and emergency alarms, may get to the same result by detecting abnormalities and reacting to abnormal activities (e.g., lack of motion, falls) [48, 50–52]. Another very important issue related to safety is wandering, a phenomenon typically characterizing older adults affected by serious cognitive impairments, while still capable of walking. Some UNMT with GPS tracking devices have shown to tame PHV, because they promote safe walking, preventing risks associated to wandering [65]. A correlated theme was *self-management* [43, 45–47, 50]. Both CMT and UNMT designed to provide assistance to older adults were perceived to have a positive impact on the management of their own health, thus impacting on their physical wellbeing. By providing alerts, assistive technologies may act as medicine and task reminders [46, 48], in many cases improving treatment adherence, which is a very important problem affecting older adults with cognitive impairments, who tend to forget whether they have already taken their medicines. Other studies report that ET may be also beneficial for physical activity: some UNMT [49] and SAR

[78] were specifically designed to promote *physical exercise* [49, 78] thus helping older adults to be less sedentary. Overall, all these functionalities were positively evaluated by older adults, since, by reducing or minimizing physical risks, they also reduced the likelihood of having to take more drastic steps, e.g., being forced to move to a nursing home [55, p. 7]. A last point which appears very important in this regard, though identified only by one study, was *pain relief*. PARO robot, by giving a sense of safety and reassurance, not only impacted on PV and RV, but lowered older adults' pain [71, p. 10], thus also improving their sleep quality [71, p. 11].

As previously stated, only a small minority of studies report potential concerns related to ET in relation to PHV. Some of them report considerations which apply only to SAR, while other raise more general considerations, applicable to different types of technologies. As to considerations referring only to SAR, some older adults warn on the potential risk of harm or injuries resulting from the human-robot interaction, in case of heavy and big robots [43, 71]. In one publication, for instance, the humanoid robot Pepper suddenly lifted its hand, which may have hit the older adult in case a staff member had not been present during the interaction [30, p. 6]. In general, big robots may trigger discomfort for older adults. When living alone, older adults may also live in small apartments, and it may be challenging to walk if a fairly big robot occupies most of the space [50]. Especially in those cases in which robots are mobile, and we are in front of vision-impaired older adults, it may be difficult to move around the robot [50, p. 14]. This may further worsen their deambulation and motility and make them even more sedentary. As to negative considerations related to ET in general, older adults enrolled in one study testing both CMT and UNMT have stressed that, by totally relying on ET, there is a potential risk of compromising or further worsening one's own already precarious physical abilities [57, p. 6].

### **Moral vulnerability**

The fourth most recurrent dimension identified by older adults with cognitive impairment is Moral Vulnerability (MV), appearing in 28 out of the 51 papers included in the review. In our original taxonomy, MV has both positive and negative connotations. In its positive sense, it refers to respect for older adults' dignity, preferences, and accumulated wisdom; in its negative sense, it highlights risks such as undignified treatment, stigmatisation, and infantilisation. Some of these aspects, such as dignity, may be identified also in articles included in this review. However, given the specific focus on ET, additional themes emerged, many of which align with the broader ethical debates surrounding digital technologies. Accordingly, we identified five themes falling within MV:

(i) decisional autonomy and self-determination [39, 40, 43, 52, 55, 57, 62, 67, 75, 77–79], (ii) privacy interpreted as confidentiality [45, 47, 51, 66], (iii) concern for privacy in relation to control and surveillance [31, 47, 52, 55, 66, 70, 74, 75], (iv) concern for privacy in relation to personal identity and integrity [47, 55, 57, 84]; (v) stigmatization and infantilization [41, 42, 44, 51, 55, 57, 60, 63, 65, 70, 74, 75, 83–85]. As shown in Table 7, ET appear to have both a positive and negative impact on (i), therefore being potentially facilitators of and barriers to older adults' decisional autonomy and self-determination. However, the impact of ET on all the themes falling within the broad category of MV is almost negative, thus potentially threatening confidentiality and personal integrity, raising concerns regarding surveillance, and leading to stigmatization and infantilization. As for the previous dimensions of older adults' vulnerability, we will first present the advantages of ET on MV, then proceed with the identification of their potential challenges, as reported by older adults with cognitive impairments.

The positive impact of ET to MV concerns *decisional autonomy and self-determination*. In general, older adults with cognitive impairments report that ET partially increased and/or helped restoring their independence [39, 40]. This means, in practice, that ET had a role in expanding older adults' repertoire of activities [57, p. 8], from the simplest daily activities to the more complex ones. As to the former, for instance, in a study where older adults were provided with a robotic shower, such a technology promoted a more independent shower situation: "I can shower when I want, and not when someone comes and will shower me. With [the robotic shower] I can shower independently whether someone helps me or not" [40, p. 7]. As to the latter, older adults enrolled in a study employing the humanoid robot MARIO reported that the robot acted as "wishes enabler" [43, p. 9], allowing them experiencing that they were still in part capable of self-determination. The same feeling is reported in another study employing another humanoid robot, James, where self-determination was operationalized in the possibility of not being forced to interact with others, if this appears not in line with one own's wishes: "I like being able to do what I wanted and when I wanted to do it. Before I had played some games in a group, but you'd always have to take other people into account. (...) With the robot you can kind of do your own thing" [78, p. 7]. However, as reported by other older adults, ET may be considered as "autonomy-promoting devices" [52, p. 129] only as long as final users are really put in the condition of understanding the main mechanisms and functionalities underlying these technologies [55]. In case this does not happen, the elder does not really understand what is at stake, thus perceiving herself to be without any control on the device [67, p. 482].

Notwithstanding its positive aspects on autonomy and self-determination, ET seem to play mostly as barriers to MV. First of all, several interviewees declared they could not entirely rely upon (and feel safe) when using both CMT and UNMT, describing “very risky” and “dangerous” their use with respect to *confidentiality*, for instance in case they got hacked “while using banking services or misplaced the device somewhere” [45, p.5].

Another very important set of concerns raised by participants is that monitoring techniques may fall into the slippery slope of *surveillance technologies*. Perceiving themselves as subject to 24/7 monitoring led some older adults to reject even the simplest CMT, declaring that such an interference should not be permissible, except for very specific – seriously compromised – situations [57]. In addition to critiques related to monitoring in general, other older adults have claimed that being monitored has also a negative impact in terms of the feelings it generates, e.g., powerlessness. By being monitored, older adults enrolled in one study started considering themselves as powerless, and therefore prematurely in necessity of others’ help. As a seventy-year-old man said: “(...) I am being forced in little ways to become dependent on somebody else. I’m being checked up on... It’s an interesting aspect but not one that I necessarily like” [55, p. 8]. In another study, the feeling of being monitored was so unbearable for participants, that some older adults removed the entire technical kit, providing the desire of not being surveilled as main explanation for their action [31, p. 5].

Awareness of being surveilled can trigger complex emotions, some strong enough to challenge older adults’ sense of *personal identity and integrity*. Feeling intruded upon while being monitored, some developed reactive negative feelings, which further distanced them from the technology. One older adult, for instance, declared that the technology has made him feeling stupid: “We’re not so stupid; we’re only old. We’re not stupid” [47, p. 46]. Other older adults felt humiliated by being monitored by a robot, because of several reasons: some of them considered undignifying asking humans to be looked after by machines, others considered robots too simplistic to be used in an extremely sensitive context (i.e., dementia) [47], some others reported that, by being monitored, they were put in front of all their deficiencies and mistakes as human beings affected by cognitive impairments, which further worsened their condition [57]. In other cases, personal integrity was compromised when older adults did no longer recognize their homes after the changes that were made to install pervasive technologies: “When I came in from hospital, (...) I said, ‘It isn’t my house now’. I’ve been here forty-four years and it looks entirely different” [55, p. 6].

A final set of challenges posed by ET and potentially impacting MV related to the association with *stigmatization and infantilization*. In our included publications, stigmatization arises when older adults using pervasive technologies identify themselves – or feel perceived – primarily through the lens of their illness. In one study using observations as data collection tool, for instance, “a lady with dementia was prone to removing the panel box and hiding it in her hand-bag as she did not wish to be reminded of her memory loss problem” [41, p. 139]. Other older adults reported that the technology used does not generally correspond to the person’s self-image [56]. Therefore, identification with or reduction to their illness is a widespread phenomenon affecting older adults with cognitive impairments, which tend to be maximized rather than minimized by ET. Another related theme is “social embarrassment” [51, 55, 74, 75]. The problem is not only older adults’ own feeling of being ill, but also their representations in others’ mind and within the society in general. In a study, a participant wearing the device was concerned that simplicity of ET functions would make his friends look upon him “as a ‘person with Alzheimer’s’ who needs an assistive device, and not the Sven they formerly knew” [60, p. 109]. Several older adults declared they felt embarrassed or were worried about the comments the ET might provoke [51]. In many cases the appearance of the devices [51], but also their noise [74], weight, and visibility [75], was an issue. In general, almost all older adults reported that it is very important that ET are discreet, otherwise they would feel too embarrassed in front of others and would restrict their use only to their houses [57, p. 6]. The risk for infantilization is also present in our selected studies. However, this phenomenon does not appear as the consequence of ET as such, but rather of their uptake in those who take care of older adults, which in turn may affect older adults themselves. A participant enrolled in a study, after having interacted with staff members and other professionals, reported that robots are “toys for children” [75, p.123]. Another participant enrolled in a study employing PARO robot reported that he was told he was too old “to play with this kind of thing” [44, p. 134], which in turn affected his interaction with it. In general, ET seem to exacerbate a negative representation of ageing as lonely, dependent, compromised, which, in many cases “did not correspond to older adults’ actual condition nor to their own identity (...)” [76, p. 808].

#### **Socio-cultural, political, and economic vulnerability**

The fifth most recurrent dimension is Socio-cultural, Political, and Economic Vulnerability (SPEV), being present in 14 out of the 51 papers included in the review. As the label itself suggests, SPEV is an umbrella term, which refers to those vulnerabilities emerging as a result of

unfair or unjust socio-cultural, political, and economic conditions.

In our selected studies, all referring to older adults with cognitive impairments, most papers discuss SPEV focusing specifically on its *economic* subdomain, thus reporting the impact of ET on the economic dimension of SPEV [45, 54–57, 66, 70, 78, 79, 82, 83, 85]. Among them, only one paper [85] reports a potential economic advantage of ET. Here, the interviewed older adult appreciated the potential economic benefit of the SAR, compared to other forms of assistance, as “it costs less to have a robot 24/7 with you than to hire someone” [85, p.11].

All the other eleven publications discussing the economic impact of ET frame it only in negative terms. In general, participants report that the technology proposed is “too expensive to purchase” [45, p. 6; 66, 70, 79, 82, 83, 84]. This may be even worse if we consider that the context is that of older adults with serious cognitive impairments, who tend to lose devices, especially the smaller ones (e.g., wearables), being then obliged to purchase them again, thus leading to “repeated expenses” [54, p. 9]. Precisely the low sustainability of costs created a “great deal of uncertainty” [55, p. 8], even in those who were ideally enthusiastic of the technology [57], and it was also defined as a concrete barrier to ET implementation in real-world settings [78, p. 8].

Related to the economic reasonings on the potential poor cost-effectiveness of ET, two papers discuss SPEV focusing specifically on the *political* implications of ET [56, 83]. Interviewed older adults raised critical remarks not only about the cost of technologies, but also on the institutional choices of allocating resources on technological rather than traditional forms of assistance. In their view, we should retain “from financing robotic projects” and devote “human resources to the care of the elderly” [83, p. 124].

Finally, four papers discuss socio-cultural implications of ET [56, 64, 71, 83]. Except for one study where older adults report a potential advantage of ET as a way to tame social isolation of those older adults who are socially inactive [71, p. 10], the remaining three publications point on the negative implications of ET on SPEV. Here, the emerging – negative – theme is that of the potential replacement of the care activity traditionally considered as a ‘human labour’ with the same as a purely technological and impersonal activity. In this regard, some older adults complained about the fact that there is “already too much technology dominating their everyday lives”, and that this will probably lead “in the long run, to replace care staff”, which is considered by them as a non-desirable development [56, p. 423]. All this process is considered by adults themselves to have the potential for a progressive and irreversible dehumanization of our societies [83, p.124].

### **Existential/Spiritual vulnerability**

Existential/spiritual vulnerability (ESV) appears in 3 out of the 51 publications included in the review. In our original taxonomy, ESV was associated with the experience of human finitude or the awareness of the proximity of death, generally more pronounced in adulthood and old age, as well as the concept of ‘meaning’, referred, positively, to the importance of authenticity in life, and negatively, to the risk of meaninglessness and hopelessness in late life.

In our selected papers, referring to older adults with cognitive impairment, ESV was framed both, negatively, as experience of human finitude [85] and, positively, as possibility for the acquisition of new meaning(s) [44, 57]. Regarding the latter, in one study employing PARO robot, older adults defined it as a reassuring presence, “which enhanced their sense of existence by involving participants in their quest to find meaning in their life” [44, p.133]. One participant also thought that PARO “has spirituality” (*Ibid.*). The human-robot interaction can activate the brain and stimulates it to think and to learn (*Ibid.*). As a companion robot, PARO worked as a support tool, which older people have at their disposal when they feel lonely and need support and assistance. In this way, PARO conveyed warmth and closeness, and the older adults could even establish a kind of “spiritual connection” (*Ibid.*). The use of the robot, therefore, contributed to the creation of meaning, because the activities carried out with PARO seemed to restore the older people’s desire to seek meaning in their lives. Still on this point, in a study employing both CMT and UNMT, older adults thought ET could tame ESV and contribute to the acquisition of new meaning(s), because, when “the technologies fitted and supported important activities and roles,” they “entailed added values” [57, p. 8].

On the other hand, ET may also have a negative impact on ESV, if the latter is related to the concept of human finitude [85]. In one study employing a SAR, older adults reported negative feelings, because in their understanding the robot is associated with life termination: “It must be for people who are very handicapped. It’s not for me... it makes me think that my life is terminated. I’d rather die than live with a robot” [85, p. 10]. Therefore, some participants were reluctant to use the SAR, because such robot seemed to remind them of the impairments or inevitable future deficiencies and frailties associated with ageing and the decay of their body.

### **Bottom-up emerging theme: usability**

An emerging theme not included in our original conceptual framework, but frequently reported by older adults with cognitive impairment, is usability. Usability appears in 28 papers, as an issue (positively or negatively) discussed in relation to the use of ET [14, 39, 41, 45, 47–51,



55–57, 60, 62, 63, 66, 68, 69, 74–79, 82, 84, 85] and/or as a relevant aspect to consider in order to address older adults' vulnerabilities [42, 46, 65, 78].

Among the 27 studies in which usability issues are discussed, two papers [51, 69] report that, according to older adults, ET have a positive impact, because of their ease of use. In both cases, the devices mentioned are UNMT: one is a lifelogging camera, worn around the neck [51]; the other is a smart home system [69]. In 21 papers, instead, usability has emerged as a problematic, negative-impact issue, for several reasons [14, 39, 45, 47–50, 55–57, 62, 63, 66, 68, 74–77, 79, 82, 85]. In particular, the most problematic technologies are UNMT, which are mentioned in 14 papers [39, 45, 47–49, 55, 57, 62, 66, 74–77, 79]. Finally, in 4 studies [42, 60, 78, 84], usability is framed as an ambivalent issue, both positive and negative. As to positive aspects, older adults mention ease of use and usefulness [41, 60, 78], as well as appearance [84]. In fact, older adults considered the robot pleasant, nice, and pretty [p. 806].

Concerning negative aspects, in most cases, older adults complained about the difficulties they encountered while using such technologies [14, 39, 42, 45, 48, 50, 55, 56, 60, 62, 63, 66, 68, 77, 79, 84, 85], which can cause frustration [39, 50], confusion [55], stress [56, 60, 66], distrust [62], anxiety [66, 77], uncertainty of the functional aspects [68], lack of motivation [84], but also feelings of irritation, sadness, disappointment, and loss [63]. For example, these negative emotions may stem from a lack of familiarity with the technologies [39, 45, 48], a lack of digital confidence [50], or from the complexity of the system itself [42, 66]. Such difficulties often hinder older adults from adopting ET or result in early discontinuation [39, 42, 48, 55, 66, 84].

Difficulties in using ET, often due to system complexity, are sometimes linked to awareness of, and concern about, the time and effort needed to learn how to use them properly [14, 55–57, 75].

Another usability problem identified is related to the technical defects of the devices, for instance: its unreliability [47, 56, 74, 75, 77, 82, 84] or its noise [55], which can cause restlessness and annoyance [56], frustration and/or disappointment [56, 84], confusion [74], discomfort [75], anxiety [77] and/or stress [84]. In one study [56], older adults tried to start a conversation with the SAR and “became frustrated after several failed attempts of receiving answers from the robot. Users were observed saying: ‘Look, it does not talk to me!’ ‘I told him something, but he does not say anything!’ or ‘I talked so often to you, but you don’t give me any answers!’” [p. 424].

As foreseeable, design is also a central element [49, 55, 68, 75, 78]. For instance, one participant complained about the roughness of the wearable device GENEactiv Original [49]. In another case, in a study where

traditional technologies (such as smartphones) were used [64], older adults perceived the devices “as too small or (...) heavy and awkward to carry in their pocket or purse” [p. 149]. Such design issues may lead to user discomfort [55, 78].

The four papers which discuss usability as a potentially helpful element for addressing older adults' vulnerabilities [42, 47, 65, 78], report that older adults have proposed technical improvements, mainly to the design of ET, in order to facilitate their use. For instance, they suggest increasing the font dimension of words and numbers on the display panel of the night and day calendar [42], adding the possibility to customize the monitoring system [47], extending battery life of the GPS tracking device [65] and, finally, increasing functionality, mobility, interactivity, and adjustability of the SAR, maybe also enriching robots with language learning skills and training programs in different games [78].

## Discussion

Drawing upon the growing pervasiveness of ET in the assistance and care of the ageing population, this work aimed to systematically map perceptions and experiences of older adults exposed to four categories of technologies – CMT, UNMT, VRT, and SAR – and to examine the ethically-related impact of such technologies on their vulnerabilities. Specifically, we sought to understand whether, from the perspective of older adults, ET exacerbate or mitigate their vulnerabilities. The target population included older adults with a wide range of cognitive impairments, from MCI to severe dementia.

First, this analysis revealed that, when employed in the context of aged care, ET have a twofold, ambivalent effect: they can mitigate existing vulnerabilities, while also creating new ones or exacerbating those already present. This outcome depends both on the type of technology used, and, more importantly, on the dimension of vulnerability considered. For instance, a specific class of UNMT measuring physical activity and sedentary time (e.g., GENEactiv Original, a wrist-worn acceleration sensor) provide older adults with a sense of safety, and thus appear to tame *physical* vulnerability. Conversely, insofar as they cause usability-related frustration, the same class of technologies increase *psychological* vulnerability. This ambivalence of UNMT also emerges in relation to relational/interpersonal vulnerability. On the one hand, UNMT support older adults in performing daily activities independently, thus improving independence, self-management, and a sense of control, while reducing their perceived dependence on others. On the other hand, these technologies risk diminishing the quality or frequency of human interactions, potentially deepening isolation, and the associated feeling of loneliness, among older adults.

*Second*, our analysis shows that ET have a *differential impact* across the six dimensions of vulnerability considered in this study. As detailed in the Results section, ET primarily affect, positively or negatively, the psychological, relational, physical, and moral dimension of older adults' life. Accordingly, these four emerged as the most recurrent dimensions of vulnerability. Differently, the impact of ET on the broad family of socio-cultural, political, and economic vulnerabilities was rarely reported. This is noteworthy, and it may seem counterintuitive or even paradoxical, given the extensive debates on the socio-political and economic implications of new technologies [87, 88]. However, while these debates may sound particularly relevant for academics and policy makers, the same may not equally apply to older adults affected by cognitive impairments, who eventually resulted far more concerned about the narrower impact of ET on their daily life, rather than on the broader implications and long-term consequences deriving from the introduction of ET within contemporary (ageing) societies.

*Third*, this review highlighted that ET are a very heterogeneous group of devices, in terms of software and components used, the specific scope they are developed for and, ultimately, also in terms of the ethical questions which accompany their use. However, despite these differences, our analysis found *consistent patterns* in how older adults perceive vulnerability across all types of ET. This is a key finding, as it supports the broader perspective adopted in this study: treating ET for the ageing population as a unified category, within which similar ethical and experiential concerns emerge. For instance, usability-related frustration is a common experience among older adults, regardless of the specific subcategory of ET they are using. Likewise, the risk of isolation is linked to the general introduction of technology into the daily lives of older adults, whether it be a SAR, a wearable device, or another kind of ET.

Likewise, ET also appear to share a common positive feature, which we refer to as *compensation*. Our analysis shows that the use of CMT, UNMT, SAR and VRT helps older adults with cognitive impairments to *compensate* for their psycho-physical decline caused not only by natural ageing, but also by their underlying pathological conditions. This aligns with the literature on the Selective Optimization with Compensation model [89], particularly studies examining ET as a strategy for managing ageing-related challenges [90–93]. These studies suggest that environmental sensors, wearables and robots, can help older adults maximising their gains and minimising their losses, thereby (consciously or unconsciously) promoting “successful ageing” [89]. In this view, ET, when properly implemented, can support older adults in recognizing, enhancing, and leveraging their residual capacities. This

is also corroborated by our findings, which show that ET may allow to contain physical and cognitive decay, and to improve older adults' health awareness, stimulating to the extent possible their engagement in taking care of themselves. Therefore, framing ET in aged care as a form of compensation offers a more positive perspective on residual autonomy and capacities in contexts inhabited by extremely vulnerable subjects, where the rhetoric of technological empowerment may appear ill-suited [94, 95].

On the other hand, it is important to maintain a critical perspective, despite these seemingly positive results. Indeed, the Selective Optimization with Compensation model may be reductionist, potentially reinforcing an *interventionist logic*, which has been criticised in the Science and Technology Studies (STS) and Age Studies [96–98]. Within this logic, ageing is viewed merely as a *target* for intervention, and technology as a *tool* to address it: “older people are seen as needing technological interventions and an implicit but strong relation between ageing and care is drawn” [98, p. 2848]. As an alternative to this reductionist and ageist view, Peine and Neven propose the “CAT-model” [98], which emphasises the *co-constitution of ageing and technology* [98, p. 2847]. According to this framework, the acceptance, use and impact of ET result from an ongoing accomplishment, in which the life-worlds of older adults, images of ageing, design and technological artefacts intertwine in a dynamic relationship [98]. This approach is particularly valuable because it places users at the centre: “older people are not necessarily passive recipients” of ET, “they may adapt, circumvent, use selectively or decide not to use a technology at all. But the technology can be subsumed in the life-world of older people. Once there, it also starts to re-shape the forms and practices of ageing. Thus, in its most basic form, the CAT-model points to the fact that the design and use are *reciprocally related*” [98, p. 2850].

Finally, despite our own expectations as researchers, the selected studies did not provide sufficient or exhaustive data to answer a potentially related research question, namely, whether older adults themselves offer suggestions to address vulnerabilities related to ET. However, two main observations may help laying the groundwork for future research. First, usability was portrayed in some studies both as a source of vulnerability (e.g., when older adults speak of “poor usability”), and as a factor that, if properly addressed, may itself mitigate other vulnerabilities, such as those arising from technologies not designed with older adults' needs and expectations in mind. In this sense, enhancing usability can be seen as a preliminary solution, suggested by older adults, to mitigate vulnerabilities caused by technology shortcomings.

However, usability alone cannot address all dimensions of vulnerability related to the introduction of ET in aged

care. As some older adults themselves recognise, while certain vulnerabilities can be mitigated by improving usability, others are more complex and require structural interventions, both technological and non-technological. In particular, when discussing relational/interpersonal vulnerability, older adults acknowledged that, although technology can be beneficial, they are highly critical of delegating care labour to machines. In other words, improving remote communication interfaces does not appear to adequately address complaints of social isolation. On the contrary, as older adults themselves pointed out, this may risk further isolation by replacing personal interactions with virtual ones, thereby contributing to the well-known phenomenon of care dehumanization [99].

To conclude, when properly implemented and used, ET can help *mitigating* certain aspects of older adults' vulnerability, supporting active ageing and limiting physical and psychological decline. However, technology alone cannot address all dimensions of vulnerability. Indeed, some of these dimensions are more complex and multi-layered phenomena [100, 101], thus requiring genuine human interaction and, in some cases, broader socio-political interventions.

## Conclusions

This systematic study contributes to the ongoing debates on the use of ET in aged care, enriching the discussion on how technology can support the care and assistance of older adults, currently seen as a means to innovate traditional care systems and promote healthy and independent ageing.

The findings support an integrated approach that fosters ethical reflection on the use of ET, enhances its benefits in care contexts, and raises awareness of associated risks.

In doing so, this work may also encourage collaboration among the different professional figures involved in aged care (healthcare professionals, caregivers, policy makers, technology producers), thereby strengthening multi-professional collaboration. Each group can find valuable insights on ET use in aged care, contributing to a shared foundation for dialogue.

Technology developers can draw information on the preferences, beliefs, and concerns of older adults with cognitive impairments and reflect on how they can improve ET to solve some of the issues emerging from the qualitative studies, analysed in this systematic review.

Older adults may benefit if these insights lead to the design and development of ET more aligned to their needs and preferences, thus supporting their autonomy and dignity.

Professionals working in care settings (managers, caregivers, health workers), can gain a better understanding

of the potential challenges ET present, helping them making more informed decisions in daily care practices.

Finally, policymakers can use these findings to better grasp the perceived benefits and risks of ET from the perspective of older users, and incorporate this understanding into policy planning related to the implementation of ET in aged care.

## Strengths and limitations

This systematic review presents a rigorous and methodologically robust synthesis of qualitative evidence on emerging technologies and vulnerabilities in older adults with cognitive impairments. Strengths include a comprehensive and well-structured approach to data collection, extraction, and synthesis, with the latter conducted using the QUAGOL methodology, ensuring depth and consistency in thematic interpretation. The review draws on a substantial body of evidence, encompassing 51 qualitative studies, which enhances the reliability of its findings. A potential limitation lies in the fact that the review process extended over a prolonged period, during which new relevant studies may have been published. As such, the findings, while still highly relevant, could be further enriched by integrating more recent literature.

## Abbreviations

|            |                                                                    |
|------------|--------------------------------------------------------------------|
| AD         | Alzheimer's dementia                                               |
| CASP       | Critical appraisal skills programme                                |
| CMT        | Conventional monitoring techniques                                 |
| ESV        | Existential/Spiritual Vulnerability                                |
| ET         | Emerging Technologies                                              |
| GPS        | Global Positioning System                                          |
| MCI        | Mild Cognitive Impairment                                          |
| MV         | Moral Vulnerability                                                |
| PHV        | Physical Vulnerability                                             |
| PPPM (3PM) | Predictive, Preventive and Personalized medicine                   |
| PRISMA     | Preferred Reporting Items for Systematic Reviews and Meta-Analysis |
| PV         | Psychological Vulnerability                                        |
| QUAGOL     | Qualitative Analysis Guide of Leuven                               |
| RV         | Relational/Interpersonal Vulnerability                             |
| SAR        | Socially Assistive Robots                                          |
| SPEV       | Socio-cultural, Political, and Economic Vulnerability              |
| UNMT       | Unconventional Monitoring Techniques                               |
| VRT        | Virtual Reality Technologies                                       |

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12877-025-06792-x>.

Additional File 1: Search strings used for searching databases stratified by organising concepts.

Additional File 2: Example of QUAGOL single scheme.

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## Authors' contributions

CG and VS originated the idea of conducting a systematic review of qualitative evidence exploring the nexus between emerging technologies and vulnerabilities in older adults with cognitive impairments. CG also assisted

in devising the search algorithms, cross-checked publication selection, analyzed the material, and revised the final manuscript. AF and VS conducted the literature search, worked out most of the search and analysis methods employed, analyzed and synthesized the material. VS wrote most of the paper. Also AF and GB contributed to the writing of parts of the manuscript. All authors read and approved the final manuscript.

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### Data availability

All data generated or analysed during this study are published articles, see Table 3. Additionally, the full list of QUAGOL schema may be available from the corresponding author on reasonable request. An example of QUAGOL scheme is reported in the Additional file 2.

### Declarations

#### Ethics approval and consent to participate

Not applicable.

#### Consent for publication

All the authors gave their consent for publication.

#### Competing interests

The authors declare no competing interests.

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