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Review

Socially Assistive Robots for patients with Alzheimer's Disease: A scoping review

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HIGHLIGHTS

- Interaction of human and socially assistive robot can have applicability in actual settings, and adoption to function in human environment for Alzheimer's disease.
- To achieve this, the overall review revealed that there are still several technical challenges that must be addressed in future advancements before being integrated in real life of individuals with Alzheimer's disease.
- The results will help move towards the establishment of best practices for the development of human and socially assistive robot interaction for Alzheimer's disease and, in turn, help enhance the experience of people suffering from this disease.

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ABSTRACT

Background: The most common form of dementia, Alzheimer's Disease (AD), is challenging for both those affected as well as for their care providers, and caregivers. Socially assistive robots (SARs) offer promising supportive care to assist in the complex management associated with AD.
Objectives: To conduct a scoping review of published articles that proposed, discussed, developed or tested SAR for interacting with AD patients.
Methods: We performed a scoping review informed by the methodological framework of Arksey and O'Malley and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist for reporting the results. At the identification stage, an information specialist performed a comprehensive search of 8 electronic databases from the date of inception until January 2022 in eight bibliographic databases. The inclusion criteria were all populations who recive or provide care for AD, all interventions using SAR for AD and our outcomes of inteerst were any outcome related to AD patients or care providers or caregivers. All study types published in the English language were included.
Results: After deduplication, 1251 articles were screened. Titles and abstracts screening resulted to 252 articles. Full-text review retained 125 included articles, with 72 focusing on daily life support, 46 on cognitive therapy, and 7 on cognitive assessment.
Conclusion: We conducted a comprehensive scoping review emphasizing on the interaction of SAR with AD patients, with a specific focus on daily life support, cognitive assessment, and cognitive therapy. We discussed our findings' pertinence relative to specific populations, interventions, and outcomes of human-SAR interaction on users and identified current knowledge gaps in SARs for AD patients.

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1. Introduction

1.1. An ageing population and dementia

Cognitive impairment at an early stage, referred to as mild cognitive impairment (MCI), usually does not interfere with everyday activities. After 5 years of follow-up of MCI, 38 % of such individuals have received a diagnosis of dementia (Cheng, 2017, Mitchell & Shiri-Feshki, 2009). In older people, recognizing cognitive impairment is an important part of providing comprehensive medical care because subtle issues with memory in early stages are often considered due to typical age-related changes rather than to signs of dementia (Sanford, 2017).

Worldwide, the population of older adults (60 years and over) will double between the years 2000 and 2050 (Shankle, 2005). With aging, the risk of dementia particularly Alzheimer's disease (AD) - the most common form of dementia - rises dramatically (Londzin et al., 2021). The effects of AD are non-reversible, as currently pharmacological treatment options for AD-related memory loss and other cognitive symptoms are limited (Ward et al., 2013). Stages of AD can be distinguished by cognitive abnormalities, behavioral problems, difficulty in daily life tasks, as well as a progressive loss of autonomy (American Psychiatric Association, 2013). Such stages exist on a spectrum of severity: preclinical AD, early-stage AD (mild), middle-stage AD (moderate), and late-stage AD (severe).

1.2. Cost of Alzheimer's disease

In 2015, the global cost estimates for dementia were US $957.56 billion, and will be US $2.54 trillion in 2030, and US $9.12 trillion in 2050 (Jia et al., 2018). Canada currently spends over $12 billion annually to care for individuals with dementia; by 2038 this cost is expected to rise to $153 billion (Peprah & McCormack, 2019). The mean direct annual medical cost estimate for those with dementia was $11, 678, which was twice as much as those for people without dementia ($6042) (Peprah & McCormack, 2019). Importantly, when cognitive impairment gets worse, the cost distribution tends to get worse as well (Peprah & McCormack, 2019). Consequently, assessing cognitive impairment, identifying its cause, and proposing therapy at early stages would be an important goal.

1.3. Needs of those living with dementia

The physical, mental, social, and spiritual needs of those living with dementia increase significantly day-by-day (Yumoto et al., 2019). In the moderate stage of AD, when memory is no longer reliable, those with such illness are often limited to their homes, leading to social isolation (Reppou et al., 2016). There is consequent desire for company, for someone with whom one might socialize, and perhaps understand and care for their needs (Yeh et al., 2021).

1.4. Socially assistive robots for interaction with individuals with AD

Social activities may have a significant positive influence on controlling the progression of symptoms of dementia, and in the maintenance of quality of life (Kostavelis et al., 2016). Robots appear to showing a potential role (Salichs et al., 2016). During human-robot communication, a robot can be programmed to handle direct interactions with individuals, such as asking questions or explaining instructions (Varrasi et al., 2019). Such human-robot interaction (Christa Maree Stephan et al., 2013) is not limited to language-based encounters; it includes assessing human-like movement, emotion, and facial recognition (Ozgur et al., 2020). A robot collects targeted data using its multimodal interfaces, and this can be used for subsequent data analysis by experts. In this context, two forms of robots exist: (1) assistive robots, and (2) socially interactive robots (Maddahi et al., 2020). Assistive robots can support and assist people in hospitals and homes, such as wheelchair robots for mobility aids, companion robots, or manipulator arms for the physically disabled (Feil-Seifer & Mataric, 2005). Socially interactive robots (Maddahi et al., 2020) on the other hand are those whose primary responsibility is to engage in human-robots interaction. In 2005, a socially assistive robot (SAR) was conceptualized as a convergence of assistive robots and socially interactive robots in order to aid human users to live independently in their own homes (Feil-Seifer & Mataric, 2005). SAR and socially interactive robots share a common focus to build a close and successful interaction with humans in order to provide support and aid (Feil-Seifer & Mataric, 2005).

1.5. Role of AI in socially assistive robots

Artificial Intelligence (AI) is a subfield of computer science that can analyze complex big data (Ramesh et al., 2004). Its ability to exploit meaningful relationships within a dataset can be used in diagnosis, treatment, and outcome prediction in a variety of clinical scenarios (Ramesh et al., 2004). Recent advancements in AI have shown promise with use and reliability of SAR in the field of dementia, including applications in multimodal perception and feedback, personalization, and adaptability (Aziz et al., 2015, Rudovic et al., 2018). Using AI, the SAR can be adapted and personalized to each individual user (Sutton & Barto, 2018). Such robot adaptation enables dynamic modification of robot behaviour for diverse users (Tsiakas et al., 2016). For example, reinforcement learning as a field of AI is a training strategy that rewards desired behaviors while penalizing undesirable ones (Qureshi et al., 2018). It allows a robot to learn from its interactions with people to enhance the effectiveness of robot-assisted cognitive-related procedures (Sutton & Barto, 2018). For example, Tsiakas and colleagues (2016) (Tsiakas et al., 2016) used two interactive reinforcement learning methodologies i.e., learning from feedback (Knox & Stone, 2012) and learning from guidance (Cruz et al., 2015), to enable the NAO robot to adapt its behaviour to each specific user. The robot's goal was to foster work progress and attention training by monitoring, instructing, and adapting to user skills. This could improve a safe adaptation of robot to the current user by utilising human knowledge provided through these two channels (Tsiakas et al., 2016). Furthermore, AI can combine inputs from numerous input sensor modalities (e.g., using visual text, audio, haptic cues) to give the SAR valuable information about a user such as personal requirements, desires, emotions, and environmental elements (Paletta et al., 2018, Taranović et al., 2018). In addition, AI can offer a better assessment of a participant's response during an intervention, and enhancing the effectiveness of therapeutic sessions (De Carolis, Palestra, & Pino, 2019).

1.6. Application of socially assistive robot for individuals with AD

SAR has been used for differeent purposes. Below we will explain some of these applications.

- *Cognitive assessment*

Human-SAR interaction has recently been used as a novel method for cognitive assessment (Varrasi et al., 2019, Zedda, 2021), andthis development is particularly significant given the absence of a unified testing method for the early detection of AD (Oskouei et al., 2020). Physicians use a variety of approaches and tools to help make a diagnosis including (1) Obtaining a medical and family history from the individual, including psychiatric history and history of cognitive functioning; (2) Asking a family member to provide input about changes in thinking skills and communication of the affected person, (3) Conducting paper-pencil cognitive, physical, and neurological tests. The latter include

- Montreal cognitive assessment (MoCA) is a brief 30-question test that takes 10 to 12 minutes to finish, and covers several cognitive domains (Nasreddine et al., 2005).
- DemTect takes 8–10 minutes to use, is easily administered, and is independent of respondent age or education (Kalbe et al., 2004).
- Trail Making Test (TMT) is a neurophysiological test for visual scanning and working memory (Reitan, 1958).
- Bells Test (BT) identifies visual deficits that may accompany some forms of dementia (Gauthier et al., 1989).
- Clinical Dementia Rating (CDR) is a semi-structured and clinician-rated interview that uses data from the patient and an informant to stage the progression of dementia (Hughes et al., 1982).

Such cognitive assessment tests are the conventional, inexpensive, and rapid approaches for early detection of AD. The first step in a cognitive assessment using human-SAR interaction is choosing an appropriate cognitive test that can be used to the robotic intervention scenario. The chosen cognitive test could be digitalized, the part for monitoring by care providers should be easily identifiable, and importantly, the assessment should produce quantifiable findings (Luperto et al., 2019).

Human-SAR communication provides the potential for a robot to watch and supervise participants during the test. Given that those with AD may have difficulties in verbal communication which generates psychological distress (Zucchella et al., 2018), and may affect testing. It is acknowledged that there is a lack of systematic evaluation for verbal and non-verbal communication in the common cognitive assessment methods. Some communication data can be extracted from verbal interactions/dialogues, and eye movements which have been found associated with AD (Jonell et al., 2017), but human-SAR interaction might provide the possibility to check other cognitive aspects to extend predictive variables based on social interactions and mood disturbances (Petersen et al., 1999).

- *Daily life support*

Due to the progressive nature of AD, many patients become incapable of caring for themselves and require supplemental help (Salichs et al., 2016). Most of those who affected are aged 65 or older and hope to stay at home with care provider help, rather than going to nursing care facility (Broekens et al., 2009). Robots can, based on level of AD, support individuals in some daily life activities such as food preparation, and with finding the location of personal items located in various places in their home (Arias and Sanchez, 2018, Broughton et al., 2016, Kostavelis et al., 2016). Such help may enhance sense of personal autonomy and may also increase their safety by preventing hazardous events (Gerłowska et al., 2018).

- *Cognitive Therapy*

Therapeutic robots can be deployed in a health care facilities to assist with rehabilitative services (Mordoch et al., 2013), and as such, may be seen as a non-pharmacological treatment option for older dementia patients (Leszek et al., 2017). However review articles on use of robots for those with dementia are limited (Broekens et al., 2009, Chan et al., 2021, Lancioni et al., 2021, Martinez-Soldevila et al., 2021, Mordoch et al., 2013). We therefore conducted a comprehensive scoping review emphasizing on the interaction of SAR with AD patients, with a specific focus on daily life support, cognitive assessment, and cognitive therapy. We discuss our findings' pertinence relative to specific populations, interventions, and outcomes of human-SAR interaction on users.

2. Methods

2.1. Study design

Our scoping review was based on the methodological framework suggested by Arksey & O'Malley (2005). The protocol is available on the Open Science Framework (OSF) (osf.io/qkyn5/). Our review consists of five following steps.

Step 1) Identifying the research question

Our research question was: 'What are the available published articles on the use of SAR for individuals with AD, their caregivers, and care providers?'

Step 2) Identifying the relevant articles

An information specialist (GG), an AI-health researcher, and geriatrics and neuroscience experts developed a comprehensive search strategy. A search was done from date of inception until January 2022 in the bibliographic databases i.e., CENTRAL (Cochrane Library), IEEE Xplore, CINAHL (EBSCO), EMBASE (Ovid), MEDLINE (Ovid), Web of Science Core Collection, Scopus, and ACM Digital Library. Extracted records were imported into EndNote software version X9.2 (Clarivate Analytics).

Step 3) Study selection

Articles without full text, as well as book chapters, were excluded. Database search protocol was restricted to English-language peer-reviewed publications addressing population, intervention, comparison, outcomes, setting, and study nature (PICOS) (Stone, 2002):

Population: Published articles that used human-SAR interaction for those with dementia due to AD, along with their family care provider (caregiver), and paid professional care providers (care providers). ***Intervention:*** articles that proposed and/or discussed the concept, and/or developed, and/or tested SAR robots for human-SAR interactionwere included. We excluded papers that: (1) used only AI (without robotic intervention), and (2) utilized a robot that was not suitable for human-SAR interaction/communication (e.g., nanorobot). ***Comparison:*** No limitations were defined. ***Outcomes:*** Outcomes related to the robots (e.g., acceptability, reliability), its impacts on the individuals receiving care (e.g., health outcomes, cognitive outcomes, behavioral outcomes), and on care providers and caregivers (e.g., health outcomes, cognitive outcomes, behavioral outcomes). ***Study design:*** We included all paper designs (qualitative, quantitative, or mixed methods), experimental and quasi-experimental papers (randomized controlled trials, quasi-randomized controlled trials, nonrandomized clinical trials, interrupted time series, and controlled before-and-after studies), observational (cohort, case control, cross- sectional, and case series), qualitative (ethnography, narrative, phenomenological, grounded theory, and case studies), and mixed methods studies (sequential, convergent). Article selection occurred in two stages: firstly, according to the eligibility criteria, title and abstract were screened by a reviewer (VK) and confirmed by a second senior reviewer (SAR). Secondly, full texts of the included articles from the previous step were reviewed and categorized as included or excluded article. Those articles that met our inclusion criteria were retained for full text review and data extraction.

Step 4) Charting the data

There are a number of factors that could affect human-SAR interactions. For data extraction, in consultation with team members, we selected the variables that were more relevant and feasible for the type of review we conducted. While some were the most commonly identified in the research we analyzed, others were less frequently mentioned, but of particular interest to us in order to advance this subject. The latter were AI methods employed to power human-robot interaction (HRI) to see if there was a gap in the way investigations were carried out and reported. Data were collected in an Excel file based on some aspects of the Cochrane EPOC (Effective Practice and Organization of Care) (Luperto et al., 2019). EPOC is a data collection checklist to record the data extraction. We modified and adopted the intervention characteristics section of the EPOC template based on this study. To date, there is not a single framework that unifies the factors for the aim of this study, however, to put it simply, factors related to humans (population characteristics), robots, and the social interaction between humans and robots (intervention characteristics, and outcomes) can all be considered and grouped as factors influencing HRI (Hopko et al., 2022). These variables checked with the team of experts and based on their suggestion, the final checklist was prepared. The final template was used for the data extraction. The included variables in the checklist for the data extraction were:

- *Population characteristics:* number of participants, age, sex, nationality, educational status, severity of AD, target population such as patients, caregivers and care providers.
- *Intervention characteristics:* type of robot, total duration of intervention, frequency and duration of each session, co-interventions to facilitate the HRI, application of intervention, AI-powered HRI.
- *Outcomes:* time point for measuring the outcome, methods for measuring outcome, evaluation of HRI for AD patients.

Step 5) Summarizing and reporting the results

We summarized the collected data using descriptive statistics and did a narrative synthesis structured under the three headings cited above. We reported the results based on a PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist for reporting (Tricco et al., 2018). The filled PRISMA-ScR checklist is available in Appendix A.

3. Results

The initial search strategy yielded 1717 articles. Following deduplication, 1250 remained. After screening of titles and abstracts of the remaining papers, 252 articles met the inclusion criteria and underwent a full-text review in the second step. Finally, 125 articles were included (Fig. 1).

3.1. Characteristics of articles

Interventions based on SAR for people in various stages of AD have been utilized mostly since 2015. Fig. 2 depicts the number of published articles in full-year periods up to December 2021.

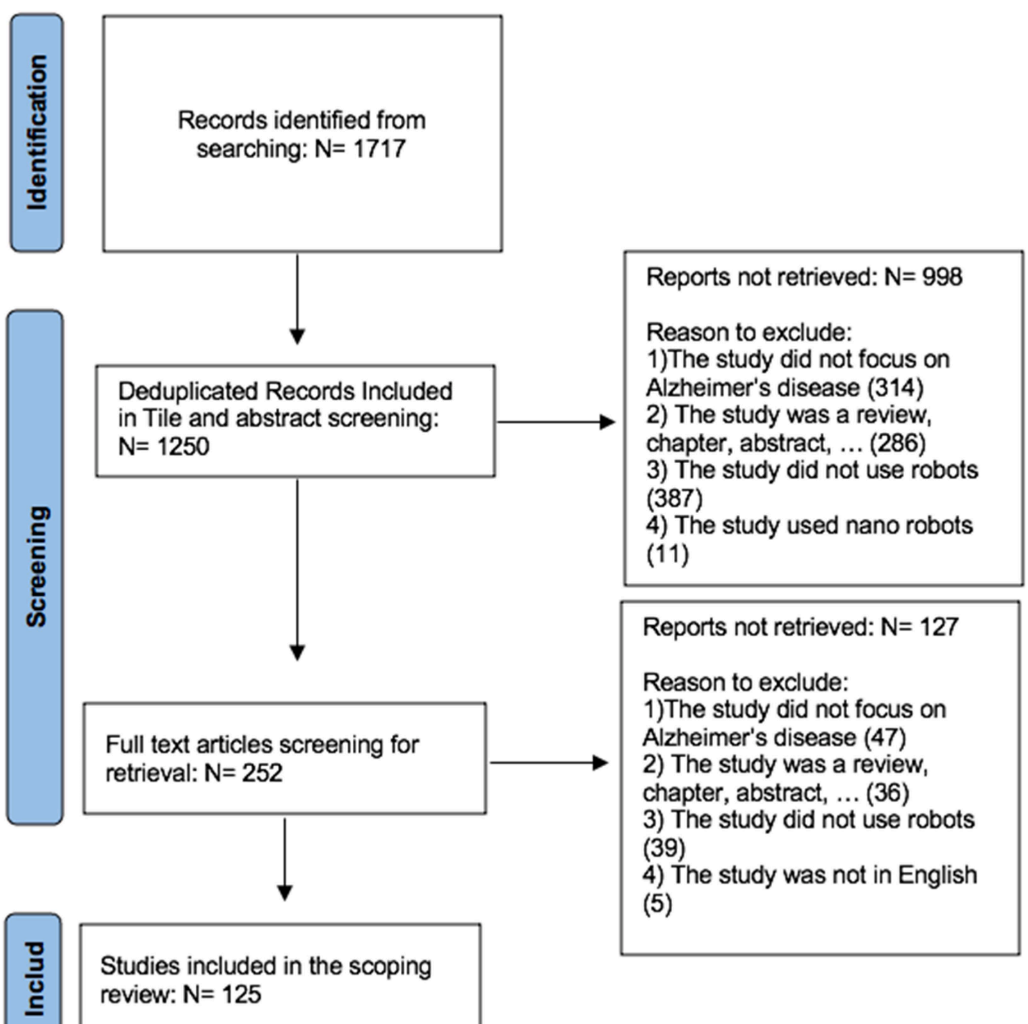

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study selection procedure.

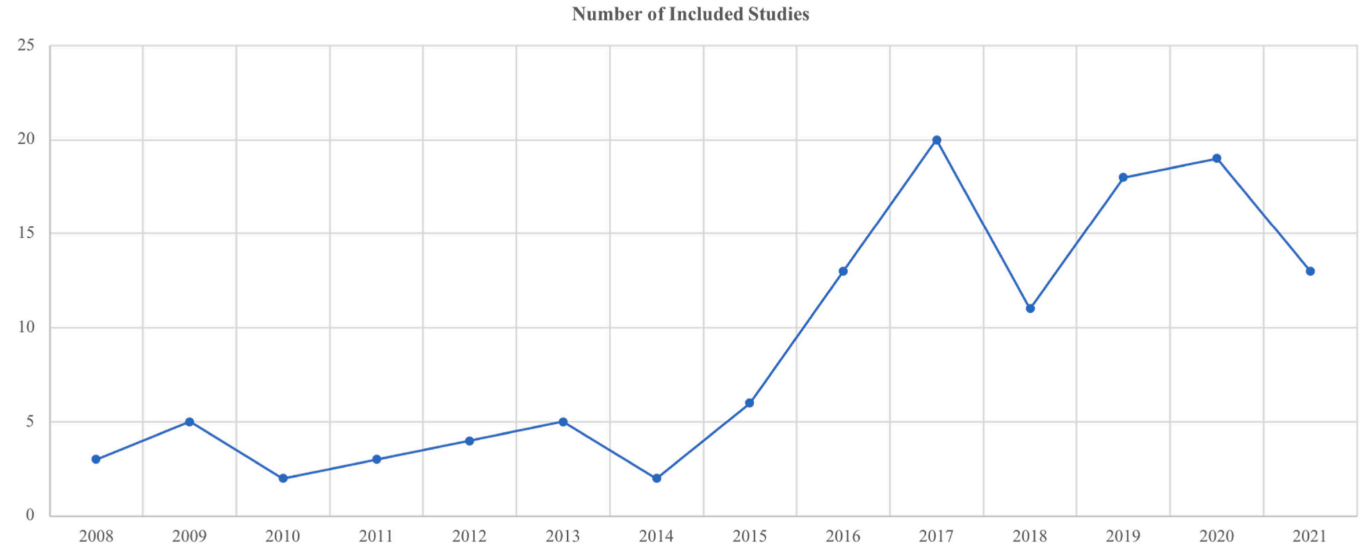

Fig. 2. The year distribution of human-SAR interaction studies for persons at various stages of AD.

3.2. Population characteristics

3.2.1. Sample size

Of 125 articles, 99 articles reported the number of people who took part in each study, for a total of 2159 participants.

3.2.2. Age, sex, and nationality

The age and standard deviation of the participants were provided in 68 % (85 out of 125) of the publications, as shown in Table 1. The weighted mean age for all participants was 54 years old.

Sex distribution was reported in 68 of the 99 articles reporting their sample sizes. Both sexes were studied in all the articles except four, such that of the 2159 participants 1559 (72 %) were women. Nationality-relevant indicators were not mentioned in any of the articles.

3.2.3. Educational status

18.4 % (23/125) of articles reported the educational status of their participants. The reporting format for this varied as some articles reported average years and standard deviation, while others listed it according to levels of attainment (elementary school, middle school, high school, or academic degree e.g., engineering) (Taranović et al., 2018).

3.2.4. Severity of the disease

Severity of the disease of participants was mentioned in 90 % (113 out of 125) of the articles. This included those in normal health, and those at various stages of AD (MCI, moderate, severe). Three articles had datasets consisting of diverse groups of participants (e.g., AD and other forms of dementia such as behavioral variant AD, frontotemporal dementia, semantic dementia, vascular dementia, progressive supranuclear palsy, mixed dementia, corticobasal degeneration, Lewy body disease, idiopathic normal pressure hydrocephalus, head injury dementia).

3.2.5. Target population of study

Of the 125 articles, 100 targeted patients. While 20 addressed both patients and other users (including caregivers and/or care providers), 5 uniquely studied caregivers.

3.3. Intervention characteristics

3.3.1. Type of robot

84 of the 125 articles identified the type of robot used. They could be divided into three types: human-like robots, animal-like robots, and unfamiliar/other types of robots (Table 2).

In a decreasing order of use, they included:

NAO (n = 13), PARO (n = 9), Pepper (n = 8), Telenoid (n = 8), MARIO (n = 4), Kompaï (n = 4), torso mounted on Pioneer mobile platform (n = 4), RAMCIP (n = 4), PaPeRo (n = 3), Eva (n = 2), Hasbro (n = 2), omni (n = 2), Slibot (n = 2), Pleo (n = 2), Bomy (n = 1), Chapit (n = 1), Cota (n = 1), ED (custom-designed tele-operated robot) (n = 1), giraffe (n = 1), Hobbit (n = 1), James (n = 1), Kabochan (n = 1), Kuri (n = 1), Lego (n = 1), Milo R25 (n = 1), MATY (n = 1), MOBOT (n = 1), Prlro (n = 1), Q.bo (n = 1), robotic ARM (n = 1), sheep robot (n = 1), and Ludwig (n = 1). Rarely two of these robots were studied in a single article, e.g,. NAO and PARO (Soler et al., 2015), and Cota and Prlro (Obayashi et al., 2020).

3.3.2. Applications of socially assistive robot for AD patients

Robots found in our review can be categorized into three groups, according to their applications (Fig. 3).

3.3.2.1. Daily activities support. The majority of the articles (n = 72) showed that SARs could support:

- Daily assistance of patients with empowering and fostering their autonomy (n = 28/72, 39 %) e.g., eating, and food preparation (Kostavelis et al., 2016, Law et al., 2019)
- Social engagement of patients (n = 25/72, 34 %) e.g., communication with people (Tsardoulias et al., 2017)
- Making patients to feel more at ease in a negative mood (n = 7/72, 10 %) e.g., agitation, depression (Agrigoroaie & Tapus, 2017, Park et al., 2021)
- Facilitate medical interventions at home (n = 4 out of 72, 5.5 %) e.g., monitoring bed rest, medicine intake (Antona et al., 2019, D'Onofrio et al., 2018), (Kostavelis et al., 2016)
- Train people caring for dementia patients (n = 4 out of72, 5.5 %), e.g., to learn and practice the skills they need in their daily roles as those who care for patients (Maddahi et al., 2020)
- Navigation assistance to older individuals (n = 2 out of 72, 3 %), e.g., to give them confidence for going out of their home, to assist them in locating their items within the home (Broughton et al., 2016)
- Ensuring patients' safety (n = 2 out of 72, 3 %) e.g., a series of observations to check if oven is off, if doors and windows are locked (Kostavelis et al., 2019; Kostavelis et al., 2016)

3.3.2.2. Cognitive therapy. The creation of robot-assisted content to

Table 1
Demographic characteristics reported by the included studies.

References	*Number of participants*	*Age (mean ± SD)*	*Sex (Female:F, Male: M)*
Lin et al., 2021	14	80	M:3, F:11
Yamazaki et al., 2021	78	72.83 ± 8.5	M:30, F:48
Van Assche et al., 2021	4	86	M: 2, F:2
Striegl et al., 2021	14	75.5	M:7, F:7
Pu et al., 2021	15	75.5	M:6, F:8
Park et al., 2021	41	86.4	M:12, F:29
Obayashi et al., 2020	135	75.9 ± 6.1	M:37, F:98
Mizuno et al., 2021	63	86.5 ± 7.7	M:10, F:53
Manca et al., 2021	1	70	F:1
Gomez et al., 2021	14	75.3 ± 4.5	M:5, F:9
Fields et al., 2021	15	65	M:4, F:11
Tummers et al., 2020	1	85	NA
Pou-Prom et al., 2020	19	55	M:3, F:16
Pino et al., 2020	21	73.45 ± 7.71	M:11, F:10
Palestra & Pino, 2020	21	73.45 ± 7.71	M:11, F:10
Mois, 2020	11	74.64 ± 6.02	M:3, F:8
Maddahi et al., 2020	14	-NA-	-NA-
Lyu & Yuan, 2020	-NA-	25–78	-NA-
Lee & Davis, 2020	30	More than 60	-NA-
Lee et al., 2020	46	More than 60	-NA-
Goda et al., 2020	28	79.4 ± 7.0	-NA-
Chen et al., 2020	103	87.2 ± 7.4	M: 21, F:82
Casey et al., 2020	60	-NA-	-NA-
Brecher, 2020	1	90	-NA-
Arthanat et al., 2020	8	78.5	M:2, F:6
Andriella, Torras & Alenyà, 2020	5	22–40	-NA-
Yamazaki et al., 2019	5	92	F:5
Vostry & Zilcher, 2019	65	63–75	M:25, F:40
Stogl et al., 2019	10	66–78	M:8, F:2
Luperto et al., 2019	16	73.6 ± 5.9	M:4, F:12
Law et al., 2019	560	-NA-	-NA-
Law et al., 2019	10	75–110	M:4, F:6
Kostavelis et al., 2019	18	-NA-	-NA-
Kim et al., 2019	48	More than 60	-NA-
Kase et al., 2019	6	87.5 ± 4.5	-NA-
Feng et al., 2019	9	78–92	-NA-
Di Nuovo et al., 2019	35	26.74 ± 9.85	M:21, F:14
De Carolis, Palestra, & Pino, 2019	21	73.45 ± 7.71	M:11, F:10
Cruz-S & Favela, 2019	12	80.25	-NA-
Barrett et al., 2019	10	83 ± 10.1	M:3, F:7
Bajones, 2019	16	79.75	M:2, F:14
Antona et al., 2019	52	49.5 ± 8.6	-NA-
Werner et al., 2018	42	82.5 ± 8.7	-NA-
Taranović et al., 2018	6	28.17 ± 3.87	-NA-
Perugia et al., 2018	14	83.93 ± 7.28	M:2, F:12
Kostavelis et al., 2019	32	-NA-	-NA-
Paletta et al., 2018	6	-NA-	-NA-
Jones et al., 2018	138	More than 60	-NA-
Gerłowska et al., 2018	18	60–81	M:6, F:12
D'Onofrio et al., 2018	139	48.12 ± 15.81	M:36, F:103
Andriella et al., 2018	4	-NA-	-NA-
Wang et al., 2017	10	60.2	M:4, F:6
Varrasi et al., 2019	16	31.5 ± 14.5	M:6, F:10
Tsardoulias et al., 2017	8	More than 65	-NA-
Sandoval & Favela, 2017	9	29.22	M:4, F:5
Sancarlo et al., 2017	139	48.12 ± 15.81	M:36, F:103
Rudzicz et al., 2017	12	55 years or older	M:3, F:9
Perugia et al., 2017	14	84	M:2, F:12
Nihei et al., 2017	5	71.5	-NA-
Leszek et al., 2017	31	81.4	M:7, F:24
Korchut et al., 2017	264	55–90	M:77, F:187
Ismail et al., 2017	5	More than 59	-NA-
Ismail et al., 2017	22	More than 60	-NA-
Hirsch et al., 2017	9	-NA-	M:5, F:4
Garcia-Sanjuan et al., 2017	40	81.3 ± 8.48	M:8, F:32
Darragh et al., 2017	33	-NA-	-NA-
Bellotto et al., 2017	nA	-NA-	-NA-
Bartoli et al., 2017	40	71 ± 6 AD, 69 HC	M: 15, F:25
Wu et al., 2016	20	73	M:4, F:16
Vasileiadis et al., 2016	4	77.5	F:4
Nakahara et al., 2016	3	-NA-	M:1, F:2
Kuwamura et al., 2016	3	85	F:3
Ismail et al., 2016	22	More than 60	M:10, F:12
Hebesberger et al., 2016	10	74–95	-NA-
Demetriadis et al., 2016	45	-NA-	M:9, F:36
Tsardoulias et al., 2015	20	-NA-	M:11, F:9
Soler et al., 2015	248	80.95	M:28, F:220
Rudzicz, Wang, Begum, & Mihailidis, 2015	10	More or= 55	M:4, F:6
Pino et al., 2015	25	72.6	M:8, F:17
Joranson et al., 2015	60	62–95	M: 20, F:40
Yu et al., 2014	11	37–88	M:3, F:8
Wu et al., 2014	11	79.3	M:2, F:9
Schroeter et al., 2013	11	49–80	M:5, F:6
Pino et al., 2013	25	72.6	-NA-
Moyle et al., 2013	18	-NA-	-NA-
Heerink et al., 2013	19	19–58, 25–58	F:19
Granata et al., 2013	22	76.5	M:5, F:17
Seelye et al., 2012	8	77.5 ± 8.41	M:1, F:7
Pino et al., 2012	22	76.5	M:5, F:17
Inoue et al., 2012	5	85.8	F:5
Gross et al., 2012	8	-NA-	-NA-
Tiwari et al., 2011	10	80.5	M:5, F:5
Tapus et al., 2010	9	Over 70	M:4, F:5
Granata et al., 2010	11	66.5 ± 72.5	M:3, F:8
Tapus et al., 2009	9	Over 70	M:4, F:5
Tapus, 2009	3	Over 71	-NA-
Tapus, 2009	9	Over 70	M:4, F:5
Wada et al., 2008	14	79.2	M:4, F:10
Tapus et al., 2008	10	Over 70	M:5, F:5

SD: Standard deviation; -NA-: No answer was reported in the study; M: Male participants; F: Female participants.

prevent the advancement of cognitive decline in AD patients was the main focus of nearly half of the articles (n = 46). Distribution of included studies for sub-categories of utilising human-SAR interaction for daily life support of patients at various stages of Alzheimer's disease is illustrated at Fig. 4.

3.3.2.3. Cognitive assessment. A small number of articles (n = 7) showed robots' ability for cognitive assessment. In these articles they compared the results of cognitive assessment based on HRI against standard "Paper and Pencil" test. As illustrated in Table 3, these tests were TMT and BT (n = 1), DemTect (n = 1), Clinical dementia rating (CDR, n = 2). One article did not report on the test used.

The majority of articles did not report on psychometrics. The exceptions were two articles that used the same robot, namely Pepper. Varrasi and colleagues (Varrasi et al., 2019) calculated the Spearman-Brown Coefficient and the Alpha Coefficient (0.73 and 0.67, $p < 0.01$ respectively). Di Nuovo and colleagues (Di Nuovo et al., 2019) reported Spearman correlations of robotic-based test and the standard "Paper and Pencil" MoCA scores as 0.637, $p < 0.01$.

Table 2
Brief characteristics of the robots used in the included studies of this scoping review.

Type of robot	Number of studies used this robot	Name of robot	Image of robot	Robot's characteristics
Human-like robot	n = 13	NAO		NAO can move and adapt to the environment (25 degrees of freedom). It has two-dimensional cameras to recognize shapes and people, in addition to four directional microphones and speakers to interact with humans in 20 languages (De Carolis, Palestra, & Pino, 2019).
Animal-like robot	n = 9	PARO		PARO provides the benefits of animal therapy for patients with the five kinds of sensors: tactile, light, audition, temperature, and posture sensors (Wang et al., 2022).
Human-like robot	n = 8	Pepper		Pepper can move naturally (20 degrees of freedom), recognize speech and dialogue in 15 languages, recognize faces and basic human emotions in addition to interacting with humans by talking through its sensors, two/three-dimensional cameras, touch screen, and conversation ability (Varrasi et al., 2019).
Human-like robot	n = 8	Telenoid		Telenoid is like a mobile phone in the shape of an alien. It relays the voice and replicate the facial and head movements of human (Yamazaki et al., 2021).
Human-like robot	n = 4	MARIO		MARIO is a social robot with 1.5-metere-tall with large, animated eyes. It can be activated by voice or touchscreen (Casey et al., 2020).
Human-like robot	n = 4	Kompaï		Kompaï help people walking, detect falling, and can be adapted on the people's needs (Wu et al., 2014).
Human-like robot	n = 4	Torso mounted on pioneer mobile platform		Torso mounted on Pioneer mobile platform is a humanoid robot equipped with a speaker, color camera, and eye-safe laser range finder (Tapus et al., 2009).
Unfamiliar robot	n = 4	RAMCIP		RAMCIP has the elevation mechanism allows the robot to reach both higher (1.75metere) and lower (floor) locations with the same arm. It has microphone, tablet, and speakers (Kostavelis et al., 2019).
Human-like robot	n = 3	PaPeRo		PaPeRo (Partner-type-Personal-Robot) has facial recognition system using camera, microphone, ultrasonic sensors, etc (Nihei et al., 2017).

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Table 2 (*continued*)

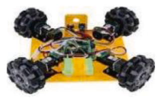
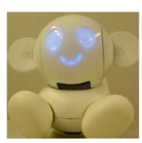
Type of robot	Number of studies used this robot	Name of robot	Image of robot	Robot's characteristics
Human-like robot	n = 2	Eva		Eva is an easy-to-use robotic arm with compact size, and 6 degrees of freedom (Cruz-S & Favela, 2019).
Animal-like robot	n = 2	Hasbro		Hasbro is an animal-like robot companions could provide an elegant solution to enhance person-centered care, notably without replacing human contact (Tummers et al., 2020).
Unfamiliar robot	n = 1	Omni		Omni is a robotic platform with specialized directional wheels (Bartoli et al., 2017).
Human-like robot	n = 2	Silbot		Sil-bot is an animatronic care Bot that can speak and recognise face. It is developed to be a companion for elderly people (Law et al., 2019).
Animal-like robot	n = 1	Pleo		Pleo is a robot dinosaur robot using like a living pet that can explore, learn, and demand attention (Perugia et al., 2018).
Unfamiliar robot	n = 1	Bomy		Bomy provides a smart care for elderly and people in a risk of dementia. It has display, arms for movement, touch screen, head touch sensor, and 3D camera (Lee et al., 2020).
Animal-like robot	n = 1	Chapit		Chapit is an animatronic mouse-shape robot that can understand and respond to verbal commands using its embedded ear microphones and integrated database of words and phrases (Goda et al., 2020).
Human-like robot	n = 1	Cota	-NA-	Cota has a camera, microphone, speaker, and LED. It also monitors the person with a bedside infrared camera, which can send alerts to caregivers as well as the central nursing station in case of emergencies such as falls (Obayashi et al., 2020).
Unfamiliar robot	n = 1	ED		ED (custom-designed tele-operated robot) is a robotic arm with same features as these arms (Wang et al., 2017).
Animal-like robot	n = 1	Giraffe		Giraff is a multipurpose telepresence robot that provides its specific potential for observation and monitoring functions (Luperto et al., 2019).
Unfamiliar robot	n = 1	Hobbit		Hobbit can provide several safety and entertainment functions with low-cost components (Bajones, 2019).
Unfamiliar robot	n = 1	James		James can listen and talk. It also has touch screen to communicate. Its advanced camera can do facial recognition and determine the age, and gender (Van Assche et al., 2021).

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Table 2 (*continued*)

Type of robot	Number of studies used this robot	Name of robot	Image of robot	Robot's characteristics
Human-like robot	n = 1	Kabochan		Kabochan is a social robot that can have verbal communication with human via talking and singing (Chen et al., 2020).
Human-like robot	n = 1	Kuri		Kuri has sensitive microphones to hear, touch sensors in the cap, HD camera to capture photos and video, and gestural mechanics to interact with eye blink, smile, and head movements (Kubota et al., 2020).
Unfamiliar robot	n = 1	Lego robot		Lego robot is used to inspired imaginations and challenge the minds. It can be coded to walk, talk, and play games, or complete tasks (Demetriadis et al., 2016).
Human-like robot	n = 1	Milo		Milo is a human-like robot mostly used to help identify human emotions using a range of vocal and facial expressions it can do (Pou-Prom et al., 2020).
Unfamiliar robot	n = 1	MATY		MATY encourages communication with relatives and promotes routines by eliciting the person to act, using a multisensorial approach including projecting biographical images, playing suggestive sounds, or emitting soothing aromas (Simão & Guerreiro, 2019).
Unfamiliar robot	n = 1	MOBOT		MOBOT (mobility aid robot) is a mobile autonomous robot to automate testing of repetitive functions on mobile devices (Werner et al., 2018).
Human-like robot	n = 1	Q.bo		Qbo is a small robot that can recognize faces and objects and itself in the mirror, understand speech, and navigate autonomously. Users can assemble and program it by themselves (Chan et al., 2019).
Unfamiliar robot	n = 1	Prlro	-NA-	Prlro has a camera, microphone, speaker, LEDs. Its size is 40mm*180mm*178 mm (Obayashi et al., 2020).
Unfamiliar robot	n = 1	Robotic Arm		Robotic Arm is a mechanical arm, usually programmable, like human arm functions. It can be used alone or as part of a complex robot (Chen et al., 2020).
Animal-like robot	n = 1	Sheep robot		Sheep robot is an animal-like social robot is used for dementia patients (Feng et al., 2019).
Human-like robot	n = 1	Ludwig		Ludwig is a walking, talking robot equipped with a sensor for audio and video. He has a microphone in his ears, and a camera in his eyes (Rudzicz et al., 2017).

3.3.3. *Equipment and socially assistive robot*

During HRI, some articles explored the use of equipment for human-SAR interaction including camera (n = 10) (Casey et al., 2020; Chen et al., 2020; Chen et al., 2020; Gerłowska et al., 2018, Kostavelis et al., 2016; Nakahara et al., 2016; Palestra & Pino, 2020; Perugia et al., 2018; Seelye et al., 2012; Tsiakas et al., 2016; Wu et al., 2016), sensors (n = 8) (Kuwamura et al., 2016; Manca et al., 2021; Nakahara et al., 2016; Perugia et al., 2018; Sandoval & Favela, 2017; Simão & Guerreiro, 2019; Tsiakas et al., 2016), rollators (Di Nuovo et al., 2019), and a set of paddles for tangible activities (n = 1) (Darragh et al., 2017).

3.3.4. *Duration of human-robot interaction*

The included articles provided information on one or more of the following conditions: (1) Over half of studies (63 out of 125) reported the time employed to explore specific HRI, (2) about one third of the included studies (45 out of 125) recorded the frequency which HRI was

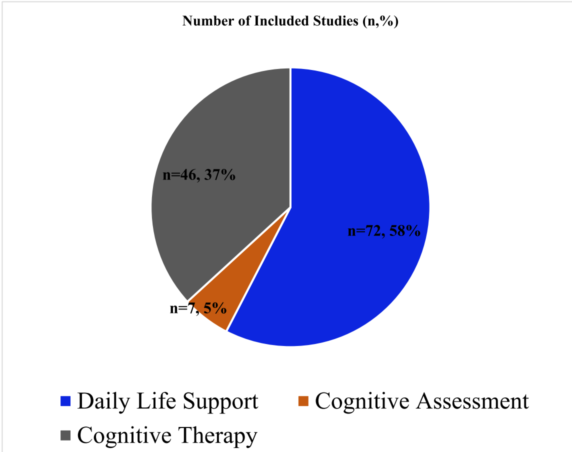

Fig. 3. The included research was distributed (n: number, and % percentage of the included studies) in several applications of human-SAR interaction for patients in various stages of AD; Daily life support (n = 72, 58 %), Cognitive therapy (n = 46, 37 %), Cognitive assessment (n = 7, 5 %).

repeated or was happened, (3) out of 125 studies 42 reported the duration of each session of HRI. Appendix B shows the intervention duration used for diverse types of robots based on the specific object of the study.

3.3.5. AI-powered robot

None of the articles mentioned a particular detail about AI-powered robot. Their details were about the methodology of using HRI for AD patients. They focused uniquely on outcomes of using SAR for individuals with AD.

3.4. Outcomes

3.4.1. Time points of outcome measurement

In the reviewed articles, purposeful outcomes from human-SAR interaction were measured at different time points, commonly at baseline, and post intervention. Thus, it provided the possibility to assess the true outcomes better. An article did a follow-up measurement, days after completing their post-intervention assessment phase (Arthanat et al., 2020).

3.4.2. Methods for measuring outcome

Out of 125 articles, 111 (89 %) described their measurement methods usingdifferent techniques depending on the objectives.

Use of a questionnaire was the most common (n = 52 out of 111) way to measure the outcome of a human-SAR interaction. Such an enquiry assessed participants' reactions either through face-to-face interviews or paper-based queries at different time points. Questionnaire content varied according to the targeted user groups (e.g., patients, care provider), targeted cognitive capacities (e.g., memory or anxiety), and study objectives (e.g., users' assessment of robot or robot efficacy). Some of these questionnaires (n = 12 out of 52) were based on recognized diagnostic criteria for dementia, as well as medical, neuropsychological, neurological, and psychiatric evaluation tools such as the behavioral rating scale for the mental states (NM scale) (Fukunaga et al., 2006); Instrumental Activities of Daily Living scale (IADL) (Lawton & Brody, 1969); Mini-Mental State Examination (MMSE) (Folstein et al., 1975); CDR (Hughes et al., 1982); and Geriatric Depression Scale (GDS) (Yesavage et al., 1982). Table 4 lists the criteria used in the included articles to measure the questionnaire-based outcomes for performance evaluation of human-SAR interaction in dementia patients.

Other measurements were observations during session i.e. reaction time or time to complete the activity (n = 41 out of 111) (Arthanat et al., 2020, Gomez A et al., 2021, Kim et al., 2019, Taranović et al., 2018); neuroimaging-based measures (n = 2 out of 111) e.g., MRI, fMRI, EEG (Goda et al., 2020, Salichs et al., 2016, Simão & Guerreiro, 2019); and mixed methods (n = 16 out of 111) combination of observations with questionnaires (Di Nuovo et al., 2019, Kim et al., 2019, Mizuno et al., 2021, Pino et al., 2011).

3.4.3. Evaluation of socially assistive robots for AD

For the evaluation of SAR for people with AD, three categories can be generated from the reviewed articles: (1) articles that test and validate the use of SAR for AD; (2) articles that evaluate the features of different SAR platforms for AD; and (3) articles that suggest the next steps for the agendas of researchers in SAR for AD. A summary of the articles evaluating their methods is provided in Table 5.

Table 3
Intervention characteristics of the included studies for cognitive assessment using human-SAR interaction.

Type of robot	Extracted features	Cognitive assessment test
Pepper robot	Visuospatial/Executive, Language and Attention, Naming, Abstraction, Delayed Recall, Orientation	Montreal cognitive assessment (MoCA)
Giraffe robot	Based on Cognitive Screening Test	TMT and BT
Qbo robot	Based on the Cognitive Screening Test and Activities of Daily Living	DemTect
NAO robot	Time Elapsed, Transition Test, Currency Conversion, Storytelling, Complex and Repeat Statement, Object Identification, Personal Questions	Was Not Mentioned
Telenoid	Patients' conversational data	Clinical Dementia Rating (CDR)
Omni	Simple reaction times, Position tracking, and Stabilization tasks	Clinical Dementia Rating (CDR)

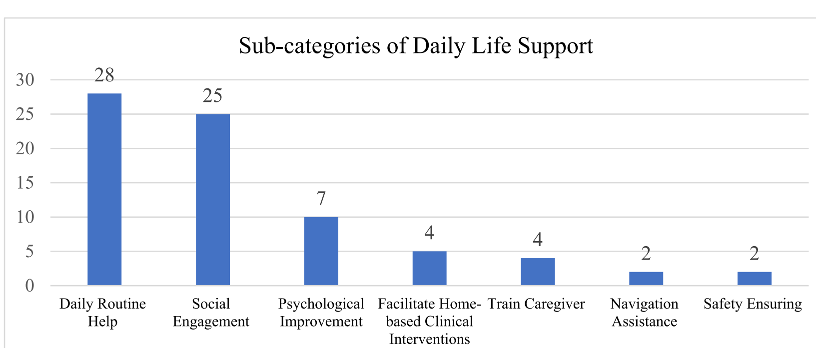

Fig. 4. Distribution of included studies for use of SARs for daily life support.

Table 4
Available criteria used by the included studies to measure the questionnaire-based outcome for performance evaluation of human-SAR interaction in AD (Alzheimer's Disease) patients.

Outcome	*Questionnaire*	*References*
Cognitive/ memory functions	MMSE; Severe MMSE (sMMSE); CNS Vital Signs; Cambridge Neuropsychological Test Automated Battery (CANTAB); Global Deterioration Scale (GDS); Clinical Dementia Rating (CDR); International Classification of Diseases and Associated Disorders (ICD-10); Functional Independence Assessment (FIM); Degree of Daily Life Independence Score for People with Dementia (DDLIS-PD)	Kase et al., 2019,Kubota et al., 2020,Lee et al., 2020), Maddahi et al., 2020, Obayashi et al., 2020, Stogl et al., 2019)
Robot impact	Apathy Inventory (AI); Neuropsychiatric Inventory (NPI); Apathy Scale for Institutionalized Patients with Dementia Nursing Home version (APADEM-NH); Quality-of-Life Scale (QUALID) Quality of Life in Alzheimer's Disease; Rating Anxiety in Dementia; Geriatric Depression;	(Feng et al., 2019, (Heerink et al., 2013), Lee et al., 2020), (Rudzicz, Wang, Begum, & Mihailidis, 2015), (Vostry & Zilcher, 2019)
Social bonding	Observational Measurement of Engagement (OME); Observed Emotion Rating Scale (OERS); World Health Organization's ICF	(Di Nuovo et al., 2019, Obayashi et al., 2020)
Cognitive impairment	Rowland Universal Dementia Assessment Scale (RUDAS); MoCA	(Gerłowska et al., 2018), (Tsardoulias et al., 2017)
Behavior monitoring	Human skeleton-based detection; Cohen-Mansfield Agitation Inventory-Short Form (CMAI-SF)	(Gerłowska et al., 2018, Kuwamura et al., 2016, Sandoval & Favela, 2017)
Reality orientation	Nishimura Mental State Scale for the older people (N-M scale); Normal ADL; Hierarchic Dementia Scale-Revised (HDS-R)	(Korchut et al., 2017)

4. Discussion

Our scoping review yielded 125 included articles focused on the human-SAR interaction for individuals with AD. This study focused on three main categories of factors that may have impacts on interactions between humans and SAR. These factors were population characteristics, intervention characteristics, and outcomes. Our review led to the following discussions:

4.1. AI-powered human-robot interaction

Our review demonstrated that published articles mentioned little about how AI specifically enhances humans-SAR interaction. The majority of research focused explicitly or implicitly on the effects of humans-SAR interaction for AD individuals, but there was no detailed explanation about the AI methods. Explaining the specific AI methods used in HRI can be advantageous because social interaction of some SARs with humans has real-time perception and intelligence, including the capability to do Natural Language Processing (NLP), i.e. the capacity of computer software to interpret natural language as it is spoken and written (Arksey & O'Malley, 2005). Recently, generative pre-trained transformer (GPT) has shown improved performance when operating with extremely limited training data (Sezgin et al., 2022). For example, generative pre-trained transformer 3 (GPT-3) performed human-like logical and intellectual responses such as writing essays, answering complex questions, and conducting sentiment analyses (Sezgin et al., 2022). The introduction of GPT-3 has also rekindled interest in how NLP might be used to address current healthcare issues (Nath et al., 2022). It should be mentioned that in individuals with AD, cognitive decline can make it more difficult for them to communicate their ideas through typical sentence structures (Klimova et al., 2015) or facial expressions (Beer et al., 2014), which can restrict the application of standard NLP, and facial expression detection technique for determining the state of the user. Thus, SARs need to have backup plans for preserving essential functions. Using tools like sensor fusion techniques to take advantage of multimodal interaction is one strategy (Nocentini et al., 2019). Sensors play a fundamental role in HRI (Perugia et al., 2018). Robots manage to understand emotions of the users using social cues (i.e., posture and body movement, facial expression, and head and gaze orientation), and these social cues are detected by sensors. Using sensors to detect human pose help execute the physical activity services offered by the SARs, daily life activities (e.g., eating, sleeping, mobility), and medication management (Kim et al., 2022). Care for frail older adults who may also have memory issues would benefit greatly from a record of their sleep patterns, movements, and falls using SARs (Nocentini et al., 2019). An issue related to sensors is that data acquisition from sensor can face delays, so an effort for the future studies could be to find and use the sensors that are more reliable and practical in real-world situations (Sonntag, 2016). In addition, it is better that robots have multi sensors to acquire different types of data (Sonntag, 2016). To achieve this goal, microphones, 2D and 3D vision sensors, thermal cameras, and face-trackers could be used to create a system that gives a complete sensor coverage to the robot, and therefore each device could cover a different area (Nocentini et al., 2019).

4.2. Type of robots

We reported on robot's types, those that were human-like, animal-like, or unfamiliar appearance (Yuan et al., 2021). NAO, a human-like robot, was used more than other robots in the studies we reviewed. Perhaps one reason is because of its shape and ease of transportation. Humanoid appearance of a robot can facilitate HRI (Eyssel et al., 2011) and adaptation to the environment (Spatola, 2019). SARs with a more human-like appearance were scored higher on engagement, perceived intelligence, and intent to use in comparative studies centered on assistive tasks (Moro et al., 2019). In addition to the appearance of NAO, its interaction modes (verbal and non-verbal communication, gestures, displays, etc.), along with its frameworks for perception and intelligence also have significant impact on determining the interaction's success (Papadopoulos et al., 2022, Robinson & Nejat, 2022).

An animal-like robot, PARO was the second-most commonly used robot in the studies reviewed. PARO is employed in the welfare and medical sectors in a number of developed countries and regions (Inoue et al., 2021). Previous studies found PARO effective in different areas including enhancing quality of life, enjoyment, emotional expression, social interaction, and lowering the need for neuropsychiatric medication to treat anxiety and stress (Kang et al., 2020), (Moyle et al., 2013), (Petersen et al., 2017), (Robinson et al., 2013). PARO can reduce stress among family members and support the older persons with dementia (Petersen et al., 2017). PARO can increase the motivation of care givers of dementia patients, and thus it can provide high-quality home care (Hung et al., 2019). PARO can be used in intensive care settings due to its high safety standards, which include antibacterial processed fur and magnetic shielding function (Technology). However, PARO may not be an ideal robot for people who show little interest at first (Inoue et al.,

Table 5
Outcome analysis of human-SAR interaction based on user experiments.

Application	References	Stage of AD	Target population	Final outcomes
Daily Life Support	Lin et al., 2022	Healthy, MCI, AD	Patient	Individuals demonstrated elevated levels of human-robot interaction, but the activity influenced the type of interaction.
	Van Assche et al., 2021	MCI	Patient	The robot proved to be promising in terms of alleviating feelings of loneliness and social isolation.
	Obayashi et al., 2020	Mild, moderate, and sever AD	Patient	The results showed that the older participants aged ≥80 benefited more from the human-SAR interaction than the younger cohort did.
	Fields et al., 2021	MCI	Patient	This case study showed that depression, loneliness, and face scores had significantly decreased across time periods of human-SAR interaction and these declines differed between people with dementia and those without dementia.
	Arthanat et al., 2020	AD	Caregiver	The caregivers asserted the potential of the SAR to relieve care burden and envisioned it as a next-generation technology for care providers.
	Cruz-S & Favela, 2019	Mild to moderate-stage AD	Patient	Patients with Dementia who participated in the study engaged and enjoyed the interaction with the SAR.
	Werner et al., 2018	MCI, early-stage AD	Patient	The Robotic-integrated navigation system was effective for improving navigation within a real-life environment in potential end-users, especially in those with cognitive impairment.
	Taranović et al., 2018	MCI	Patient	Results of the study suggest that a reduced complexity of interaction does not significantly affect the user experience and may improve task performance.
	Gerłowska et al., 2018	MCI	Patient	The study showed that 76.5 % of participants strongly agreed that the robot presence would enhance the user’s security and 53 % that it would benefit his/her quality of life.
	D’Onofrio et al., 2018	MCI	Caregiver	21.8 % of Caregiver declared that the proposed robotic intervention should be useful to improve quality of life, quality of care, safety, emergency communications, home-based physical and/or cognitive rehabilitation programs, and to detect isolation and health status changes of their patients.
	Wang et al., 2017	Mild-to-moderate AD	Patient, Caregivers	Positive consequences of robots in caregiving scenarios could include decreased frustration, stress, and relationship strain, and increased social interaction via the robot. A negative consequence could be decreased interaction with care provider.
	Sandoval & Favela, 2017	AD	Patient	Preliminary results showed that the residents enjoyed the human-SAR interaction sessions.
	Sancarlo et al., 2017	AD	Patient	The presented novel approach employing robot companions, and its effect will be: (1) to facilitate and support persons with dementia and their care provider, and (2) reduce social exclusion and isolation.
	Perugia et al., 2017	Mild to moderate AD	Patient	AD Participants affected with apathetic and depressive syndromes, as measured with Neuropsychiatric Inventory (NPI), showed significantly less pleasure during interactions with robot with respect to participants without such disorders.
	Ismail et al., 2016	MCI	Patient	The finding reveals that the presence of an assistive spiritual robot can benefit older people by assisting them to perform spiritual practices.
	Darragh et al., 2017	MCI, and mild dementia,	Patients, Caregivers of those with MCI or dementia, those with expertise in MCI or dementia research, clinical care, or management	A homecare robot could provide both practical and therapeutic benefits for the mildly cognitively impaired with 2 broad programs providing routine and reassurance; and tracking health and well-being.
	Broughton et al., 2016	MCI	Patient	This framework may then be used by a robot navigating the environment to preserve an internal record of where items were last detected and where they are most likely to be at any given moment in time.
	Rudzicz et al., 2015	AD	Patient	Analysis reveals that speech recognition remains a challenge in this setup, especially during household tasks with individuals with AD. Across the verbal behaviors that indicate confusion, older adults with AD are likely to simply ignore the robot.
	Pino et al., 2015	AD	Patient	The results showed that combining quantitative and qualitative methodologies yielded an accurate understanding of the parameters influencing SAR acceptability. Participants recognized the potential benefits of SAR in assisting with home care for adults with cognitive impairment.
	Wu et al., 2014	MCI, Healthy	Patient	They identified several barriers to robot-acceptance, including older adults’ uneasiness with technology, feeling of stigmatization, and ethical/societal issues associated with robot use.
	Pino et al., 2013	MCI, AD	Patient, Caregiver	Caregivers and people with MCI had a higher perceived usefulness and acceptance of the system than healthy older individuals.
	Moyle et al., 2013	Mid- to late-stage AD	Patient	PARO had a moderate to large positive influence on participants’ quality of life.

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Table 5 (*continued*)

Application	References	Stage of AD	Target population	Final outcomes
				Proposed human-SAR interaction had a moderate to large positive influence on participants' quality of life. Findings suggest human-SAR interaction may be useful as a treatment option for people with dementia; however, the need for a larger trial was identified.
	Seelye et al., 2012	MCI	Patient	Results from the present study showed that a small sample of independently living, cognitively intact older adults and their remote collaterals responded positively to a remote-controlled robot with video-communication capabilities.
	Inoue et al., 2012	MCI	Patient	These results suggest the possibility of using this robot to support independent living by persons with dementia.
Cognitive Assessment	Bartoli et al., 2017	Healthy, MCI, AD	Patient	This robotic assessment, lasting less than 1 h, provides detailed information about the integrity of visuo-motor abilities. The data can aid the understanding of the complex pattern of deficits that characterize this pervasive disease.
	Nakahara et al., 2016	AD	Patient	The proposed human-SAR interaction can provide opportunities for older populations to communicate over the long term.
	Di Nuovo et al., 2019	MCI	Patient	Study found a significant correlation between the automated scoring and the most widely used paper-and-pencil tests.
	Varrasi et al., 2019	MCI	Patient	Study showed promising results of the robotic psychometric tool for detecting MCI, also compared to its traditional paper version.
	Yamazaki et al., 2021	Mild, moderate, and sever AD	Patient	The result suggests the potential of predicting dementia severity from the patient's engagement in daily conversation and his or her basic information.
Cognitive Therapy	Pu et al., 2021	AD, and Healthy	Patient	Human-SAR interaction could improve sleep patterns for nursing home residents living with dementia and chronic pain.
	Park et al., 2021	MCI	Patient	A robot-assisted, multi-domain cognitive training program can improve the efficiency of global cognitive function and depression during cognitive tasks in older adults with MCI, which is associated with improvements in memory and executive function
	Pino et al., 2020	MCI	Patient	The study resulted in an increase of visual gaze from patients and reinforce of therapeutic behavior reducing, in some cases, depressive symptoms. Unexpectedly, significant changes in prose memory and verbal fluency measures were detected.
	Lee et al., 2020	MCI	Patient	The robot-based cognitive intervention showed greater improvement in working memory than did the group without cognitive intervention (control).
	Goda et al., 2020	AD, and Healthy	Patient	Older people who have cognitive decline and use day-service centers are less likely to experience the immediate benefits of human-SAR interaction, including positive emotions and mental relaxation.
	Chen et al., 2020	AD	Patient	Human-SAR interaction was potentially effective at reducing short-term neuropsychiatric symptoms and relevant care provider distress for residents with dementia.
	Vostry & Zilcher, 2019	AD, multiple sclerosis, stroke-ischemic type	Patient	The results of the research show that robotic therapy may be an appropriate and adequately selected intervention in people with cognitive deficits. Positive development was recorded in all groups in somatic, cognitive and social.
	Kim et al., 2019	MCI	Patient	The robot intervention group showed a greater improvement in the attention function than the control group.
	Kase et al., 2019	MCI	Patient	The results suggested that reminiscence group therapy (RGT) by tele-operated robot can promote communication in a way like that of human facilitated RGT.
	Jones et al., 2018	AD	Patient	Participants with severe agitation had poor response to robot. Lower levels of agitation and higher cognitive functioning were associated with better responses.
	Leszek et al., 2017	AD	Patient	Robot therapy will be one of the powerful tools for the care of older dementia patients as a non-pharmacological treatment. However, it evokes serious problems such as aggressiveness and agitation in AD patients specifically.
	Ismail et al., 2017	AD	Patient	The finding revealed that utilizing the therapeutic robot embedded with spiritual design elements of spiritual practices can derive positive effects and enhance spiritual emotions towards older people.
	Garcia-Sanjuan et al., 2017	Healthy, MCI, severe AD	Patient	Results revealed that the proposed human-SAR interaction is usable and engaging for users with no or MCI, and even though it is less usable for persons with severe impairment.
	Hebesberger et al., 2016	AD	Patient	According to the findings, a robot can improve motivation, group coherence, and mood inside the group.
	Demetriadis et al., 2016	AD	Patient	They concluded that the existing data supports additional research into the influence of programming activities on MCI patients as a cognitive training and evaluation tool for critical mental abilities (such as analysis and planning) and cognitive processes such as attention.

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Table 5 (*continued*)

Application	References	Stage of AD	Target population	Final outcomes
	Soler et al., 2015	MCI	Patient	Patients in robot group showed a decline in cognition as measured by the MMSE scores, but not the sMMSE.
	Joranson et al., 2015	MCI, AD	Patient	This study found a long-term effect on depression and agitation by using Paro in activity groups for older people with dementia in nursing homes.
	Yu et al., 2014	MCI, AD	Patient	According to the comments from the patients' therapist, robots promoted conversation between the participants. Furthermore, participants demonstrated improvement in patients' moods (pre-intervention: 3.44, post-intervention: 2.44), but the difference did not reach statistical significance.
	Tapus et al., 2009	MCI	Patient	Results showed that this approach can engage the patients and keep them interested in interacting with the robot, which, in turn, increases their positive behavior.
	Tapus et al, 2009	MCI, moderate, severe AD	Patient	The results of the study depicted a more efficient, natural, and preferred interaction with the robot.
	Wada et al., 2008	MCI	Patient	The results showed that interaction with robot improved patients' and older people's moods, making them more active and communicative with each other and their care provider s. Results of urine tests revealed that interaction with Paro reduced stress among the older individuals.
	Tapus et al., 2008	MCI, Healthy	Patient	SAR provided a customized help protocol through motivation, encouragements, and companionship to users suffering from cognitive changes related to aging and/or Alzheimer's disease.

2021). Inoue and colleagues discovered that the characteristics of individuals who may benefit from PARO are distinguished not by the severity of dementia, but by their level of interest in PARO (Inoue et al., 2021).

Despite the findings of other research that appearance, and behavior of robots have a major influence on the positive interactions of consumers and robots (Ruijten et al., 2019), none of the included studies evaluated the effect of type, appearance, size, and interaction modes of SAR on HRI. To offer suggestions for successful SAR development, a thorough investigation of needs of end-users about these factors, especially their expectations of SARs is needed. This may result in distinct design characteristics which are crucial to future deployment and long-term use.

4.3. Target population

4.3.1. Patients

In our review, the majority of the articles (80 %) targeted patients. Surveys completed by older adults revealed high ratings for the SAR's perceived friendliness, intelligence, and safety as well as its usefulness and ease of use (Robinson & Nejat, 2022). According to some studies (Broadbent et al., 2012), robots could promote social interaction among patients, help with group activities, and be used as therapeutic tools (Birks et al., 2016). Positive effects on wellbeing were found in a systematic review of the application of SARs in the care of older adults (Kachouie et al., 2014). It has been demonstrated that using the SAR robot to care for dementia patients reduces stress and fosters social interaction (Wada & Shibata, 2007). Robots can help older adults maintain their independence and reduce social isolation and depression (Khosravi & Ghapanchi, 2016). Patients could greatly benefit from having SAR available at all times (Bedaf, Draper, & Gelderblom, 2016). Use of SARs among people with dementia was perceived to be beneficial in several studies. Studies showed that health professionals appreciated the capacity of robots to tranquilize patients with dementia in distress. (Moyle et al., 2018, Robinson et al., 2016). SAR opened up new means of communication for those suffering from dementia (Gustafsson et al., 2015), improved their moods, decrease isolation in these people (Robinson et al., 2016), and effectively improve on currently available therapeutic interventions for them (Bemelmans, Gelderblom, Jonker, & De Witte, 2016).Our scoping review's results were in-line with previous studies results about the use of SARs for patients with dementia due to the AD. Our review results showed that SAR robots presence mostly would increase patients' quality of daily life, especially in terms of alleviating feelings of loneliness, and social isolation (Fields et al., 2021, Gerłowska et al., 2018, Inoue et al., 2012, Moyle et al., 2013, Pino et al., 2015, Sancarlo et al., 2017, Van Assche et al., 2021), helping patients feel more at ease during unpleasant moods like agitation and depression (Agrigoroaie & Tapus, 2017, Park et al., 2021), and facilitating medical interventions such as those related to monitoring bed rest and medicine intake at home (Antona et al., 2019, D'Onofrio et al., 2018, Kostavelis et al., 2016).

4.3.2. Care providers and caregivers

As our results showed, a limited number of studies have addressed care providers, caregivers, and their views about the use of SARs. Though, it is important for care providers and caregivers to engage in investigations regarding the contribution of robots and their impacts on patient's care. They are important stakeholders in the use of SARs in healthcare because they have to collaborate and work side by side with SARs (Papadopoulos et al., 2018). Care providers and caregivers who were surveyed without having interacted with a robot and were required to imagine its capabilities, typically expressed doubt about the robot's application in a medical setting, and denied that humanoid robots could carry out any clinical duties (Goransson & Pettersson, 2008, Broadbent et al., 2012, Fuji et al., 2011). According to Bedaf et al. (2018), care providers were hesitant about using SARs because senior patients have little experience with technology and may require assistance in using the robot. Moreover, seniors would miss out on social interactions if the care provider was a robot rather than a human (Bedaf et al., 2018). In contrast, some care providers and caregivers supported the potential of the SAR to relieve care burden and envisioned it as a next-generation technology for taking care of older adults (Arthanat et al., 2020, D'Onofrio et al., 2018, Wang et al., 2017). According to certain studies, caregivers and care providers viewed the integration of SAR robots into clinical environments positively (Arthanat et al., 2020, Broadbent et al., 2016, Robinson et al. 2016, Zsiga et al., 2013). Additionally, they reported an enhancement in their perception of these robots following interactive sessions (Gustafsson et al., 2015, Robinson et al., 2016). In addition, SARs can take over repetitive activities of the older aduls, and may help caregivers do more valueded activities with the older adults (Wang et al., 2017). Therefore to conclude regarding these mix views, it is essential to carry out additional research in this field given how quickly technology is developing in the healthcare (Papadopoulos et al., 2018).

4.4. Sex considerations in SAR-human interactions

As highlighted in our results, participants of the included articles were predominantly female (72 %). However, based on the previous studies (Abel et al., 2020, Kuo et al., 2009), men and women showed different results when it came to the participant's attitude towards robots. Studies on emotional aspects of HRI have been suggested that men would have more closeness to the robot as partner than women (Choi et al., 2017). In addition, male seniors were more proactive than female ones, exhibiting a greater willingness to engage with them and assigning higher ratings to their attributes (Esposito et al., 2020). Considering both female and male participants is important in HRI because of differences in social behaviour and roles in society (Doherty & Eagly, 1989). In line with human-human conformity effects, female participants felt a stronger conformity effect than male participants (Shiomi & Hagita, 2019). Conformity is a significant social phenomenon in which an individual or group shapes the attitudes, convictions, or actions of another individual or group (Shiomi & Hagita, 2019). Therefore, at the light of these considerations, it is essential for future research to include a representative sample of both male and female patients when examining the use of socially assistive robots, and investigate potential gender-specific responses and outcomes.

4.5. Limitations

This review has provided an overview to the application of SARs in the AD population. It is limited, however, by our inclusion of only peer-reviewed English articles and the absence of manual searches. Another limitation of this study is that we omitted some factors that could affect human-SAR interactions. These aspects such as usability (designing robots with user-friendly interfaces)(Gerłowska et al., 2018, Granata et al., 2013), safety (ensuring the safety of humans during interactions) (Gerłowska et al., 2018), ethics (implementing ethical considerations in robot behavior and decision making) (Alaieri & Vellino, 2016), feedback mechanisms (providing clear feedback to users) (Axelsson et al., 2022), privacy (addressing privacy concerns related to data collection) (Chatzimichali et al., 2021), and customization (allowing customization based on individual preferences) (Lacroix et al., 2022) were not within the primary focus of our investigation. Future research endeavors should aim to address these excluded factors, providing a more comprehensive analysis of the intricate landscape of HRI.

5. Conclusion

Our review identified current research and gaps in the use of SAR for individuals with AD. This review highlighted that patients would experience a higher quality of life with SAR, especially in terms of a decrease in feelings of loneliness and social isolation. However, in order to better understand end users' needs and expectations, future research should engage care providers and caregivers in addition to patients in their investigations, and assess the impact of SAR type, appearance, and interaction modes on human-robot interactions. They should also mention details about AI-powered SARs for AD patients, and the difficulties they faced. This could show some of the current technological limitations about this aspect. Additionally, in order to develop and leverage SARs for people with AD, research needs to use a representative sample of both men and women, and to consider additional factors such as usability, safety, and ethics that were not thoroughly investigated in this study but may have an impact on human-robot interactions.

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CRediT authorship contribution statement

Vania Karami: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Mark J. Yaffe:** Writing – review & editing, Supervision, Conceptualization. **Genevieve Gore:** Writing – review & editing, Methodology, Formal analysis. **AJung Moon:** Writing – review & editing, Methodology. **Samira Abbasgholizadeh Rahimi:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

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Appendix A. PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist containing the page number where each reporting criterion is addressed

Section	Item	PRISMA-ScR checklist item	Reported on page #
Title			
Title	1	Identify the report as a scoping review.	1
Abstract			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/ objectives lend themselves to a scoping review approach.	3–5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5
Methods			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	6–7

(*continued on next page*)

(*continued*)

Section	Item	PRISMA-ScR checklist item	Reported on page #
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	6
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	6
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	6–7
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	6–7
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	6–7
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	6–7
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	7
Results			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7–8
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	7–9
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	7–13
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	7–13
Discussion			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	14–16
Limitations	20	Discuss the limitations of the scoping review process.	14–16
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	16–17
Funding			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	18

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

Appendix B. Duration of human-SAR interaction used for different type of robots based on the proposed application

Application of robot	Type of Robot	Duration of intervention	Timing (frequency\duration of each episode)
Daily life improvement	NAO	3 weeks	6 sessions
	James	2 Weeks	-NA-
	NAO	-NA-	3 sessions
	Slibot	6 Weeks	Twice per Week/ 60 min
	MATY	-NA-	3 h with a break in between weekly/24 h
	Sil-bot	6 months	24 h
	Robot sheep	-NA-	20 min
	Eva	-NA-	34 min
	MARIO	4 weeks	3 times per week
	Hobbit	21days	24/7 basis
	Pleo	6 weeks	1 time weekly
	RAMCIP	3 to 7 days	24 h
	RAMCIP	4 months	24 h
	MARIO	1 time	6 min
	Mobile robot	2 days	24 h
	ED	5–10 days	-NA-
	PaPeRo	7days	2 h/day
	MARIO	1time	6 min
	Ludwig	-NA-	3 sessions
	Pleo	6 weeks	3 sessions/ 20 min
	PaPeRo	7days	Daily
	Torso mounted on Pioneer mobile platform	6 months	Once per week/22 min
	Mobile robot	10 days averagely	Daily

(*continued on next page*)

(*continued*)

Application of robot	Type of Robot	Duration of intervention	Timing (frequency\duration of each episode)
	Paro	5 months	1 per month /2h
	Telenoid	3 months	Once or twice a week / 798.7 sec
	Kompaï	1 month	1 session
Cognitive assessment	Telenoid	-NA-	20 min
	Giraff	-NA-	20 min
	Pepper	2 sessions	-NA-
	Pepper	1 time	-NA-
	Omni	-NA-	40 min
Cognitive therapy	PARO	6 Weeks	30 min/daily
	Cota, Prlro	8 Weeks	-NA-
	PaPeRo	2 Weeks	-NA-
	Pepper	6 Weeks	2 days a week
	Hasbro	12 months	-NA-
	NAO	8 weeks	weekly /1 h and a half
	NAO	8 weeks	weekly / 1 h and a half
	-NA-	4 weeks	30 min/weekly
	-NA-	12 weeks	Daily in the morning and evening
	Bomy	4 weeks	5 days a week/60 min
	Chapit	-NA-	5 min
	Kabochan	32 weeks	-NA-
	Robotic cat	1 time	24h
	Wam arm	1 time	-NA-
	Telenoid	10 weeks	-NA-
	Omni	5 days	1 h
	-NA-	1 to 3 months	1 h
	-NA-	4 weeks	60 min/day
	Telenoid	6 sessions	20 min
	Nao	2 months	-NA-
	PARO	10 weeks	15 min 3 times per week
	Mobile robot	1 month	2 times per week/45 min
	Lego robot	8 Weeks	1times per week/45–60 min
	NAO, PARO	3 months	2 days a week/30–40 min
	PARO	12 weeks	Twice per Week/ 30 min
	PARO	1 session	-NA-
	Torso mounted on Pioneer mobile platform	6 months	Once per week/22 min
	Torso mounted on Pioneer mobile platform	6 months	Once per week/22 min
	PARO	-NA-	20 min
	Torso mounted on Pioneer mobile platform	3 months	2 times per week

-NA-: no answer was reported in the study; h: hour, min: minute.

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