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Feasibility, acceptance, and impact of socially assistive robots in non-drug interventions with people with dementia: A scoping review

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Abstract

Background: With increasing research on robotics, socially assistive robots may broaden potential forms of non-drug interventions for the increasing numbers of people with cognitive impairments. Existing reviews have concentrated on one robot, one intervention, or one outcome only. With this paper, we attempt to gain an overarching perspective on different types of socially assistive robots in various non-drug interventions, and their feasibility, acceptance, and impact.
Objective: We conducted a scoping review of research on socially assistive robots used in non-drug interventions for people with dementia (PwDs) or people with mild cognitive impairment (PwMCIs) to determine whether the use of robots is feasible, accepted, and yields a positive impact on the attendees.
Methods: We used the online databases PubMed, CINAHL, and IEEE Xplore to identify relevant studies published up to the end of 2018. To be included, studies had to involve PwDs/PwMCIs and deploy a robot in a non-drug intervention. Ambient Assisted Living (AAL) structures were excluded.
Results: This review included a total of 70 records with 21 different robots (12 animaloids, 4 humanoids, 5 mechanoids). The findings indicated that feasibility is a necessity for acceptance, which in turn is a necessity to generate an impact. Robots are feasible as long as they function and as long as non-cognitive symptoms (e.g. agitation) do not get in the way of conducting the intervention. Results for acceptance were mixed, but generally, PwDs and PwMCIs were interested in interacting with the robots. No coherent positive impacts other than increased communication, engagement, and pleasure were found. Neither cognitive nor other non-cognitive symptoms of PwD/PwMCI were significantly positively influenced by controlled studies.
Conclusions: Firstly, more research should focus on feasibility and acceptance. Secondly, studies examining possible impacts need to be better structured and comparable.

Keywords: Review [MeSH], dementia [MeSH], cognitive dysfunction [MeSH], robotics [MeSH], non-drug intervention

Introduction

In 2015 the World Health Organization estimated that about 47 million people worldwide lived with dementia (World Health Organization, 2015). Even though a stable or declining prevalence of the disease is reported in some countries (Wu et al., 2017), the estimated total number of people with cognitive impairment is increasing as the older population is growing worldwide (United Nations et al., 2020). At the same time, the research field of robotics is expanding – a search on PubMed yields over 20,000 results for the MeSH-Term "*robotics*" for the years 2010 to 2019, compared to 6,200 results for 2000 to 2009. Furthermore, robots are recognized as an expanding option for delivering healthcare services without replacing healthcare workers (European Parliament, 2017). Although some authors see the shortage of professional healthcare workers as one reason to employ robots in this field (Broadbent et al., 2009; Maalouf et al., 2018).

The objective of this paper was to condense the existing scientific publications on people with dementia (PwDs) or mild cognitive impairment (PwMCIs) partaking in non-drug interventions that utilized a socially assistive robot. Published reviews so far have only reported either on one type of robot (e.g. Chang & Sung, 2013; Moyle, Arnautovska, et al., 2017), one type of inter-

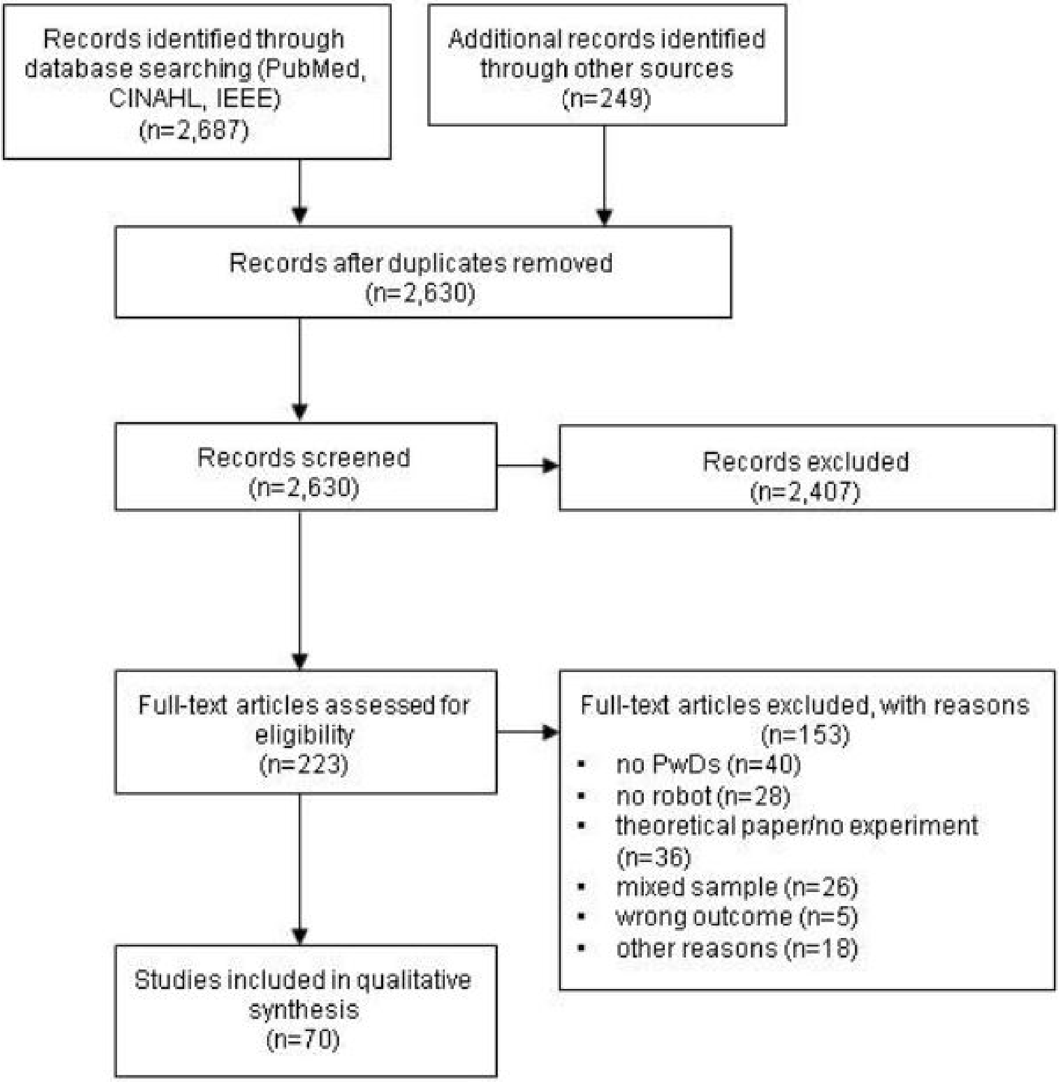


Figure 1. PRISMA-ScR FlowChart.

vention (e.g. Filan & Llewellyn-Jones, 2006), or one outcome (e.g. Broadbent et al., 2009) and sometimes limited their inclusion criteria to Randomized Controlled Trials (RCTs) (e.g. Van der Roest et al., 2017). Robotics for people with cognitive impairment is still a new field without an established terminology and with a diverse group of scientists working in it. Depending on the specific robot scientific research is in different stages: from feasibility testing in labs to RCTs on effects with hundreds of participants. A scoping review is therefore well-suited to give an overview of the existing knowledge. As far as we are aware, there is currently no other published review that does not limit study inclusion by type of socially assistive robots, by type of non-drug interventions, or by type of study designs and incorporates the outcomes feasibility, acceptance, and impact of non-drug interventions for PwDs or PwMCIs. The following research questions were formulated: *"Is the employment of a socially assistive robot in non-drug inventions for people with cognitive impairment feasible, is it accepted and does it yield an impact on the attendees?"*

Methods

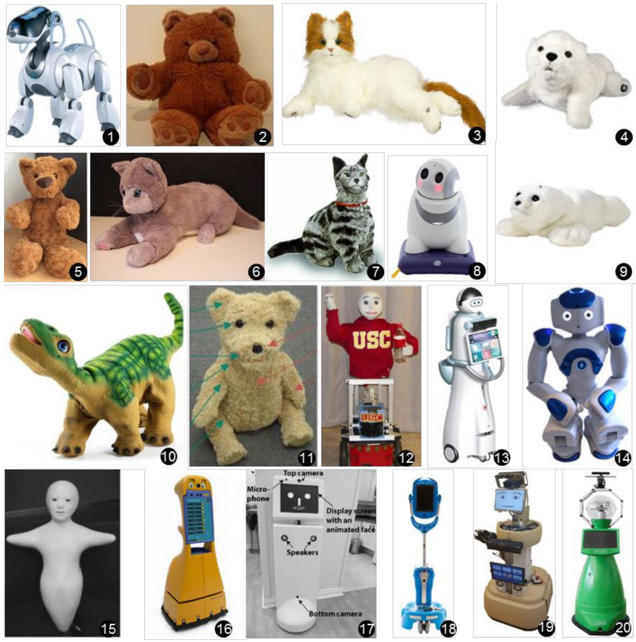
Our paper follows the PRISMA Extension for Scoping Reviews (Tricco et al., 2018) and the procedure proposed by Schmucker et al. (2013) and Arksey and O'Malley (2005). A separate protocol was not published or registered.

Eligibility criteria (PICO)

To be relevant, records needed to involve PwDs of any type and/or PwMCIs as the primary target. Interventions that targeted PwDs/PwMCIs

Table 1. Feature matrix comparing the functions of different robot platforms (A: Communication via noises, B: Speech-based communication, C: Large scale navigational capabilities, D: Individually extensible software, E: Autonomous functions).

	Robot name [no.]	Function				
		A	B	C	D	E
Animaloid	*Aibo* [1]	+	-	+	+	+
	Bear Type [2]	+	-	-	+	+
	CuDDler [5]	+	-	-	+	+
	Cuddling Kitty [3]	+	-	-	-	+
	JustoCat [6]	+	-	-	-	+
	NeCoRo [7]	+	-	-	-	+
	PaPeRo [8]	+	+	+	+	+
	Paro [9]	+	-	-	-	+
	Pleo [10]	+	-	+	-	+
	Teddy Bear Type [11]	+	+	-	+	+
	Unknown Dog Type	?	?	?	?	?
	WowWee Seal Cub [4]	+	-	-	-	+
Humanoid	*Bandit II* [12]	-	+	+	+	+
	Kompaï [13]	-	+	+	+	-
	Kompaï 2/ MARIO	-	+	+	+	+
	NAO [14]	-	+	+	+	+
	Telenoid [15]	-	-	-	-	-
Mechanoid	*CompanionAble* [16]	-	+	+	+	+
	ED [17]	-	+	+	+	+
	Giraff [18]	-	-	+	-	-
	RAMCIP [19]	-	+	+	+	+
	Scitos G5 [20]	-	+	+	+	+



Note. Source: 1: Robot Center (n.d.); 2: Heerink et al. (2013); 3: Heerink et al. (2013); 4: (Robots.nu, n.d.); 5: Moyle et al. (2016); 6: JustoCat (n.d.); 7: Martinez-Martin and del Pobil (2018); 8: NEC Corporation (n.d.); 9: Rouaix et al. (2017); 10: Pleoworld (n.d.); 11: Nihei et al. (2017); 12: Tapus (2009); 13: Kompaï Robotics (n.d.); 14: Rouaix et al. (2017); 15: Yamazaki et al. (2014); 16: Schroeter et al. (2013); 17: Begum et al. (2015); 18: TelepresenceRobots.com (n.d.); 19: RAMCIP-Project (2017); 20: Hebesberger et al. (2016)

and their caregivers (CGs) were included as well. Every type of non-drug intervention was eligible for inclusion as well as every possible way to employ a socially assistive robot within these interventions. Theoretical papers without actual robot deployment were excluded. We defined a robot as a closed technical entity with a visibly limited sphere of influence (in contrast to Ambient Assisted Living (AAL) structures) that is '*capable of automatically carrying out a complex series of movements*' ('*Robot*', 2010). Records with and without control groups were included. Outcomes needed to be about the feasibility or impact of the robot-assisted intervention, or acceptance of the robot, or any combination of these. We defined feasibility as the '*capability of being done*' ('*Feasibility*', 2010) and acceptance as any form of positive reaction towards the robot. Outcomes could be qualitative, quantitative, or mixed-method. All types of studies were included. The records needed to be written in English or German and published in journals or conference proceedings. Reviews were excluded but used as a starting point for the hand search. Publications up to November 2018 were included.

Records involving children or individuals with congenital or acquired brain damage, stroke, autism, or Chorea Huntington were excluded. If a study involved PwDs/PwMCIs but only surveyed CGs, it was excluded as well. Records employing AAL structures without a robot or technical devices that are not robotic (e.g. computers, GPS, clocks) or utilizing the robot to compensate solely for physical deficits were excluded. Records with mixed samples of healthy elderly people (HEPs) and PwDs/PwMCIs were excluded if the results were not differentiated by cognitive ability.

Search strategy

Electronic bibliographic databases were systematically searched to identify relevant records. To cover research done in the medical field, nursing science as well as engineering, computing, or technology science, the following databases were chosen: PubMed, CINAHL, and IEEE Xplore. The search strategy was drafted using MeSH-Terms (if available) and the databases' thesauruses. The search strategy combined the two themes of PwDs/PwMCIs (exemplary terms were '*dementia*' or '*cognitive impairment*') and

Table 2.1. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (1: Aibo).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
1		✓		Greco et al., 2009 Italy	memory clinic	24 PwMCIs or PwDs	Cross-sectional, no comparison, no randomisation, quantitative	Acceptance assessment	Individual introduction and demonstration of robot (once a few min)	Standardised interview
1			✓	Hamada et al., 2008 Japan	care facility	5 PwDs, 6 PwDs	Longitudinal, no comparison, no randomisation, mixed-method	Recreational	Individual card game with robot (10min/d for 5d); group ball game with robot (40min/d for 5d)	Observation (Action factors), 5-point scale on memory, emotion, self-expression and personal relationships (external assessment)
1			✓	Kimura et al., 2010 Japan	care facility	11 PwDs, 6 HYPs	Cross-sectional, parallel comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (30min once a mo.)	Neuroactivity via EEG
1			✓	Kramer et al., 2009 USA	care facility	18 PwDs	Cross-sectional, crossover, block randomised, quantitative	Animal-assisted therapy	Individual visitation either alone or with dog or with robot (3min/w for 3w)	Observation of conversation, touch and look
1	✓			Naganuma, Ohkubo, 2015 Japan	care facility	2 PwDs	Cross-sectional, no comparison, no randomisation, qualitative	Animal-assisted therapy	Completing short tasks with robot as a group (once a few min)	Observation
1		✓		Odetti et al., 2007 Italy	memory clinic	24 PwMCIs or PwDs	Cross-sectional, no comparison, no randomisation, quantitative	Acceptance assessment	Individual introduction and demonstration of robot (once a few min)	Standardised interview
1			✓	Sakairi, 2004 Japan	care facility	8 PwDs	Cross-sectional, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot (once for 30min)	MMSE, Nishimura dementia scale, counting of utterances

robot-assisted therapy (exemplary terms used were '*robots*', or '*assistive technology*'). The final search strategies can be found in the Appendix. Additional records were searched using the reference lists of reviews, project websites, and Google Scholar. The first database search was performed on the 25th of January 2018. The last search update was done on the 08th of November 2018. Literature search and screening were performed by the researchers CW, MR, and EG.

The search results were exported into Clarivate Analytics EndNote X8, and duplicates were deleted. Each record's title and abstract were screened by CW to determine eligibility. Records were excluded in that phase if they focused on any other disease than dementia of any form or MCI, used the robot for surgery or medical imaging (e.g. MRI), studied children or HEPs living in assisted facilities, or used technology that was not robotic such as hearing aids, cochlear implants, GPS transmitters, smartphones, computers, laptops, tablets, sensors, clocks, or lamps. The full-text screening and data charting were conducted separately by CW and MR. A pilot test was conducted with five records, leading to refinements in the data extraction sheet and manual, assisted by EG. Disagreements in the screening process

Table 2.2. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (1: Aibo, 2: CuDDler, 3: JustoCat, 4: NeCoRo, 5: PaPeRo).

Robot type	Objective			Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
	F	A	E							
1		✓		Tamura et al., 2004 Japan	geriatric rehab	13 PwDs	Longitudinal, crossover ABA, no randomisation, quantitative	ADLs & occupational therapy	Occupational group therapy with first toy and then robot (5min/d for 4d); occupational group therapy with either dressed or undressed robot (5min/d for 3d)	Observation of conversation, touch and look
2	✓	✓		Moyle et al., 2016 Australia	care facility	5 PwDs	Longitudinal, no comparison, no randomisation, mixed-method	Animal-assisted therapy	Animal-assisted individual therapy with robot (up to 30min/d on 3d/w for 5w)	CMAI, semi-structured interviews, OERS, observation (engagement, affect, agitation)
3		✓	✓	Gustafsson et al., 2015 Sweden	care facility	3 PwDs, 14 CGs	Longitudinal, crossover ABA, no randomisation, mixed-method	Animal-assisted therapy	Animal-assisted individual therapy with robot (free access to robot for 7w) vs care as usual	QUALID, CMAI, qualitative Interview (CGs)
4			✓	Libin, Cohen-Mansfield, 2004 USA	care facility	9 PwDs	Longitudinal, crossover, randomised, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with either robot or plush toy (once 10min each)	ABMI aggression, affect, engagement
4			✓	Libin, Libin, 2005 USA	care facility	14 PwDs	Longitudinal, crossover, randomised, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with either robot or plush toy (once 15min each)	LMPR-pet, agitation, affect, interest
5	✓			Chu et al., 2017 Australia	care facility	139 PwDs	Cross-sectional, no comparison, no randomisation, qualitative	Recreational	Introduction of robot, singing songs, playing bingo in group (once for unspecified duration)	Observation (approaching robot, pleasure, interacting with robot, interacting with others)
5	✓	✓		Inoue et al., 2012 Japan	care facility	5 PwDs	Longitudinal, no comparison, no randomisation, quantitative	ADLs & occupational therapy	Individually talking with robot for information support (30min for 3-5d)	Observation, remarks
5	✓			Nishiura et al., 2014 Japan	care facility	1 PwD	Longitudinal, single case, no comparison, no randomisation, quantitative	ADLs & occupational therapy	ADLs support from robot (3d/w for 2w)	Performance rate, observation

were solved through discussion and by involving EG. The following data items were extracted if they were available: type of robot, authors, year of publication, land of origin, setting of intervention, sample size of intervention group, sample size of control group, study design, intervention type, length of intervention, treatment of control group, outcome measures, ethical aspects (including funding and author bias), and results.

For critical appraisal, we noted whether any of the contributing authors had developed the robot or further developed hard-/or software. The source of funding was extracted along with statements about the ethics committee's approval of the study and the collection of informed consent. We grouped the records by the outward appearance of the robot and summarized the results for each group. To illustrate the search strategy, we created a flow chart (*Figure 1*). Tables were created to provide an overview of the basic functions of the robot (*Table 1*) as well as the records' objectives and study approaches (*Table 2*).

Results

In the database search, 2687 citations were identified, and 249 additional citations were identified through hand search. After duplicates were removed, 2630 citations were screened by title and abstract. 2407 of these were excluded, 14 due to non-attainable abstracts and 12 for not being written in English or German (for other reasons, see above). 223 records were examined for eligibility, of which 153 were excluded. The remaining 70 records were considered eligible and were included in this review. The flow chart (*Figure 1*) illustrates the screening process.

Table 2.3. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
6			✓	Bemelmans et al., 2015 Netherlands	care facility	71 PwDs	Longitudinal, crossover ABAB, quasi-experimental, quantitative	Animal-assisted therapy, ADLs & occupational therapy	Robot for individual therapeutic and care support interventions (as needed for 16w) vs care as usual	IPPA
6	✓			Bemelmans et al., 2016 Netherlands	care facility	23 PwDs	Longitudinal, no comparison, no randomisation, qualitative	Animal-assisted therapy, ADLs & occupational therapy	Robot for individual therapeutic, care support or visitation interventions (10-15min/1-2d/w for 3w)	Observation
6		✓		Chang et al., 2013 USA	care facility	10 PwDs	Longitudinal, no comparison, no randomisation, qualitative	Animal-assisted therapy	Multi-sensory behavioural group therapy with robot (30-45min/d on 1d/w for 8w)	Observation (interaction with robot)
6			✓	Demange et al., 2018 France	geriatric hospital	17 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot (15min/d on 2d/w for 2w)	I-PANAS, system usability scale, perception scale
6			✓	Inoue et al., 2011 Japan	day care center	5 PwDs	Longitudinal, crossover ABA, no randomisation, qualitative	Animal-assisted therapy	No therapy (twice for 30min) vs animal-assisted individual therapy with robot (once for 30min)	Dementia Care Mapping, observation
6			✓	Jones et al., 2018 Australia	care facility	138 PwDs (Paro intervention), 140 PwDs (plush toy intervention), 137 PwDs (control)	Cluster RCT, 3 arms, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot vs animal-assisted individual therapy with plush toy vs care as usual (each 10min/d on 3d/w for 10w)	Agitation, affect, engagement, CMAI, RUDAS
6			✓	Jøranson et al., 2015 Norway	care facility	30 PwDs intervention, 30 PwDs control	Cluster RCT, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot vs care as usual (30min/d on 2d/w for 12w)	BARS, CSDD

Of the included 70 records 51 employed a robot resembling an animal (animaloid). Ten records used robots resembling a human being (humanoid) and 10 records employed mechanoid robots that resemble neither an animal nor a human. One record used an animaloid and a humanoid robot. *Table 1* provides an overview of the basic functions of the employed robots.

Regarding objectives, 21 records reported on the feasibility of the robot deployment, 31 on acceptance, 35 on the impact of the robot-assisted interventions, and 15 on either feasibility and acceptance or acceptance and impact.

The records were published between 2004 and 2018. The studies took place worldwide with 28 in Europe, 22 in Japan, 14 in Northern America, and 9 in Oceania.

Most of the interventions (61) took place in care facilities such as nursing and retirement homes, daycare centers, hospitals, and rehabilitation centers. Eleven interventions were carried out in the participants' private homes or AAL labs. Two records carried out interventions in care facilities and at home.

Table 2.4. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
6			✓	Jøranson et al., 2016a Norway	care facility	30 PwDs intervention, 30 PwDs control	Cluster RCT, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot vs care as usual (30min/d on 2d/w for 12w)	QUALID, medication use
6			✓	Jøranson et al., 2016b Norway	care facility	30 PwDs	Longitudinal, no comparison, no randomisation, qualitative	Animal-assisted therapy	Animal-assisted group therapy with robot vs care as usual (30min/d on 2d/w for 12w)	Ethogram
6			✓	Liang et al., 2017 New Zealand	day care center	15 PwDs and CGs intervention, 15 PwDs and CGs control	Block RCT, mixed methods	Animal-assisted therapy	Animal-assisted group therapy with robot at day-care centre (30min/d on 2-3d/w for 6w) and robot at home (free access for 6w) vs care as usual	Addenbrooke's Cognitive Examination, CMAI, NPI, CSDD, observation (emotions, interactions), blood pressure, salvia or hair cortisol, heart rate, medication use
6		✓		Marti et al., 2006 Italy	care facility	1 PwD	Longitudinal, single case, no comparison, no randomisation, qualitative	Animal-assisted therapy	Animal-assisted individual therapy with robotv (as needed for 24w)	Observation
6			✓	Moyle et al., 2013 Australia	care facility	18 PwDs	Longitudinal, crossover, randomised, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot vs reading group (each 45min/d on 3d/w for 5w; 3w wash-out period)	AWS, QoL-AD, AES, GDS (depression), RAID, OERS
6			✓	Moyle et al., 2017a Australia	care facility	138 PwDs (Paro intervention), 140 PwDs (plush toy intervention), 137 PwDs (control)	Cluster RCT, 3 arms, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot vs animal-assisted individual therapy with plush toy vs care as usual (each 10min/d on 3d/w for 10w)	Observation (agitation, affect, engagement), CMAI
6	✓	✓		Moyle et al., 2017b Australia	care facility	5 PwDs out of 138 PwDs (Paro intervention)	Cluster RCT, 3 arms, qualitative	Animal-assisted therapy	Animal-assisted individual therapy with robot (10min/d on 3d/w for 10w)	Observation

The sample size of the intervention group ranged from 1 to 165 PwDs and/or PwMCIs with a median of 10. Twelve records had a control group. The sample sizes of the control group ranged from 5 to 290 with a median of 30. Eighteen records performed a crossover comparison. Sample sizes in crossover studies ranged from 3 to 71 with a median of 11.5. Sixteen records performed randomization. Most studies were longitudinal (54) or employed quantitative methods (43).

The interventions used in the records were dementia specific and focused on deficits in motor function, cognition, activities of daily living (ADLs), non-cognitive symptoms, overall well-being, communication, and leisure activities. Most records (40) used the robot in animal-assisted therapy. Six records employed the robot in two or more types of interventions.

The length of the intervention varied from 2 minutes to 10 hours with a median of 30 minutes. The length of the intervention period ranged from a one-time implementation in 18 records up to 5 years in 1 record with a median of 6 intervention days.

The control treatments were either care as usual (12), animal-assisted therapy with a toy (10), animal-assisted therapy with a dog (4), Nordic walking (2), or other interventions such as physiotherapy, art therapy, cognitive exercises, reading groups, visits, group games, or videos (1 each). Seven records executed two or more control treatments.

Table 2 presents the general study characteristics sorted by the robot. The results of the included records are summarized in the following. For the functions and a picture of a specific robot please refer to *Table 1*, for the objectives and interven-

Table 2.5. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
6			✓	Moyle et al., 2018 Australia	care facility	Daytime: 67 PwDs (Paro intervention), 55 PwDs (plush toy intervention), 53 PwDs (control); Night time: 98 PwDs (Paro intervention), 95 PwDs (plush toy intervention), 87 PwDs (control)	Cluster RCT, 3 arms, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot vs animal-assisted individual therapy with plush toy vs care as usual (each 10min/d on 3d/w for 10w)	Wearable activity tracker (daytime and night time activity, step count)
6			✓	Petersen et al., 2017 USA	care facility	35 PwDs intervention, 26 PwDs control	Block RCT, quantitative	Animal-assisted therapy	Animal-assisted group therapy vs care as usual (20min/d on 3d/w for 12w)	RAID, CSDD, GDS (cognition), GSR, pulse, pulse oximetry, medication use
6			✓	Šabanović et al., 2013 USA	care facility	10 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Multi-sensory behavioural group therapy with robot (30-45min/d on 1d/w for 7w)	Observation (amount and duration of interaction)
6		✓		Takayanagi et al., 2014 Japan	care facility	19 PwDs, 11 PwsDs	Longitudinal, crossover, randomisation unclear, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot vs animal-assisted individual therapy with plush toy (each for 15min once; 12-24w wash-out)	Observation (talking, touching, looking, emotions)

tions used in the records please refer to *Table 2*.

Animaloid robots
Animaloid robots are robotic representations of animals. Apart from pets and teddy bears, other species such as seals and dinosaurs are mimicked. Animaloid robots are typically used in animal-assisted therapy but can also be employed in other interventions.

Aibo
Feasibility
The robotic dog Aibo was identified as a gaze target and communication cue serving as a start-

Table 2.6. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
6		✓		Thodberg et al., 2016 Denmark	care facility	43 PwDs (Paro intervention), 43 PwDs (dog intervention), 37 PwDs (plush toy intervention)	Block RCT, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with robot vs animal-assisted individual therapy with dog vs animal-assisted individual therapy with plush toy (each 10min/d on 2d/w for 6w)	Observation (visual contact, physical contact, conversation)
6			✓	*Valentí Soler et al., 2015 Spain	care facility and day care center	92 PwDs (Paro intervention), 50 PwDs (NAO intervention), 36 PwDs (dog intervention), 70 PwDs (control)	Block RCT, quantitative	Cognitive, physiotherapy	Occupational group therapy with NAO vs animal-assisted group therapy with Paro vs care as usual and animal-assisted group therapy with Paro vs animal-assisted group therapy with dog vs care as usual and occupational therapy with NAO and animal-assisted therapy with Paro (each 30-40min/d on 2d/w for 3mo.; wash-out 9mo.)	GDS (cognition), QoL, MMSE, sMMSE, NPI, APADEM-NH
6			✓	Wada et al., 2004a Japan	care facility	12 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1h/d on 2d/w for 10w)	GDS (depression)
6			✓	Wada et al., 2004b Japan	care facility	12 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1h/d on 2d/w for 10w)	Face scale, GDS (depression)
6		✓	✓	Wada et al., 2005a Japan	hospital	14 PwDs	Cross-sectional, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy (once for 20 min)	Neuroactivity via EEG, standardised interview

ing point for interaction between PwDs (Naganuma et al., 2015).

Acceptance
Two records showed that Aibo was perceived as non-threatening and was generally liked. However, most participants thought Aibo would not be useful to them and were not willing to use it (Greco et al., 2009; Odetti et al., 2007). Compared with a plush toy, 1 report described that interactions with Aibo were observed less often. No significant differences in interactions were found when a normal Aibo was compared with an Aibo wearing fur (Tamura et al., 2004).

Impact
Two records found an improvement in cognition (short-term memory and Mini-Mental State Examination (MMSE) score) after Aibo assisted therapy (Hamada et al., 2008; Sakairi, 2004). One record reported that scores on the Nishimura dementia scale were steady or improved slightly (Sakairi, 2004). One record found an increase in emotional control and an increase in accommodation to society after the robot-assisted interventions (Hamada et al., 2008). Neither of the records reported statistical parameters.

For EEG measures, 1 record found an improvement in neuroactivity for all participants, espe-

Table 2.7. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
6			✓	Wada et al., 2005b Japan	care facility	12 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1 h/d on 2d/w for 5-12mo.)	Face scale, GDS (depression)
6			✓	Wada et al., 2005c Japan	care facility	12 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1h/d on 2d/w for 5-17mo.)	Face scale, counting of utterances
6			✓	Wada et al., 2005d Japan	care facility	12 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1h/d on 2d/w for 5-12mo.)	Face scale, GDS (depression)
6			✓	Wada et al., 2006 Japan	care facility	13 PwDs, 1 HEP	Longitudinal, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1 h/d on 2d/w for 10w)	Face scale
6			✓	Wada et al., 2007 Japan	day care center/ at home	5 PwDs	Longitudinal, crossover ABA, no randomisation, mixed-method	Animal-assisted therapy	Art therapy (2h/d on 1d/w) and robot at home (access for 1w) vs care as usual	Neuroactivity via EEG, caregiver diaries
6		✓	✓	Wada et al., 2008 Japan	hospital	14 PwDs	Cross-sectional, no comparison, no randomisation, mixed-method	Animal-assisted therapy	Animal-assisted therapy with robot (once for 20min)	Neuroactivity via EEG, standardised interview, caregiver diaries
6			✓	Wada et al., 2009 Japan	care facility	1 PwD	Longitudinal, single case, no comparison, no randomisation, quantitative	Animal-assisted therapy	Animal-assisted group therapy with robot (1 h/d on 2d/w for 67mo.)	Face scale, GDS (depression)
6			✓	Wada, Shibata, 2006 Japan	care facility	1 PwD	Longitudinal, single case, no comparison, no randomisation, quantitative	Animal-assisted therapy	Free access to robot in communal space (9h/d for 8w)	Observation (amount and time of interaction), stress hormones in urine

cially for PwDs with greater cognitive decline. The biggest improvement was reported for the intervention session, where Aibo was remotely controlled by a researcher (Kimura et al., 2010).

Increased movement (Hamada et al., 2008), utterance, and conversations between PwDs were observed (Hamada et al., 2008; Sakairi, 2004).

Compared with a dog visit, no significant differences in touching or looking were found, although significantly longer looks at Aibo were reported. Compared with an unaccompanied visit and a dog visit, PwDs initiated significantly less conversation in the Aibo visit. (Kramer et al., 2009).

Bear type robot, Cuddling Kitty, and WowWee Seal Cub

One record used the bear type robot, the robotic cat Cuddling Kitty, the WowWee Seal Cub, and the robotic dinosaurs Pleo and compared them in an acceptance assessment.

Acceptance

The participants expressed a preference for the WowWee Seal Cub and Cuddling Kitty over the bear type robot and Pleo. The robotic seal and cat were caressed and liked by a majority of the PwDs, whereas 40% of PwDs liked the bear type robot or Pleo. Nevertheless, the record did not find one robot that was liked by every participant and concluded that different robots suited differ-

Table 2.8. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (6: Paro, 7: Pleo, 8: teddy bear type social robot, 9: unknown dog type robot, 10: Bandit II).

Robot type	Objective			Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
	F	A	E							
6			✓	Wada, Shibata, 2007 Japan	care facility	1 PwD	Longitudinal, single case, no comparison, no randomisation, quantitative	Animal-assisted therapy	Free access to robot in communal space (9h/d for 8w)	Observation (amount and time of interaction), stress hormones in urine
7		✓		**Heerink et al., 2013 Netherlands, Spain	care facility	15 PwDs	Cross-sectional, cross-over, no randomisation, qualitative	Acceptance assessment	Introducing different robots in group (each for 15min once)	Observation (interaction with robot), remarks
7		✓		Perugia et al., 2017 Spain	care facility	8 PwDs / 14 PwDs	Longitudinal, crossover, randomised, quantitative	Recreational	Playing cognitive games in groups (35-40min/d on 1 d/w for 3w); playing cognitive games in groups vs playing freely in groups with robot (each three time for 35-40min on 1d/w in 6w)	Ethogram, OME, OERS
8	✓			Nihei et al., 2017 Japan	care facility	3 PwDs	Longitudinal, crossover, no randomisation, qualitative	Communication	Unpredicted behaviour by a robot in communal space (150min/d for 4d)	Observation (interaction with robot, being near robot)
9		✓		Marx et al., 2010 USA	care facility	56 PwDs	Cross-sectional, crossover, randomisation unclear, quantitative	Animal-assisted therapy	Animal-assisted individual therapy with three different dogs vs animal-assisted individual therapy with robot dog vs animal-assisted individual therapy with plush toy vs occupational individual therapy with dog video vs art therapy with dog colouring book (each for 3-15min once; 5min wash-out)	OME
10	✓			Tapus et al., 2009a USA	care facility	3 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Recreational	Individual music therapy with robot (10-20min/d on 1d/w for 12mo.)	Test performance, performance time

ent PwDs depending on personal preference and biographic aspects (Heerink et al., 2013).

CuDDler

Feasibility

The robotic teddy bear CuDDler sometimes failed to operate, had parts that were easy to break, and had motors that made loud noises. The malfunctioning resulted in less interaction with CuDDler by the PwDs and more agitation towards it (Moyle et al., 2016).

Acceptance

Observed reactions were mostly neutral (86.5%) and seldom positive (10%) or negative (3.5%). Enjoyment in interacting with CuDDler was observed in 40% of PwDs. In an interview, 40% of the participants stated that they liked it, the other deemed it too heavy and not soft enough. They viewed CuDDler as childish and did not want it in the care facility (Moyle et al., 2016).

JustoCat

Acceptance

The CGs viewed the robotic cat JustoCat as a good facilitator for interaction and communication between PwDs (Gustafsson et al., 2015).

Impact

No significant improvements in quality of life (QoL) or agitation measured by the Cohen-Mansfield Agitation Inventory were reported

Table 2.9. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (10: Bandit II, 11: Kompaï, 12: NAO).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
10	✓			Tapus et al., 2009b USA	care facility	3 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Recreational	Individual music therapy with robot (10-20min/d on 1d/w for 8mo.)	Test performance, performance time, standardised questionnaire (acceptance)
10		✓		Tapus et al., 2009c USA	care facility	3 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Recreational	Individual music therapy with robot (10-20min/d on 1d/w for 8mo.)	Test performance, performance time
10	✓			Tapus, 2009 USA	care facility	3 PwDs	Longitudinal, no comparison, no randomisation, quantitative	Recreational	Individual music therapy with robot (10-20min/d on 1d/w for 8mo.)	Test performance, performance time
11	✓	✓		Wu et al., 2014 France	AAL lab	6 PwMCIs, 5 HEPs	Longitudinal, parallel comparison, no randomisation, mixed-method	ADLs & occupational therapy, cognitive therapy	Robot supporting individual on IADLs (1 h/d on 1d/w for 4w)	Robot-acceptance questionnaire, semi structured interview, focus group, performance time, error rate, help required
11	✓	✓		Salatino et al., 2017 Italy	AAL lab	4 PwMCIs; 6 CGs	Cross-sectional, no comparison, no randomisation, mixed-method	ADLs & occupational therapy, physiotherapy	Robot supporting individual on IADLs (once for unspecified duration)	Observation, usability questionnaire
11	✓	✓		Kouroupetroglou et al., 2017 Italy, Ireland	care facility/at home/ hospital	10 PwDs	Longitudinal, no comparison, no randomisation, qualitative	ADLs & occupational therapy	Robot supporting individual on IADLs (5-30min/d on 2d/w for 4-8w)	Questionnaire (external assessment), questionnaire (self-assessment)
12		✓		Rouaix et al., 2017 France	hospital	9 PwDs	Longitudinal, crossover, no randomisation, quantitative	Physiotherapy	Individual physiotherapy (20min once) vs individual physiotherapy with robot psychomotor therapy (20min/d on 1d/w for 3w)	Menorah Park Engagement Scale, satisfaction with intervention, appreciation of robot, observation (empathy), EVIBE, I-PANAS

(Gustafsson et al., 2015).

NeCoRo

Impact

One record reported that agitation significantly decreased when participants used the plush toy but not when they used NeCoRo (Libin & Cohen-Mansfield, 2004), whereas the other record found a decrease in agitation for both robots and plush toy (Libin & Libin, 2005). Both records reported a significant increase in pleasure and interest in the robot (Libin & Cohen-Mansfield, 2004; Libin & Libin, 2005) that could not be found for the plush toy (Libin & Cohen-Mansfield, 2004). One record found no significant changes in anxiety or anger (Libin & Cohen-Mansfield, 2004).

Concerning engagement, 1 record found no changes at all (Libin & Cohen-Mansfield, 2004), while the other reported that PwDs engaged with the robot for longer compared with the plush toy (Libin & Libin, 2005).

Table 2.10. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (12: NAO, 13: Telenoid, 14: CompanionAble, 15: ED).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
12			✓	*Valentí Soler et al., 2015 Spain	care facility and day care center	92 PwDs (Paro intervention), 50 PwDs (NAO intervention), 36 PwDs (dog intervention), 70 PwDs (control)	Block RCT, quantitative	Cognitive, physiotherapy	Occupational group therapy with NAO vs animal-assisted group therapy with Paro vs care as usual and animal-assisted group therapy with Paro vs animal-assisted group therapy with dog vs care as usual and occupational therapy with NAO and animal-assisted therapy with Paro (each 30-40min/d on 2d/w for 3mo.; wash-out 9mo.)	GDS (cognition), MMSE, sMMSE, NPI, QoL, APADEM-NH
13		✓		Yamazaki et al., 2014 Denmark	at home	1 PwD	Longitudinal, no comparison, single case, no randomisation, qualitative	Communication	Individual use of robot for telepresence (total of 2h in 2d)	Observation (touching, hugging), utterances
14	✓	✓		Gross et al., 2012 Netherlands	AAL Lab	4 PwDs, 4 CGs	Longitudinal, no comparison, no randomisation, qualitative	ADLs & occupational therapy	Individual use of robot to support ADLs and IADLs (10h/d for 2d)	Observation, semi structured diary, semi structured interview
14	✓	✓		Schroeter et al., 2013 Netherlands, Belgium	AAL Lab	2 PwMCIs, 4 PwDs; 5 CGs	Longitudinal, no comparison, no randomisation, mixed-method	ADLs & occupational therapy	Individual use of robot to support ADLs and IADLs (10h/d for 2d)	Observation, semi structured diary, semi structured interview, questionnaire
15	✓	✓		Begum et al., 2013 Canada	AAL Lab	5 PwDs with CGs	Cross-sectional, no comparison, no randomisation, mixed-method	ADLs & occupational therapy	Individual use of robot to prompt ADLs performance (once for 120-150min)	Semi structured interview, Almere Questionnaire, observation (number of steps, number of prompts, adherence, times of engagement with robot, completeness of task)

PaPeRo

Feasibility

Using PaPeRo, a robotic baby animal, to encourage ADLs, 2 records found that the robot was understood by PwDs most of the time (Inoue et al., 2012; Nishiura et al., 2014). One record employing recreational activities reported that the PwDs approached the robot more often, initiated more interactions with it, and showed more signs of pleasure after they improved the robot (Chu et al., 2017).

Acceptance

87% of the remarks by PwDs about PaPeRo were positive. The other 13% of the remarks were related to difficulties in using the robot and viewing it as a children's toy (Inoue et al., 2012).

Paro

Thirty two of 33 records used the robotic seal Paro for animal-assisted therapy. One record used Paro for cognitive training and physiotherapy. Two records studied feasibility, 9 acceptance, and 26 the impacts of interventions.

Feasibility

Paro was found most feasible in therapeutic interventions compared with social and care interventions (Bemelmans et al., 2016). However, non-cognitive symptoms of PwDs, espe-

Table 2.11. Overview of objectives (F: Feasibility, A: Acceptance, E: Effects), study approaches, interventions and outcome measures. (15: ED, 16: Giraff, 17: RAMCIP, 18: Scitos G5).

Robot type	Objective F	Objective A	Objective E	Source/ Country	Setting	Sample	Design	Type of intervention	Intervention length and frequency	Outcome measures
15		✓		Begum et al., 2015 Canada	AAL lab	10 PwDs with CGs	Cross-sectional, no comparison, no randomisation, qualitative	ADLs & occupational therapy	Individual use of robot to prompt ADLs performance (once for 150min)	Observation of Human-Robot-Interaction
15		✓		Wang et al., 2017 Canada	AAL lab	10 PwDs with CGs	Cross-sectional, no comparison, no randomisation, qualitative	ADLs & occupational therapy	Individual use of robot to prompt ADLs performance (once for 150min)	Semi structured interview
16	✓	✓		Tiberio et al., 2012 Italy	rehab	8 PwMCIs, 9 HEPs	Longitudinal, Crossover AABB, parallel comparison, no randomisation, quantitative	Communication	Individual cognitive exercise (13min/d for 2d) vs individual cognitive exercise using robot for telepresence (13min/d for 2d)	Heart rate, heart rate variability, State-Trait Anxiety Inventory, I-PANAS
16		✓	✓	Moyle et al., 2014 Australia	care facility	5 PwDs; 13 CGs	Longitudinal, no comparison, no randomisation, qualitative	Communication	Individual use of robot for telepresence (4-53min up to six times in 6-8w)	Observation, semi structured interview
17	✓	✓		Gerłowska et al., 2018 Poland	lab	8 PwMCIs, 10 HEPs	Cross-sectional, parallel comparison, no randomisation, quantitative	ADLs & occupational therapy	Individual use of robot to assist with ADLs (up to 3h once)	UEQ
18	✓			Hebesberger et al., 2016 Austria	care facility	10 PwDs	Longitudinal, crossover, no randomisation, mixed-method	Physiotherapy	Nordic walking group therapy with and without robot (45min/d on 2d/w for 4w)	Observation, self-assessment, external assessment, group discussion
18	✓	✓		Gerling et al., 2016 Austria	care facility	10 PwDs	Longitudinal, crossover, no randomisation, qualitative	Physiotherapy	Nordic walking group therapy with and without robot (45min/d on 2d/w for 4w)	Observation

Abbreviations: CGs: Care Givers; HEP: Healthy Elderly Person; HEPs: Healthy Elderly People; HYPs: Healthy Young People; PwD: Person with Dementia; PwDs: People with Dementia; PwMCIs: People with MCI; PwsD: Person with severe Dementia; ADLs: Activities of Daily Living; IADLs: Instrumental Activities of Daily Living; RCT: randomised controlled trial; ABMI: Agitated Behaviours Mapping Instrument; AES: Apathy Evaluation Scale; APADEM-NH: apathy scale for institutionalised dementia patients; AWS: Algase Wandering Scale; BARS: Brief Agitation Rating Scale; CMAI: Cohen-Mansfield Agitation Inventory; CSDD: Cornell Scale for Depression in Dementia; EVIBE: Évaluation instantanée du bien-être; GDS (cognition): Global Deterioration Scale; GDS (depression): Geriatric Depression Scale; GSR: Galvanic Skin Response; I-PANAS: International Positive and Negative Affect Scale; IPPA: Individually Prioritised Problems Assessment; LMPR-pet: Libin Multidimensional Person-Robot Interactions Scales; MMSE: Mini-Mental State Examination, sMMSE: severe Mini-Mental State Examination; NPI: Neuropsychiatric Inventory; OERS: Observed Emotions Rating Scale; OME: Observational Measurement of Engagement; QoL: Quality of Life; QoL-AD: Quality of Life in Alzheimer's Disease; QUALID: Quality of Life in Dementia Scale; RAID: Rating Anxiety in Dementia; RUDAS: Rowland Universal Dementia Assessment Scale; UEQ: User Experience Questionnaire. Note. Care facility includes geriatric care and nursing homes. * Study used one animaloid and one humanoid robot. ** Study used four different animaloid robots.

cially high levels of aggression, could render animal-assisted therapy inapplicable (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017).

Acceptance

Five records reported positive reactions towards and interactions with Paro (Chang & Sung, 2013; Inoue et al., 2011; Marti et al., 2006; Wada, Shibata, Musha, et al., 2005; Wada et al., 2008). One also described negative reactions, where Paro was viewed as childish and stigmatizing (Demange et al., 2018). One record indicated that because of changing mood and health conditions the use of Paro did not fit every PwD at every intervention session (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017).

Compared with a plush toy, 2 records found more positive interactions and emotions with Paro (Takayanagi et al., 2014; Thodberg et al., 2016). Compared with a dog, no significant differences were found except for less eye contact with Paro (Thodberg et al., 2016).

Impact

Cognition: Four records found no significant change in cognition (Liang et al., 2017; Valentí Soler et al., 2015; Wada et al., 2004a, 2004b). Compared with a humanoid robot, a dog, and a control group, 1 record reported a decrease in cognition for all groups and no significant difference between the robots (Valentí Soler et al., 2015). One record described that PwDs with lower cognitive impairment experienced more pleasure using Paro and initiated more eye contact (Jones et al., 2018).

Non-cognitive symptoms in general: Two records did not find a significant difference in the Neuropsychiatric Inventory (NPI) for Paro compared with a control group (Liang et al., 2017), compared with Nao and a control group, or compared with a dog and a control group (Valentí Soler et al., 2015).

Agitation: No significant differences in agitation were found for Paro compared with a control group (Jøranson et al., 2015; Liang et al., 2017) or a plush toy (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017). One record described a significant decrease in agitation for the Paro group in a follow-up (Jøranson et al., 2015), and another record found that lower agitation levels were correlated with more interactions (Jones et al., 2018).

Anxiety: One record found higher anxiety levels during the Paro intervention (Moyle et al., 2013), and 2 records reported decreased anxiety in a pre-post comparison (Moyle et al., 2013; Petersen et al., 2017).

Apathy: Two records found no changes in apathy in a pre-post comparison (Moyle et al., 2013; Valentí Soler et al., 2015). One reported no difference between Paro and a control group (Moyle et al., 2013), while the other found no difference for a Paro group compared with a dog group or a control group (Valentí Soler et al., 2015). One record described significant decreases in apathy for the Paro and NAO groups compared with the control group (Valentí Soler et al., 2015).

Depression: Five records noticed an improvement in depression after the Paro intervention (Jøranson et al., 2015; Wada et al., 2009; Wada, Shibata, et al., 2005a, 2005b; Wada, Shibata, Sakamoto, et al., 2005), 1 reported no significant change (Moyle et al., 2013) and 1 found a significant increase in depression after the Paro intervention had ended (Liang et al., 2017). Compared with a control group, 1 record reported a decrease in depression for the Paro group (Petersen et al., 2017), while 2 did not find a significant difference between the groups (Jøranson et al., 2015; Moyle et al., 2013).

Wandering: One record found an increase in wandering for the Paro group (Moyle et al., 2013), while 1 record reported significantly reduced activity and step count for Paro compared with a plush toy and a control group (Moyle et al., 2018).

Behavior: Positive interactions with and responses to Paro by PwDs were described by 2 records (Liang et al., 2017; Moyle, Jones, Murfield, Thalib, Beattie, Shum, O'Dwyer, et al., 2017). One of them also noted negative responses (Liang et al., 2017). Four records reported that the Paro intervention led to more communication between PwDs (Jøranson, Pedersen, Rokstad, Aamodt, et al., 2016; Šabanović et al., 2013; Wada & Shibata, 2006, 2007). One record reported a decrease in interactions with Paro over the course of the intervention (Jøranson, Pedersen, Rokstad, Aamodt, et al., 2016), while another noted an increase (Šabanović et al., 2013).

Mood and affect: Seven records described improved mood and increased positive affect after the Paro intervention (Demange et al., 2018; Wada et al., 2009; Wada, Shibata, et al., 2005a, 2005b; Wada et al., 2004b, 2006; Wada, Shibata, Sakamoto, et al., 2005). One described more observed pleasure but also more sadness with Paro (Moyle et al., 2013). Compared with a plush toy, Paro reduced agitation and neutral affect, and compared with a control group, Paro increased observed pleasure (Moyle, Jones, Murfield, Thalib, Beattie, Shum, O'Dwyer, et al., 2017).

Quality of life: Three records noticed an improvement after the Paro intervention (Bemelmans et al., 2015; Jøranson, Pedersen, Rokstad, & Ihlebæk, 2016; Moyle et al., 2013). One record compared Paro with NAO and a control group and found no significant difference. When Paro was compared with a dog and a control group, a significant increase in QoL was reported for Paro (Valentí Soler et al., 2015). Applying Dementia Care Mapping, 1 record reported that well-being increased for PwDs who willingly interacted with Paro. It decreased for those who did not interact with Paro (Inoue et al., 2011).

Drug usage: Decreased use of psychotropic drugs (Jøranson, Pedersen, Rokstad, & Ihlebæk, 2016) and pain and behavior medication (Petersen et al., 2017) was reported. Compared with a control group, no significant differences were described (Liang et al., 2017).

Utterance: One record found an increase or utterance during the intervention, especially when Paro was switched on (Wada, Shibata, Sakamoto, et al., 2005).

Stress: Two records reported a reduced level of stress hormones in urine for the intervention with Paro (Wada & Shibata, 2006, 2007), while 1 record did not find a difference in cortisol levels between Paro and a control group (Liang et al., 2017). Compared with a control group, 1 record found a decrease in blood pressure and heart rate for the Paro group (Petersen et al., 2017) and 1 did not (Liang et al., 2017). Galvanic skin response and pulse oximetry were found to increase in the Paro group (Petersen et al., 2017).

Neuroactivity (EEG): Three records reported improved or stabilized neuroactivity for half of the participants after the Paro intervention. Neuroactivity improved most for PwDs who liked the robot (Wada et al., 2007; Wada, Shibata, Musha, et al., 2005; Wada et al., 2008).

Pleo
The robotic dinosaur Pleo was used in an acceptance assessment and a recreational activity.

Acceptance
In the acceptance assessment, different robots were compared. The participants expressed a preference for the WowWee Seal Cub and the Cuddling Kitty over the robotic dinosaur Pleo. The robotic seal and cat were caressed and liked by a majority of the PwDs, whereas 40% of PwDs liked Pleo (Heerink et al., 2013).

Comparing free play with Pleo with cognitive training, 1 record found that the robot intervention was significantly less difficult and significantly more pleasurable for PwDs. The participants were significantly less alert and more emotionally involved when playing with the robot (Perugia et al., 2017).

Teddy bear type robot
Feasibility
One study found that the teddy bear type robot could only feasibly serve as a communication facilitator for the PwDs when it was new or started moving by itself. With familiarization, the interest in the robot decreased within days (Nihei et al., 2017).

Unknown dog type robot
One record (Marx et al., 2010) used a toy robot resembling a dog, but the authors did not describe in detail, which robotic dog was used.

Acceptance
The record compared the robot with different dogs and dog-related stimuli such as a coloring book and a puppy video. PwDs reacted positively to all stimuli. No significant difference in the attitudes towards the robots compared with the other stimuli was found (Marx et al., 2010).

Humanoid robots
Humanoid or anthropomorphic robots resemble humans in their form, and the programming of many humanoid robots makes them appear even more human as well. Humanoid robots are used in interventions that could potentially profit from Human-Robot-Interactions such as physiotherapy, occupational therapy, cognitive therapy, and recreational activities.

Bandit II
Feasibility
Using Bandit II in music therapy and observing the interactions of participants, 3 records found that participants' reaction time and error rate decreased over time. Therefore, they concluded that the self-adapting algorithm of Bandit II was feasible in adapting the difficulty of the game to the PwDs' abilities (Tapus, 2009; Tapus et al., 2009a, 2009c).

Acceptance
Comparing the robot with a computer avatar administering the same activity, 1 record reported that PwDs reacted more positively to the robot and preferred it to the computer (Tapus et al., 2009b).

Kompaï
Feasibility
Two records described that PwDs had problems using Kompaï's touchscreen and understanding the speech synthesis (Kouroupetroglou et al., 2017; Salatino et al., 2017). Compared with HEPs, no significant differences in the use of Kompaï were found for PwMCIs. (Wu et al., 2014).

Acceptance
Three records found that Kompaï was perceived by PwDs and PwMCIs as non-threatening, friendly, and enjoyable, and participants liked using it (Kouroupetroglou et al., 2017; Salatino et al., 2017; Wu et al., 2014). Two records reported on improvement suggestions made by the participants such as improved speech synthesis (Kouroupetroglou et al., 2017) or alterations of applications for time management or medication scheduling (Salatino et al., 2017). One record described that although PwMCIs found Kompaï helpful, they would refuse to buy one because of the stigma of depending on a device (Wu et al., 2014).

NAO
Acceptance
Observing NAO and PwDs in Human-Robot-Interactions and Human-Therapist-Interactions, 1 record found no significant differences in engagement and observed mostly neutral and no negative emotions. The record found significantly more positive emotions in sessions with the robot compared with sessions without the robot (Rouaix et al., 2017). One record described that PwDs were significantly more appreciative of an intervention session with the robot than without it (Rouaix et al., 2017).

Impact
Concerning cognitive functions (Global Deterioration Scale, MMSE, and severe Mini-Mental State Examination (sMMSE)) 1 record did not find a significant difference in a pre-post comparison. Comparing NAO with Paro and a control group,

a significant decrease in cognition measured by Global Deterioration Scale was found for all groups. No difference in cognition measured by sMMSE, and a significant decrease in cognition measured by the MMSE for the NAO group were reported (Valentí Soler et al., 2015).

Regarding non-cognitive symptoms, a significant decrease in NPI scores, especially in irritability, was found for NAO in a pre-post comparison. Comparing NAO with Paro and a control group, no significant changes were reported in the overall NPI score for any group (Valentí Soler et al., 2015).

Telenoid

Acceptance

One single-case study used the telepresence robot Telenoid and found that the PwD was willing to use the robot and engage in a conversation. The PwD remarked positively on the robot and felt as though the conversational partner was there with him (Yamazaki et al., 2014).

Mechanoid robots

The outer form of mechanoid robots does not resemble an animal or a human being, although eyes and a mouth are often hinted at. Mechanoid robots are often used to provide a service to the user through direct Human-Robot-Interaction. There are also mechanoid robots that help with physical tasks such as moving, getting up, or getting (un) dressed. Because of the scope of this paper, these types of robots were not included.

CompanionAble

CompanionAble was used by 2 records within an AAL structure.

Feasibility

One record found that the robot was feasible but needed to be more personalizable and more flexible (Gross et al., 2012), while the other record reported on technical failures in person detection and system stability as well as an unintuitive interface and a lack of speech recognition (Schroeter et al., 2013).

Acceptance

Both records found that PwMCIs and PwDs were accepting of CompanionAble, reacting positively, and enjoying its use. (Gross et al., 2012; Schroeter et al., 2013). It was also reported that the participants reacted forgivingly towards failing functions (Schroeter et al., 2013).

ED

The robot ED was used by 3 records to guide PwDs trough ADLs within an AAL structure.

Feasibility

One record found that PwDs with lower cognitive impairment could follow the robot's prompts more easily than people with higher impairment (Begum et al., 2013).

Acceptance

One record reported that Human-Robot-Interaction took place, and PwDs communicated mostly non-verbally with the robot but were hesitant to ask it for help or start a conversation. More negative than positive emotions were observed (Begum et al., 2015). Two records found that ED was seen as helpful for PwDs with low cognitive impairment by their CGs. PwDs held a positive and interesting attitude towards the robot but stated that they would not need a robot (Begum et al., 2013; Wang et al., 2017).

Giraff

Feasibility

One record described only minor technical issues with the telepresence robot Giraff itself (e.g. with the microphone or the camera). Major issues were reported regarding a stable internet connection and the need for more personnel to help with troubleshooting when needed (Moyle et al., 2014).

Acceptance

Two records described that PwDs and PwMCIs showed positive emotions and were engaged using Giraff (Moyle et al., 2014; Tiberio et al., 2012). Compared with HEPs, 1 record reported that PwMCIs viewed Giraff as less helpful and more annoying and were less willing to use the robot (Tiberio et al., 2012).

Impact

For impact on cognitive exercises, 1 record found significantly higher arousal in PwMCIs and HEPs in robot sessions compared with therapist sessions. No significant changes in heart rate or anxiety were found when comparing robot sessions with therapist sessions and comparing PwMCIs with HEPs (Tiberio et al., 2012).

RAMCIP

One record compared PwMCIs to HEPs using RAMCIP for different ADLs.

Feasibility

Significant differences were reported on how PwMCIs and HEPs rated RAMCIP as being isolating vs. connective, although a direction was not reported. No difference in overall usability was found (Gerłowska et al., 2018).

Acceptance

High levels of acceptance but low levels of effectiveness were found for HEPs and PwMCIs.

Both groups found RAMCIP to be non-obtrusive, with the capability to decrease caregiver burden and facilitate communication, and to provide help and security. The only significant differences between PwMCIs and HEPs were found for the subscales repelling vs appealing and novel vs ordinary, although no direction was reported (Gerłowska et al., 2018).

Scitos G5

Feasibility

Two records described that the feasibility of Scitos G5 was compromised by technical difficulties regarding the navigation and operation of the robot, leading the robot to become a burden for the therapists (Gerling et al., 2016; Hebesberger et al., 2016). One record reported that the PwDs tried to interact with the robot but could not operate the touch-screen (Gerling et al., 2016).

Acceptance

One record found that therapists and PwDs alike showed a positive and interesting attitude towards the robot. Scitos G5 functioned as a point of reference for the PwDs and had a positive influence on the group dynamic (Hebesberger et al., 2016).

Critical appraisal

In 26 records, at least one of the authors had developed the robot that was studied. In 12 other records, the authors further developed hardware and/or software for the intervention they applied.

Funding came from various sources: 33 records were government- and/or EU-funded, 7 were funded through public or private trusts, and 12 were industry-funded. Seven records received funding from more than one source. Funding was not stated in 25 records.

Ethical advice was obtained from ethics committees in 32 records. Informed consent from the participants and/or their proxies was obtained in 41 records.

Discussion

Summary of evidence

In this scoping review, we found 70 records that researched feasibility, acceptance, and/or impact of socially assistive robots in non-drug interventions for PwDs and PwMCIs published between 2004 and 2018.

Feasibility

Robots that ran autonomously or were teleoperated were feasibly when functioning properly (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017; Tapus, 2009; Tapus et al., 2009a, 2009b, 2009c). Technical failures and malfunctioning could cause agitated PwDs (Moyle et al., 2016) or make the robot a burden for the therapists (Gerling et al., 2016; Hebesberger et al., 2016). When PwDs and PwMCIs operated a robot themselves, difficulties with touch-screen and speech synthesis lowered the feasibility (Gerling et al., 2016; Kouroupetroglou et al., 2017; Salatino et al., 2017). Operating the robot by themselves was easier for participants with lower cognitive impairment (Begum et al., 2013). Non-cognitive symptoms of the participants – especially agitation and aggression – and disinterest in the robot made interventions less feasible (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017; Moyle et al., 2016; Nihei et al., 2017). Feasibility is a requirement for acceptance (Gross et al., 2012; Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017; Salatino et al., 2017).

Acceptance

PwDs and PwMCIs mostly viewed robots as non-threatening, non-obtrusive, and friendly (Gerłowska et al., 2018; Greco et al., 2009; Odetti et al., 2007; Salatino et al., 2017). Positive comments centered on the robots' cute appearances or the interest in interacting with it (Demange et al., 2018; Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017; Wang et al., 2017). Negative comments addressed the robots as being not useful, childish, and stigmatizing (Begum et al., 2013; Demange et al., 2018; Wang et al., 2017; Wu et al., 2014). Acceptance could also vary at every intervention session depending on the current mood or health condition of the participants (Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017).

Impact

We found consistent evidence for positive impacts on pleasure (Chu et al., 2017; Jones et al., 2018; Libin & Cohen-Mansfield, 2004; Libin & Libin, 2005; Moyle et al., 2013; Moyle, Jones, Murfield, Thalib, Beattie, Shum, O'Dwyer, et al., 2017), engagement (Jones et al., 2018; Moyle, Jones, Murfield, Thalib, Beattie, Shum, & Draper, 2017; Moyle, Jones, Murfield, Thalib, Beattie, Shum, O'Dwyer, et al., 2017), communication between PwDs or PwMCIs (Gerłowska et al., 2018; Gustafsson et al., 2015; Naganuma et al., 2015) as well as talking (Hamada et al., 2008; Liang et al., 2017; Takayanagi et al., 2014) and uttering (Sakairi, 2004; Wada, Shibata, Sakamoto, et al., 2005) in general. No consistent evidence was found for impacts on cognition, non-cognitive symptoms like agitation, anxiety, depression, wandering, apathy or other neuropsychiatric symptoms, quality of life, drug use, neuroactivity, and stress-related measurements. Some studies pointed to improvement through robot-assisted therapy, some to decline, and some to no change at all. Possible confounders on positive impacts are '*liking the robot*' and '*wanting* *to interact with the robot'*. As these are linked to improvements in neuroactivity (Wada et al., 2007; Wada, Shibata, Musha, et al., 2005; Wada et al., 2008) and improvements in QoL (Inoue et al., 2011). Acceptance is hence the foundation for positive impacts.

Interventions and study designs

The most used interventions were animal-assisted therapy, physiotherapy, recreational therapy, occupational therapy, and ADLs support. Although we did not limit the eligibility criteria to certain forms of non-drug interventions, none of the included records used robots for dance therapy, art therapy, aromatherapy, light therapy, or Snoezelen therapy. Furthermore, none of the records employed a uniquely new and innovative intervention that was only possible due to the functions of the robot. Study designs were mostly longitudinal and employed qualitative methods. Small sample sizes (median of 10 participants) and seldom use of control groups (12 of 70 records) or crossover comparison (18 of 70 records) make the results of the records hardly comparable.

Categorizing robots

We decided to sort the robots by their outer form into animaloid, humanoid, and mechanoid. Another possible categorization would be by function into companion, therapeutic partner, or coach (Rabbitt et al., 2015). Categorizing by function would have assigned some robots two categories, e.g. Aibo as a companion and therapeutic partner, and none to Telenoid and Giraff, which are communication devices only. Other categories could be the form of operation: teleoperated or autonomous. Categorizing by the form of operation would have assigned two dimensions to Aibo, CuDDler, and NAO but none to Kompaï, which was operated by the PwMCIs themselves. Therefore, both alternative categorizations were not chosen.

Critical appraisal

In 54% of the records, the robot was either developed by one of the authors or hardware and/or software were further developed. The findings for the former should be viewed with caution, especially those with industry or unclear funding. Therefore, independent studies conducted by researchers without a financial interest in robot usage are key in future research.

Limitations

There are some limitations to this scoping review. Relevant records may have been missed, if they were written in a language other than English and German or were published after the final search update in November 2018. Compared with the 70 records included in this review, it is rather unlikely that additional records would have changed the overall results. A broad search term was used to identify possible records, resulting in a long screening process. This was deemed necessary as there were no established terms for robot-assisted interventions. This scoping review is a synopsis of studies that differ in quality and study design. So the reported study results are barely comparable to each other. As robot-assisted interventions for people with cognitive impairment is a novel area of research without established standards and conventions, our broader approach to this topic seemed appropriate.

Conclusion

Besides fixable technical problems, autonomous and teleoperated robots are feasible for non-drug interventions with PwDs or PwMCIs. Robots that are operated by PwDs or PwMCIs seem less feasible – at least for the current generation of people with cognitive impairment. Compared with humanoid and mechanoid robots, feasibility was not often studied for animaloid robots. This could be because some of the animaloid robots (JustoCat, Paro, Aibo, PaPeRo, and Pleo) are mass-produced and available on the consumer market. However, these animaloid robots were not initially targeted towards individuals with cognitive impairments – except for Paro. Therefore, feasibility issues should not be overlooked. As it has not been sufficiently studied, feasibility – for all forms of socially assistive robots – needs to become part of the focus in robotic-related research.

PwDs and PwMCIs mostly enjoyed interacting with the robots, although concerns about the stigma of dependency or infantilization were voiced. An immediate need for robots was not always seen by PwDs or PwMCIs. The findings on acceptance may be biased since people not accepting of robots may decline to participate in the study. Furthermore, cultural differences may be at play as people with different cultural backgrounds show different attitudes towards animaloid and humanoid robots (Bartneck et al., 2007; Nomura et al., 2008). However, acceptance of interventions cannot be presumed per se especially considering the stigmata surrounding cognitive impairment and dependency (Lion et al., 2019) – and thus needs to be established before possible impacts can be addressed, especially for vulnerable target groups.

Apart from increased communication, engagement, and pleasure, no coherent evidence was presented. This applies almost exclusively to animaloid robots, as the impacts of humanoid and mechanoid robots have not been studied much. Furthermore, these positive impacts are not exclusively linked to robot-assisted therapy but can be found in other dementia-specific interventions (Abraha et al., 2017). To thoroughly assess the impacts of robot-assisted interventions, a structured intervention must be studied. But only 7 different RCTs were included in this scoping review with 10 records reporting on them. More studies with high evidence level are needed to find evidence for the impacts of robot-assisted interventions.

None of the records used the features of the robots to create a new and innovative intervention (e.g. interactive scenarios between PwDs/PwMCIs and the robot). Robot-assisted interventions still need to show that they can accomplish more or different things than other non-drug interventions. The opportunity to do so, which arises with new technology, should be taken in future research, giving more room to personalization and possibly activating PwDs one could not reach before.

In a nutshell, socially assistive robots are feasible, can be accepted by people with cognitive impairment, and can support their participation in social situations. However, their widespread implementation will depend on whether interventions will be relevant and effective in the care of PwDs, and whether such interventions will receive adequate funding or not.

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Appendix I: Final search strategies

	Search terms
PuBMed	"dementia" [MeSH Terms] OR dementia [Title/Abstract] OR "cognitive dysfunction" [MeSH Terms] OR MCI [Title/Abstract] OR "cognitive impairment" [Title/Abstract] OR "Alzheimer's disease" [Title/Abstract] **AND** "ai artificial intelligence" [MeSH Terms] OR robotics [Title/Abstract] OR robots [Title/Abstract] OR "artificial intelligence" [Title/Abstract] OR "self-help devices" [MeSH Terms] OR "assistive technology" [Title/Abstract] OR "assistive system" [Title/Abstract] OR "assisted ambient living" [Title/Abstract] OR AAL [Title/Abstract] OR "man-machine systems" [MeSH Terms] OR "man-machine system" [Title/Abstract]
CINAHL	AB dementia OR AB MCI OR AB cognitive impairment OR AB alzheimer's disease OR MH "Dementia+" OR MH "Cognition Disorders+" **AND** MH "Artificial Intelligence+" OR MH "Assistive Technology Devices+" OR MH "Assistive Technology Services" OR MH "Assistive Technology" OR MH "Assisted Living" OR AB robotics OR AB robot OR AB assisted ambient living OR AB AAL OR AB assistive technology OR AB artificial intelligence OR AB assistive system OR AB man-machine
IEEE Xplore	"Index Terms":dementia OR "IEEE Terms":dementia OR "Index Terms":cognitive impairment OR "Index Terms":Alzheimer's disease OR "IEEE Terms":social factors OR "IEEE Terms":behavioral science **AND** "IEEE Terms":robots OR "Index Terms":robots OR "IEEE Terms":artificial intelligence OR "Index Terms":artificial intelligence OR "IEEE Terms":ambient intelligence OR "Index Terms":ambient intelligence OR "IEEE Terms":man-machine systems OR "Index Terms":man-machine systems

Appendix II: Index of abbreviations

AAL	Ambient Assisted Living
ADLs	Activities of Daily Living
CG/CGs	Caregiver/ Caregivers
HEP/HEPs	Health Elderly Person/ Healthy Elderly People
MCI	Mild Cognitive Impairment
MMSE	Mini-Mental State Examination
NPI	Neuropsychiatric Inventory
PwD/PwDs	Person with Dementia/ People with Dementia
PwMCI/PwMCIs	Person with Mild Cognitive Impairment/ People with Mild Cognitive Impairment
QoL	Quality of Life
RCT	Randomized Controlled Trial
sMMSE	severe Mini-Mental State Examination