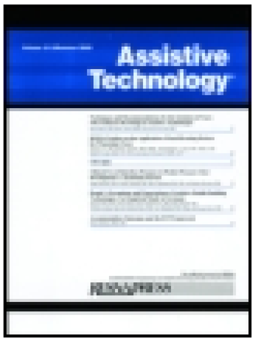

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Humanoid robots in the care of older persons: A scoping review

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ABSTRACT
The aim was to examine how humanoid robots have been used in the care of older persons and identify possible benefits and challenges associated with such use from older persons' points of view. The study was a scoping review based on Arksey and O'Malley's methodological framework. To identify peer-reviewed and non-peer-reviewed literature, a systematic search of the PubMed, Cinahl and Google Scholar electronic databases was conducted for studies published between 2013 and 2019. The PRISMA-ScR guidelines have served as a guideline. A total of 12 studies were included and resulted in four main categories related to how humanoid robots have been used in care of older persons (domain of use): Supports everyday life, Provides interaction, Facilitates cognitive training and Facilitates physical training. Potential for humanoid robots to be accepted as companions for older persons was seen, but technical issues, such as humanoid robots' slow response time or errors, emerged as key challenges. Older persons' perceived enjoyment of using a humanoid robot might also decrease over time. Validated measurements to estimate the effectiveness of using humanoid robots in the care of older persons are needed.

ARTICLE HISTORY
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KEYWORDS
benefits; care; challenges; humanoid robot; older person

Introduction

By the year 2030, more than 15% of the world population will be aged 65 years or older (Melkas et al., 2016). As the length of life and population of older persons increase, their need for assistance and healthcare becomes greater (Smer rapport, 2014). This means that many countries are considering new ways through which to meet older persons' need for care. Increasingly care is being offered in a person's own home. 12.6% of older persons living in Europe aged between 67 and 79 years receive care in their own homes. For those Europeans aged between 80 and 89 years, over 50% receive home care services while over 90% of those aged 90 years or older receive home care services (Eurostat, 2019). This means there are huge groups of older persons in need of care services such as dressing, toileting or bathing: not only at care facilities but also in their own homes. Despite daily visits from care professionals, many older persons perceive a sense of loneliness or feel a lack of a close connection through friendship (Singh & Misra, 2009). Older persons who have disabilities are prone to be institutionalized in facilities for assisted living. This might result in a reduction in both physical and cognitive health and may have a negative effect on quality of life (González-Colaço Harmand et al., 2014). Researchers (Broadbent et al., 2009; Sharkey, 2012) have found that the use of robots and artificial intelligence in the care of older persons might be a possible solution to overcome such challenges. Consequently, it is important to examine how humanoid robots (abbreviated HR) have been used in the care of older persons and to identify the possible benefits and challenges associated with such use from an older person's view.

The use and development of robots in the care of older persons is moving quickly forward. A wide range of robots exists, designed for different needs. Researchers in previous studies have investigated the use of robots in surgery (Cleary & Nguyen, 2001), rehabilitation (Balasubramanian et al., 2010), dentistry or bio-prosthetics (Belter et al., 2013); for tele-rounding (Iftikhar et al., 2011) or as assistants (Mariappan et al., 2011). Service type robots can facilitate independent living by supporting basic activities, mobility, providing household maintenance, monitoring those in need of continuous watchfulness and upholding safety (Broekens et al., 2009). Rehabilitation or therapeutic robots can even be used to facilitate physical recovery from chronic strokes among older persons (Krebs & Volpe, 2013).

HRs have already been shown to be useful for a variety of healthcare tasks. According to Mohamed and Capi (2012), HRs might have movable parts or an overall human-like appearance based on the human body (e.g., from the waist up), the human face (e.g., eyes or a mouth) or an inherent social capacity (e.g., facial expression). Most HRs are designed with vision systems, such as sensors or cameras that allow them to focus attention on specific objects or screens (Azeta et al., 2018). Because of HRs' advanced sensing and motor capabilities, they may be well suited to performing caring tasks (Niheh et al., 2017) or daily chores usually performed by humans (Cheng, 2015). The aim of this scoping review was to examine how HRs have been used in the care of older persons and identify the possible benefits and challenges associated with such use from older persons' points of view. The research questions were: 1. How

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have HRs been used in the care of older persons?, and 2. What benefits and challenges are associated with such use from older persons' points of view?

Material and methods

A scoping review approach was chosen to enable a broad assessment of how HRs are used in the care of older persons. Arksey and O'Malley's methodological framework (Arksey & O´Malley, 2005) as interpreted by Levac et al. (2010) was used. Both the conduct of scoping reviews as delineated by the Joanna Briggs Institute (2015) and the PRISMA-ScR guidelines were followed. According to Levac et al. (2010), the use of a scoping review allows for a much broader and complex assessment of an area of research than a systematic review. While a systematic review is used to focus on studies with a randomized, controlled research design, scoping reviews enable the inclusion of studies with a broader type of evidence, e.g., gray literature. Scoping reviews can facilitate the examination of the extent, range and nature of research activities; reveal the value of undertaking a full systematic review; and help researchers summarize and disseminate research findings and identify research gaps (Arksey & O´Malley, 2005). Arksey and O´Malley (2005) scoping review framework includes six stages: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting results. Not used in this study, an optional sixth step involves stakeholders.

Search strategy and information resources

Following identification of the research question in accordance with stage one of Arksey and O´Malley (2005) framework, in stage two we began to identify relevant studies. The inclusion criteria included that HRs were defined as a robot with movable parts and an overall human-like appearance based on the human body, the human face and an inherent social capacity (Mohamed & Capi, 2012). Older persons were defined as a person aged 65 years or older (WHO, 1999). Also included were studies with a focus on the use of HRs from older persons' points of view. Exclusion criteria included study focus on areas concerning surgery, monitoring systems or software and studies based on thought experiments, where participants relied on their imagination, stimulated by, e.g., pictures or videos. Also excluded were studies in which robotic pets were used, as we did not consider such to fall under the HR category (Morovitz et al., 2017).

We undertook a systematic search of the PubMed and Cinahl electronic databases between February 2 and March 31, 2018. To improve the final search, several pilot searches were first undertaken. The final search included core concepts related to the research questions and included the following: humanoid, robot, robotics, artificial intelligence, elder, elderly, elderly care, older, older adults, frailty, geriatric and aged. The core concepts combined with the Boolean operators "OR" (when searching through core concepts) and "AND" (when combining core concepts) were used in consultation with an experienced librarian (MIT Libraries). In addition to the identification of gray literature, a general internet search of Google and Google Scholar occurred.

Eligibility criteria

When searching for studies on using HRs in the care of older persons, the eligibility criteria were limited to full-text published, to-be-published studies and gray literature. Included studies were published between February 2013 to February 2018 and were written in the English, Swedish or Finnish languages. The rapid rate at which robotics technology has developed in recent years inspired our choice of start date. Included gray literature had to be considered a report, a working paper or a practice-oriented development report. An updated electronic database search was performed in January 2019 to screen new or missed studies.

Data abstraction

In accordance with stage three of Arksey and O'Malley's framework, the study selection process was drafted through team discussions with the authors as team members. The team members were considered qualified to assess paper inclusion, because they have both practical and theoretical experience of using HRs in caring situations. As can be seen in the PRISMA-ScR, as per Tricco et al.'s (2018) guidelines (Figure 1), the first search of the two databases and other sources yielded 2569 records. The removal of duplicates (690) and records not relevant to the study aim (1700) yielded 67 records. Two authors (NN and NN) independently screened these records and excluded 39, resulting in 28 full-text studies that met the inclusion criteria. Three authors (NN, NN, NN) first independently read the studies' abstracts and then together discussed the studies with regard to inclusion or exclusion. This led to the removal of 16 full-text studies, because they were not relevant to the study aim and/or research questions and/or were not considered to meet the inclusion criteria. The same three authors (NN, NN, NN) read the remaining studies in full. Some studies partially deviated from the inclusion criteria but were nevertheless included because, following discussion, they were considered relevant to the present study. The updated search yielded 112 records, which may have included duplicate records compared to the first search. Following the same selection process as above, no new studies were identified. Of the total search, 2681 studies were generated and of these, 12 studies were included. Of these, eleven were identified as scientific studies and one as gray literature.

Synthesis

In line with stage four of Arksey and O´Malley (2005) methodological framework, we used a qualitative descriptive approach (Sandelowski, 2000) to chart how HRs have been used in the various studies by category (domain of use) and the benefits and challenges of such use from the older persons' points of view. The following data were extracted and charted from each selected study: domain of use by category, author(s), year of publication, country of origin, context, study methods, sample size, robot, duration of the intervention, study aim, benefits and

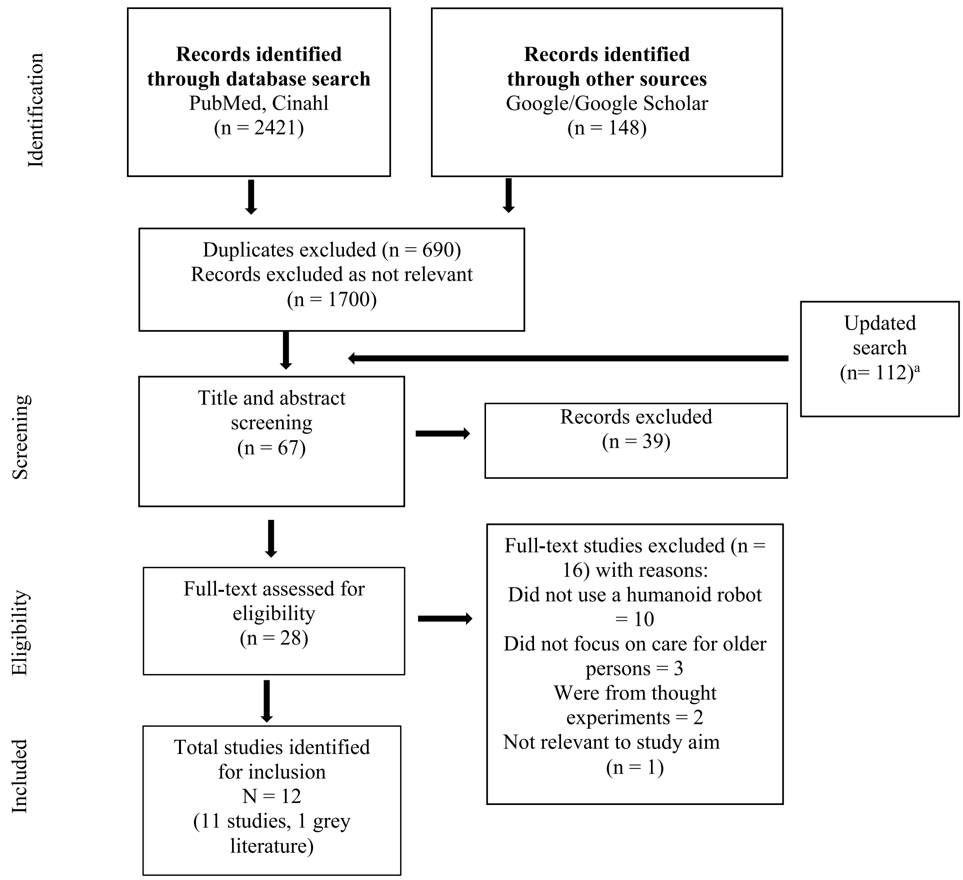

Figure 1. Flow diagram of study selection process.

challenges (Table 1). The studies were also charted in accordance with the type of HR (Table 2). When determining the categories related to domain of use, categorization was based on each included study's aim. We decided to base our categorizations on these aims because it was not always clearly stated what the HRs' domains of use were, and in the studies a large variety of and/or varying HR tasks/uses were noted. The categorization resulted in four main categories.

Ethics

As the study was a scoping review, ethical approval was not required. However, during the search strategy, professional research ethics in accordance with the Joanna Briggs Institute (2015) guidelines and the PRISMA-ScR checklist were followed.

Results

In line with stage five of Arksey and O´Malley (2005) framework, we collated, summarized and reported the results. The review included 12 studies. The majority were published in journals with a focus on HRs (3), but some were published in journals with a focus on health technology (2), the Internet (2), biomedical engineering (2), rehabilitation (2) or clinical interventions for older persons (1). Of these 12 studies, one study (Ikeya et al., 2018) was a letter to an editor and counted as gray literature. The studies used methods such as questionnaire, interview, observation and video records. Only two studies (Feingold-Polak et al., 2018; Ikeya et al., 2018) included more than 30 participants and six studies (Abdollahi et al., 2017; Doering et al., 2015; Kouroupetroglou et al., 2017; Orejana et al., 2015; Piezzo & Suzuki, 2017; Torta et al., 2014) included ten or fewer participants. In most studies a short-term perspective was seen and in three studies (Doering et al., 2015; Ikeya et al., 2018; Kouroupetroglou et al., 2017) the average intervention duration was short, between 30–45 minutes. While most of the included studies fully met the inclusion criteria, some partially deviated. Three studies (Bedaf et al., 2018; Feingold-Polak et al., 2018; Ishiguro et al., 2016) focused on both younger and older persons. Two studies (Abdollahi et al., 2017; Ikeya et al., 2018) did not explicitly mention the persons' ages, but upon reading, it emerged that their target groups were older persons with severe dementia. Three studies (Abdollahi et al., 2017; Ikeya et al., 2018; Kouroupetroglou et al., 2017) also focused on the care of older persons suffering from dementia. Nonetheless, we decided to include these studies as well, because they included a focus on HRs and older persons.

The 12 studies selected for inclusion were from Japan (3), Austria (2), the Netherlands, France, Germany, England, the United States of America (USA), New Zeeland and Israel. All studies were charted in accordance with HR model (Table 2). The HRs used were Pepper (3), iRobi, Nao, HOBBIT, PALRO, Ryan, Kompaï, MARIO, Care-O-Bot and one humanoid-companion type robot without an official model name. The

Table 1. Domain of use by category, benefits and challenges of using humanoid robots in the care of older persons.

Category 1. Supports everyday life	Author(s)/Year of publication/ Country of origin	Study aim	Context/Study methods	Sample size/Robot/Duration of the intervention	1. Benefits/ 2. Challenges
	*Wu et al., 2014 France	To observe robot-acceptance in older adults, subsequent to a 1-month direct experience with a robot.	Living lab. Questionnaire, semi structured interviews, usability-performance measures and focus group.	11 older persons (76–85 years). Kompaï. Once a week for four weeks.	1. Social influence was perceived as powerful with regard to humanoid robot (HR) acceptance. HR was perceived as non-threatening when performing tasks. 2. The participants showed low intention to use the HR, and negative attitudes toward and negative images of the HR.
	*Doering et al., 2015 Germany	To determine older persons' insights on individual usage patterns and acceptance of a mobile service robot in real life environments.	Older persons' home. Semi-structured interview, observations, audio and video records.	Three older persons (aged 67, 78 and 85). Humanoid companion-type robot. 35–40 minutes.	1. Overall user experience was positive: participants were satisfied, joy of use was rated as high. 2. Usability needed to be improved, technical issues.
	**Pripfl et al., 2016 Austria	To study how older persons experience a natural interaction with a robot in terms of usability, utility, support of independent living and feelings of safety	Private homes. Interviews, questionnaire.	18 older persons (75–89 years). HOBBIT. Three weeks.	1. Utility met users' expectations and users' feeling of safety or independence did not change over time. 2. Perceived safety did not increase. Errors in HR's actions led to frustration. Usability was negatively influenced by the HR's lack of robustness.
	*Bedaf et al., 2018 Netherlands	To evaluate from a multiple perspective the performance use and interaction of a robot in a home-like environment with older adults	Home-like environment. Questionnaire, semi-structured interview.	10 older persons (62–93 years) living at home, 7 family caregivers, 11 professional caregivers. Care-O-Bot. 1,5 hours per session.	1. Older persons accepted the HR more than the caregivers and relatives did. 2. HR's current functionalities were too limited; should execute and support more complex tasks (activities related to self-care and social participation).
Category 2. Provides interaction	Author/Year/ Country of origin	Study aim	Context/Study methods	Sample/Use of robot/Duration of the intervention	Benefits/ Challenges
	*Torta et al., 2014 Austria	Short-term and long-term evaluation of a small socially assistive robot in a smart home environment.	Smart home environment. Questionnaire.	8 older persons (70–95 years). Nao. Two weeks to three months.	1. Participants trusted the HR. Participants felt no anxiety when using the HR, because of its small size and shape. 2. Perceived enjoyment of HR might decrease over time.
	*Kouroupetroglou et al., 2017 England	To study how persons with dementia react to the presence of a robot, and whether they can interact with it using simple apps to accomplish tasks.	Nursing homes and hospital. Questionnaire.	10 older persons (all over 65 years). MARIO. Average of 30 minutes per test.	1. The HR's presence was accepted. 2. HR's multimodal interaction (verbal and visual clues) was challenging. This included timing of prompts and using a touch screen.
	**Abdollahi et al., 2017 USA	To measure how effectively a robot can provide companionship for older persons with dementia and/ or depression.	Senior community center. Surveys, interviews.	6 older persons (age not mentioned). Ryan 4–6 weeks.	1. Participants was positive toward long-term companionship, acceptance and likability. Caregivers noted HR's ability to make deep connection with participants. 2. Cannot replace human companionship.
	*Ikeya et al., 2018 Japan	To study the use of a robot in the evaluation of communication skills for older persons with dementia	Nursing home. Semi-quantitative analysis.	48 older persons (age not mentioned). PALRO. 30 minutes.	1. For persons with dementia, an HR can help measure grades of countenance, non-verbal communication and sonorous musical communication. 2. Use of a prototype HR reveled technical issues that should be solved.
Category 3. Facilitates cognitive training	Author/Year/ Country of origin	Study aim	Context/Study methods	Sample/Use of robot/Duration of the intervention	Benefits/ Challenges
	*Orejana et al., 2015 New Zealand	To test the feasibility and usefulness of robots in supporting older persons living alone to manage their medication	Older persons' homes. Questionnaire, interview.	4 older persons (over 75 years). iRobi. From three months to a year.	1. A decrease in primary care visits and phone calls to practitioners while the HR was present. Increases in quality of life. 2. Technical issues.

(*Continued*)

Table 1. (Continued).

Category 1. Supports everyday life	Author(s)/Year of publication/ Country of origin	Study aim	Context/Study methods	Sample size/Robot/Duration of the intervention	1. Benefits/ 2. Challenges
	**Ishiguro et al., 2016 Japan	To evaluate the use of the robot with respect to patient education advice regarding medication and diet adherence, using an ARCS model, for older persons with dementia.	Not mentioned. Questionnaire, interviews.	19 persons; both care receivers and care providers (30–89 years). Pepper. Duration not mentioned.	1. The communication between the HR and a person with dementia was effective, because HRs can repeat the same topic again and again. 2. If the implemented applications include only diet advice and medication advice, it is likely that the learning effect will fade and users will stop communicating with the HR.
	*Feingold-Polak et al., 2018 Israel	To test how age, location of touch and embodied presence of a humanoid robot affect the motivation of different age-group users when performing a cognitive-motor task.	Not mentioned. Questionnaire.	60 older persons (24–77 years old). Pepper. Duration not mentioned.	1. Both young and old persons found it engaging and fun to interact with the HR. 2. HR's response time was slow, which had a negative influence on participants' perceptions of the HR and motivation to continue interacting.
Category 4. Facilitates physical training	Author/Year/ Country of origin	Study aim	Context/Study methods	Sample/Use of robot/Duration of the intervention	Benefits/ Challenges
	*Piezzo et al., 2017 Japan	To design a humanoid robot guide as a walking trainer for older persons.	A university and a care facility. Questionnaire, video records.	8 older persons (73–92 years). Pepper. Duration not mentioned.	1. Older persons followed the HR's speed and interacted with it without a feeling of danger. Cute design influenced positive reaction. 2. The HR was considered more a guide to follow than a companion or caregiver to walk with.

* Scientific study published in article.
** Grey literature.

HRs were tested in different settings: nursing homes (4), private homes (3) or home-like test environments (3). In two studies, the testing area was not mentioned. The HRs used were capable of performing a wide variety of tasks. All but one study (Piezzo & Suzuki, 2017) used more than one HR task in their investigation. Consequently, we decided to even chart the studies in accordance with the HR's domain of use, emanating from each study's stated aim.

Domain of use and associated benefits and challenges

Eligible studies were organized into categories based on the HRs' domain of use in the care of older persons. Four categories were identified: (1) Supports everyday life, (2) Provides interaction, (3) Facilitates cognitive training and (4) Facilitates physical training. The studies are presented by category below, including information on the benefits and challenges of using the various HRs in the care of older persons.

Category 1. Supports everyday life

In four studies (Bedaf et al., 2018; Doering et al., 2015; Pripfl et al., 2016; Wu et al., 2014), HRs were investigated with regard to their ability to support everyday life in the care of older persons. Wu et al. (2014) observed older persons' acceptance of HRs, using a robot that could, e.g., check and update a calendar and provide medication reminders. Doering et al. (2015) investigated whether older persons accepted using an HR that could, e.g., monitor vital signs and provide medication reminders. Pripfl et al. (2016) studied how older persons experience natural interaction with HRs (usability, utility, supports independent living, feelings of safety), using an HR that could, e.g., pick up or transport objects. Bedaf et al. (2018) evaluated older persons', family caregivers' and caregivers' opinions of HRs' performance, use and interaction in a home-like environment, using an HR that could, e.g., retrieve parcels and remind the older persons to hydrate.

Benefits in support for everyday life

Regarding the use of HRs to support older persons' everyday life, the joy of HR use was rated as high (Doering et al., 2015) and the HRs social influence was perceived as powerful (Wu et al., 2014). Doering et al. (2015) and Bedaf et al. (2018) found that older persons might accept HRs as a companion in everyday life. Also, older persons found HRs non-threatening when performing tasks (Wu et al., 2014). Pripfl et al. (2016) found that the utility of the HR met users' expectations and users' feeling of safety or independence did not change over time.

Challenges in support for everyday life

Wu et al. (2014) primarily reported challenges, such as barriers related to the adoption of new technologies by older persons. In the same study older persons also showed low intention to use HRs and even negative attitudes or perceptions of HRs. Other challenges mentioned in the other studies were feelings of lack of perceived safety with the HR, frustration with errors in the HR's actions, and the HR's lack of robustness (Pripfl

Table 2. Humanoid robots, including tasks performed, as seen in the selected studies.

Humanoid robot	Tasks performed	Study author
Kompaï	Checks and adds appointments to calendar, plays games, checks weather, online grocery shopping, messaging service, reminds individuals to take medication.	Wu et al. (2014)
Humanoid companion-type robot	Facilitates videotelephony interaction, monitors vital signs, medication reminder.	Doering et al. (2015)
HOBBIT	Picks up objects from the floor, transports objects, recognizes emergencies, facilitates fitness programs, gives reminders.	Pripfl et al. (2016)
Care-O-Bot	Retrieves parcels from front door, reminds individuals to hydrate.	Bedaf et al., (2018)
Nao	Checks general and critical environmental info, plays music, manages external calls to other users and medical professionals, measures blood oxygen levels, facilitates exercise program.	Torta et al. (2014)
MARIO	Plays music and games, reads news headlines.	Kouroupetroglou et al. (2017)
Ryan	Shows photos, plays music and videos, medication reminder.	Abdollahi et al., (2017)
PALRO	Sings songs, verbal greeting, facilitates light exercise and answers quizzes.	Ikeya et al., (2018)
iRobi	Facilitates entertainment and Skype conversations, plays memory games, reminds individuals to take medications.	Orejana et al. (2015)
Pepper	Monitors medication and diet adherence, walks together with user.	Ishiguro et al. (2016)
Pepper	Walking trainer.	Piezzo & Suzuki, (2017),
Pepper	Plays cognitive motor-tasks.	Feingold-Polak et al., (2018)

et al., 2016). Older persons, family caregivers and caregivers found the HR's functionalities to be limited and that it did not support more complex tasks (Bedaf et al., 2018).

Category 2. Provides interaction

Four studies (Torta et al., 2014; Kouroupetroglou et al., 2017; Abdollahi et al., 2017; Ikeya et al., 2018) used an HR with the purpose to provide interaction for older persons. Torta et al. (2014) wanted to know whether older persons would accept HRs that act as a communication interface, using an HR that, e.g., checked environmental info, managed external calls and measured blood oxygen levels. Kouroupetroglou et al. (2017) investigated how persons with dementia react to HRs and whether they can interact with an HR using simple apps to, e.g., play music and read news headlines. Abdollahi et al. (2017) also investigated older persons with dementia but in respect to how effectively HRs can provide companionship, using an HR that, e.g., showed photos and provided medication reminders. Even Ikeya et al. (2018) investigated the use of HRs with older persons with dementia in regard to communication skills, using an HR that, e.g., sang, greeted users and answered quizzes.

Benefits in provision of interaction

Regarding the use of HRs to provide interaction, older persons trusted and felt no anxiety when using an HR (Torta et al., 2014), accepted the HR (Kouroupetroglou et al., 2017) and were positive toward long-term companionship with an HR (Abdollahi et al., 2017). Even for persons with dementia, the HR investigated was seen to help non-verbal and musical communication (Ikeya et al., 2018).

Challenges in provision of interaction

During interaction, the perceived enjoyment of HRs (novelty) was seen to possibly decrease over time (Torta et al., 2014). Older persons with dementia could find multimodal interaction challenging, i.e., interpreting an HR's verbal and visual clues (Kouroupetroglou et al., 2017). Also, while older persons expressed sadness over "saying goodbye" to an HR after using it, HRs nonetheless were not considered capable of replacing human companionship (Abdollahi et al., 2017). Furthermore, technical limitations regarding the prototype of HR was seen as too basic as its performance is still developing (Ikeya et al., 2018).

Category 3. Facilitates cognitive training

In three studies (Feingold-Polak et al., 2018; Ishiguro et al., 2016; Orejana et al., 2015), HRs were investigated with regard to their ability to facilitate cognitive training for older persons. Orejana et al. (2015) studied the feasibility and usefulness of using HRs to support older persons living alone to manage their medication, using an HR that, e.g., facilitated entertainment and played memory games. Ishiguro et al. (2016) studied both older persons' and caregivers' perceptions of HRs with respect to patient education advice on medication and diet, using an HR that, e.g., monitored medication and diet adherence and walked with older persons. Feingold-Polak et al. (2018) explored differences between how young and older persons relate to preferences (opinions and implementation) when interacting with HRs, using an HR that, e.g., played cognitive motor-tasks.

Benefits in facilitation of cognitive training

During the facilitation of cognitive training, both younger and older persons found the HR engaging and fun to interact with (Feingold-Polak et al., 2018). Also, both older persons and caregivers perceived the communication between the HR and persons with dementia was effective, possibly because the HR was able to repeat the same topic again and again (Ishiguro et al., 2016). Orejana et al. (2015) showed that the presence of an HR led to a decrease in primary care visits and phone calls to caregivers and that older persons felt their quality of life was increased while the HR was present.

Challenges in facilitation of cognitive training

Regarding challenges in the facilitation of cognitive training, some older persons were concerned that new technology applications of the HR might be too complicated (Orejana et al., 2015). Regarding technical limitations, the HR's slow response time had a negative influence on the older persons' perceptions and their motivation to continue interacting with the HR (Feingold-Polak et al., 2018). Learning effect could fade if implemented applications of the HR did not change (Ishiguro et al., 2016).

Category 4. Facilitates physical training

In one study (Piezzo & Suzuki, 2017) an HR was investigated with regard to its ability to facilitate physical training in the care of older persons. In that study, the HR was used as a walking trainer for older persons.

Benefits in facilitation of physical training

Regarding benefits of using an HR in physical training, older persons followed the HR's speed and interacted without feeling danger. They also thought that the cute design positively influenced their reactions to the HR (Piezzo & Suzuki, 2017).

Challenges in facilitation of physical training

During the physical training, some older persons chose to walk behind the HR instead of side-by-side, and the conclusion was made that the HR was more of a guide than a companion to walk with (Piezzo & Suzuki, 2017).

Discussion

The aim of this scoping review was to examine how HRs have been used in the care of older persons and to identify possible benefits and challenges associated with such use from older persons' points of view. The scoping review resulted in four categories related to HRs' domain of use in the care of older persons: Supports everyday life, Provides interaction, Facilitates cognitive training and Facilitates physical training.

In the first category, HRs were used to support older persons' everyday life. While the four studies included short-term perspectives and short intervention durations, their findings might be insightful for implementation. Even if the older persons showed an overall acceptance of the use of HRs as assistants, some challenges were noted, e.g., low intention to use the HRs. In the future studies, researchers should remember that older persons may feel vary of new technologies and should investigate what "user-friendly" means for older persons in relation to HRs.

In the second category, HRs were used to provide interaction for older persons. Three of the four studies (Abdollahi et al., 2017; Ikeya et al., 2018; Kouroupetroglou et al., 2017) focused on the care of older persons suffering from dementia. About 50 million persons have dementia worldwide (WHO, 1999), and this syndrome is one of the major causes of disability and dependency among older persons (Evans et al., 2016). Consequently, the findings of these studies might be helpful when implementing HRs in this area. Based on overall comments, older persons perceived HRs to be positive. In an earlier study (Singh & Misra, 2009), researchers found that older persons might lack close companionship in their life, and Abdollahi et al. (2017) highlighted that HRs show possibility with regard to long-term companionship. However, the older persons in Abdollahi et al.'s (2017) study gave their points of views after using an HR for a short period of time. One can question whether a long-term perspective would change older persons' points of view about finding companionship with HRs. In this category, direct comparisons were not made between persons and HRs, such as performing task directly related to providing companionship. Accordingly, the lack of a long-term perspective and the one-domain HR functionality reveal a gap in the research.

In the third category, HRs were used to facilitate older persons' cognitive training. One of the three studies included both short-term and long-term perspectives and more than 30 participants, therefore the findings from that study (Orejana et al., 2015) might be insightful. In that study, a decrease in primary care visits and phone calls to caregivers was seen when the HR was present with the older persons. Furthermore, the older persons also felt their quality of life was increased during the use of the HR. However, it is important to highlight that in these studies other persons (e.g., personnel handling the HR) were present while the HR was present. This might lead to difficulties in knowing whether the persons' experiences were affected by the presence of other persons.

In the fourth category, an HR was used to facilitate physical training. Including only one study, the findings from using an HR to guide older persons during walking was positive. The lack of studies seen in this category reveals a broad research gap, which can be considered an opportunity for future studies.

HR tasks commonly seen in many of the eligible studies were: checking the older persons' calendars, reminding them of their medication, providing different kinds of entertainment or facilitating physical training. With the exception of using an HR to facilitate older persons' physical training, one could questions whether the other three tasks noted could be performed using non-HR technologies (e.g., a tele-robotics system or google home). Even if HRs show multi-domain functionality, comparison studies could give a better understanding of the benefits and challenges associated with use of both HRs and non-HR technologies.

There was a wide variety in the design and functionalities of the HRs used in the included studies. Some of the HRs were human-size robots with no arms and on wheels, while others were small toy robots with both legs and arms. Comparing the studies' results without being aware of such differences might lead to misconstrued assumptions. Accordingly, addressing this gap might further understanding on how much HRs' appearance affects older persons' opinions of using them.

Lastly, we found that in many of the included studies technical limitations were seen to be a challenge when using HRs in the care of older persons. This was linked not only to barriers to the adoption of new technologies, as mentioned above, but also slow response time and errors in the HRs' actions. Such limitations must be addressed to ensure a robust HR, before implementation in the care of older persons. We also found that few studies investigated the ethical aspects of using HRs in the care of older persons. Even though the four categories revealed in this scoping review provide much needed insight, the ethical aspects of using HRs are perhaps of greater interest, because older persons receiving care can be considered vulnerable. We however urge caution when attempting to evaluate older persons' actual experiences of the use of HRs. To investigate the effectiveness of using HRs in the care of older persons, validated measurements, larger randomized controlled studies and studies employing a long-term perspective with larger groups of participants should be undertaken.

Limitations

In accordance with the guidelines for the conduct of scoping reviews as delineated in Arksey and O'Malley's framework, a rating of the quality of the twelve studies was not included. However, the quality of this scoping review is supported by the inclusion of the twelve studies' design, sample size, intervention and measurement. Even if most of the studies seen here had a limited number of participants and investigated short-term interventions, an overview of the current existing research was achieved. Although three of the studies included both young and older persons, and two studies did not explicitly mention the persons' ages, we decided to include them because the target group was found to include older persons. When presenting the results, we do mention whether the persons in the studies are young or old, and we also mention whether the persons suffer from dementia or not. Due to rapid technological developments, the search strategy was limited to HRs used in the care of older persons during the last six years. However, it is important to mention that this review did not cover areas such as surgery, monitoring systems, software or studies from thought experiments.

Conclusion

Through the use of a scoping review, we sought to examine how HRs have been used in the care of older persons and to identify the possible benefits and challenges associated with such use from older persons' points of view. The four main categories related to how humanoid robots have been used in care of older persons could provide a starting point for the development of further studies. In the future, validated measurements should be used to estimate the effectiveness of using HRs in the care of older persons and to facilitate HR-human comparisons. Furthermore, larger participant groups, longer interventions and clearly stated study aims should be sought.

Declaration of interest statement

All authors have contributed to the preparation of the manuscript and given final approval of the final version to be published. NN, NN and NN planned the design of the study and contributed to the data collection and data analysis. NN were responsible for the drafting of the manuscript.

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