Personal Robot Technologies to Support Older People Living Independently

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Abstract. The world's population is ageing, and the number of younger people available to care for the older population is decreasing. Digital technologies, particularly robotic technologies, are considered an important part of the solution to this looming problem. This chapter reviews some of the research over the last decade (2013 – 2023) on the development and evaluation of personal robots to assist older people living independently. The research is divided into three areas: that on older people's needs and desires in relation to personal robots and their attitudes towards robots; their reactions to personal robots after a brief experience with them; and the evaluation of older people's longer-term use of personal robots. Strengths and weaknesses of the research are discussed, as well as areas of need for further research.

Robotertechnologien zur Unterstützung älterer Menschen selbstständig zu leben

Zusammenfassung. Die Weltbevölkerung altert und die Zahl der jüngeren Menschen, die für die Pflege der älteren Bevölkerung zur Verfügung stehen, nimmt ab. Digitale Technologien, insbesondere Robotertechnologien, gelten als wichtiger Teil der Lösung für dieses drohende Problem. Dieses Kapitel gibt einen Überblick über die Forschung der letzten zehn Jahre (2013 - 2023) zur Entwicklung und Bewertung von persönlichen Robotern, die ältere Menschen dabei unterstützen, ein unabhängiges Leben zu führen. Die Forschung ist in drei Bereiche unterteilt: die Bedürfnisse und Wünsche älterer Menschen in Bezug auf persönliche Roboter und ihre Einstellung zu Robotern; ihre Reaktionen auf persönliche Roboter nach kurzer Erfahrung mit ihnen; und die Bewertung der längerfristigen Nutzung persönlicher Roboter durch ältere Menschen. Stärken und Schwächen der Forschung werden diskutiert, ebenso wie Bereiche, in denen weitere Forschung notwendig ist.

1 Introduction

It is well known that the world's population is ageing, particularly in the more developed countries. The United Nations estimates that in 2020, there were approximately 727 million people aged 65 or over worldwide, approximately 9% of the population. 65 years is a widely used, if rather arbitrary, indicator for the beginning of *old age* (see Section 2). By 2050, it is estimated there will be 1.5 billion older people, approximately 16% of the population (United Nations 2022). This may not seem like a dramatic increase, but what needs to be considered is the Potential Support Ratio (PSR), also known as the Old Age Dependency Ratio (Skirbekk et al. 2022). This is the ratio of the number of people of working age (i.e. those who produce most of the wealth in a society and who are also available as carers for older people who need support) to the number of older people (Central Intelligence Agency 2021). Europe currently has a PSR of approximately four younger people to each older person, although many European countries have a PSR of less than three younger people to each older person. However, by 2050, most developed countries will have a PSR of only two young people to each older person, which will require dramatic changes in the way we care for our older population.

Technology is often seen as a major part of the solution to this problem of how to support the older population (Schulz et al. 2015), with the concept of ambient (or active) assisted living (AAL) emerging as early as the 1970s (Monekosso, Florez-Revuelta, and Remagnino 2015) to describe "the use of information and communication technologies in people's daily living and working environment to enable them to stay active longer, remain socially connected, and live independently into old age" (Ambient Assisted Living Association n. d.). The term "ageing in place" also emerged in the 1980s, particularly among researchers in North America, became widely used from in the 2000s onwards (Vasunilashorn et al. 2012). This captures an important point, as most older people wish to live independently in their own homes for as long as possible (Gonyea and Burnes 2013; Ilinca, Leichsenring, and Rodrigues 2015; Teti et al. 2014) and this may in the near term be less expensive for society (Marek et al. 2012; A. Sixsmith and J. Sixsmith 2008) but as the number of people of working age shrinks in relation to the number of older people (i.e. the PSR goes down), the cost of human support to facilitate such ageing in place inevitably increases and this situation may no longer hold. Thus, technologies are seen as a cost-effective supplement or alternative to human support. The COVID-19 pandemic, with its worldwide lockdowns and social isolation, has seen a further increase in the relevance and motivation to understand how technological support can be provided to older people and to find solutions to combat the societal challenge of supporting the aging population.

One particular type of technology which has attracted considerable attention in this area is robotic technology. Numerous countries and governments have strongly promoted research and development of robots to support older people. For example, in the European Union, the Horizon 2020 Robotics Roadmap has a Healthcare domain and an Assistive Robotics subdomain (European Commission 2023). The USA has also had a Robotics Roadmap, initiated in 2009 and updated a number of times since, most recently in 2020 (Christensen et al. 2021), which includes developing robotic technologies to support older people. Particularly important is research in Japan, with currently one of the world's most serious ageing population problem, which has supported over two decades of intense research, both publicly and privately funded, on

robotics. By 2018 the Japanese government had invested over USD 300 million in robotics research and development (Wright 2023). China is another country with an acute ageing problem, due in part to greatly increased life expectancy and partly to the one-child policy implemented in the 1970s (Peng 2021). There is also growing interest in research into robotics for older people. However, evaluation of research from Japan suggests that providing robots to older people has not been as successful as anticipated in the 1980s. The area faces many challenges and needs careful and considered design and evaluation of potential products (Wright 2023).
This chapter will review some recent research on the development of robots for older people, the strengths and weaknesses of the research and issues which still need to be addressed. However, first, we need to consider two fundamental questions: who are older people and what are robots?

2 What is old age and what are robots?

Researchers often take the age of 65 years, the traditional retirement age in many countries, as the beginning of old age. However, it is clear that there are many factors influencing the human ageing process and many cultural differences in the perception of ageing. Researchers also often acknowledge that this is a very arbitrary criterion. People in many societies are now healthier for longer in life, may work longer or have very active retirements. Researchers in medical gerontology and related fields often divide *older people* (considered a more respectful term in English than *old people* or *elderly people*) into a number of distinct sub-groups: the *young old* (typically people 65 – 74 years), the *old* (75 to 84 years) and the *oldest old* (85 and over), although there is variation in the terms used and the ages associated with these labels (Kydd et al. 2020). These divisions are not arbitrary. Typically, people in the *young-old* group are able to live independently with little or no support and have reasonable health, although they may be noticing the effects of ageing; people in the *old* group may well experience health issues and need some support to live independently; and those in the *oldest old* group usually need considerable support to live independently and may far better in a more supported living environment. Such a nuanced approach to the definition of old age has not yet reached robotics research but would be good to consider as we move forward.

In relation to the use of digital technologies such as robots, there are further considerations about old age that need to be taken into account. For example, consider the fact that someone who is 65 in 2024 was born in 1960, turned 18 in 1978, and perhaps will be just on the point of retirement. Whereas someone who is 85 in 2024 was born in 1940, turned 18 in 1958, and retired in 2005. The typical experience of digital technology of these two people is likely to be very different, although, of course, this also depends on their cultural and economic context. But thinking of people in a typically developed world context, the 65-year-old may well have had experience with personal computers for much of their working life, with the internet and web since their early 40s (given these technologies became widely used by about 2000) and mobile and smartphones since their mid-40s. So, they may well be quite familiar with new digital technologies, both their benefits and their challenges. Whereas the 85-year-old would only have experienced these new technologies much later in their adult lives and were likely retired as the age of smartphones and apps was beginning (given that the first iPhone was launched in 2007). So, they may be much less familiar and comfortable with the idea of personal digital technologies. These are generalisations, as older people who never had any experience with new technologies are often introduced to them by their adult children, and the COVID-19 pandemic showed that when the use of technology becomes the only option for achieving a task, whether it is communicating with friends and relatives or ordering groceries or medicines, many more people, including older people, will adopt them (Haase et al. 2021; Sixsmith et al. 2022). However, it is important to consider the effects of the last 50 years of technological developments and people's likely experience of them. Perhaps, when considering the development of technologies such as robots, we should consider the likely digital technology life experiences of older people in different age bands, rather than their likely health status, as used in medical gerontology. This argument is developed in more detail in Petrie (2023).

Turning to the term *robot*, many people, particularly older people, may have an image of larger-than life and rather scary humanoid machine, a modern version (e.g. Figure 1).

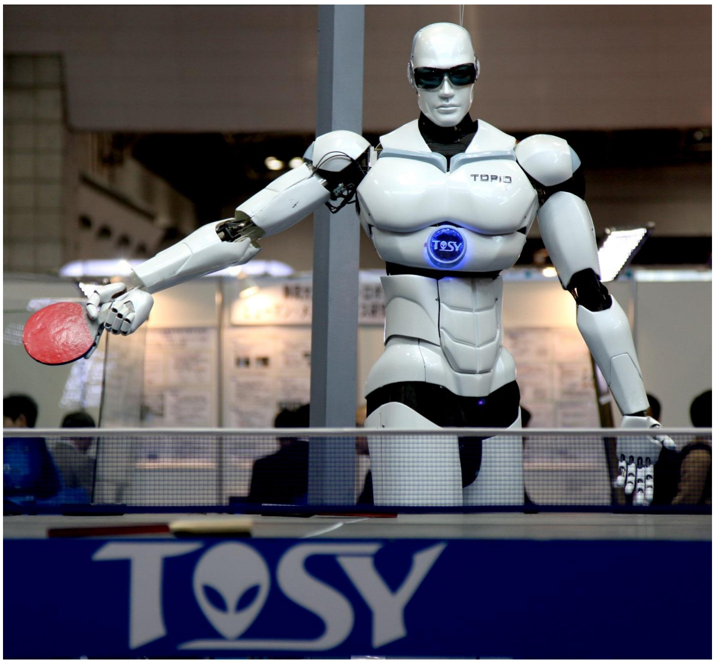

Figure 1 TOPIO By Humanrobo - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=18947366

However, robots being researched and developed for older people now come in many shapes and sizes. Sometimes even voice-only systems such as *Alexa* from Amazon and *Siri* from Apple are considered robots (although out of scope for the present discussion). In addition to more friendly-looking humanoid (or vaguely humanoid) robots (e.g., Figure 2a), robots for personal use now are often in the form of a pet. For example, *Aibo* is a well-known robot that looks somewhat like a dog (Figure 2b); *PARO* looks very like a baby seal (Figure 2c); and *MiRo* is deliberately a small mammal, but not of a specific species (Figure 2d).

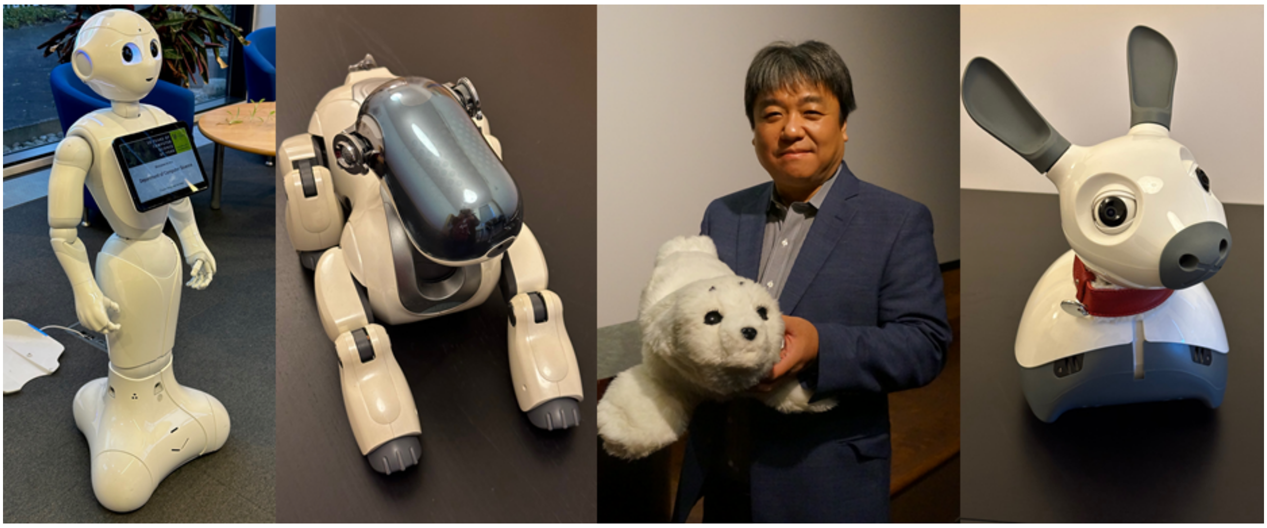

Figure 2 (a) Pepper, example of a humanoid robot; (b) Aibo, example of a pet dog robot; (c) PARO, the baby seal like robot; (d) MiRo, a non-specific animal robot; © Helen Petrie, except c: Geraldshields11, CC BY-SA 4.0, via Wikimedia Commons

In the research literature, the term *robot* is often used as an umbrella term with a description of the functionality preceding the basic word. *Social robot, assistive robot,* or *socially assistive robot* are commonly used terms. Petrie, Darzentas, and Carmien (2018) found that there were nearly 30 terms used in relation to robotic research for older people. While they suggest a classification of robots, both physical and virtual, we propose a more general term to refer to the technologies discussed in this chapter: *personal robot*. This term allows us to refer to all the different types of robots and robot-like devices now available, while not focusing particularly on their function or size. In addition, we feel this term provides a less stigmatizing term such as *(socially) assistive robot*.

The research on personal robots for older people has investigated many functions that the robots may do for the users or assist with. These can be divided into three broad areas: task-oriented functions, performing, or helping to perform tasks; companionship functions; and monitoring functions (Sharkey and Sharkey 2012). The task-oriented functions can be divided into two further areas, cognitive and physical tasks. Cognitive tasks include reminders, for example, for older people to take their medications, keep appointments and anything else important in their lives they need reminding about; providing information, from a weather report to reading a novel; physical tasks include fetching objects, cleaning, guiding exercise (this may also involve a reminder task to do some exercise), even a partner to take a walk with (which may also be a companionship function, see Karunarathne et al. 2019). Companionship functions include providing entertainment, such as dancing with the older person, playing games with the older person, or indirectly supporting companionship, by using communication technologies to connect with family members and friends. Monitoring functioning includes monitoring the older person for falls, high blood pressure or other indicators of health problems (and this may include notification of carers or medical personnel) or monitoring the environment, for example checking whether the water taps and electrical appliances have been switched off, windows or doors shut or locked as appropriate. Of course, as has already been illustrated, some functions involve a mixture of task types, some personal robots provide a mixture of different functions, and some only provide a very specific sub-set of functions.

However, for older people to use any of these functions, the idea of a personal robot and the particular type of robot needs to be acceptable, useful and usable for them. In human-computer interaction, there is the adage that "useful and usable equals used" (Dix 2008). This adage is very appropriate in the development of technologies and personal robots for older people. There is much technical development of solutions, but perhaps insufficient investigation of whether these solutions will be useful to older people, whether they will be usable and hence whether they will be used. Clearly, in the area of personal robots for older people, these three concepts pose many problems for research to be able to address effectively. Thus, the rest of this chapter will be divided into three sections, firstly looking at research which has investigated what older people actually need and desire from personal robots and their attitudes toward them; then, reviewing research which has studied older people's initial reactions to personal robots, after short-term experience with a personal robot; and finally, studies which have investigated longer term use of personal robots by older people, an area very difficult to study, but vitally important for understanding how personal robots will help older people in the future.

3 Questionnaires used in research on robots for older people

Before turning to the research, it is useful to consider the questionnaires that are commonly used in this area, as these feature frequently in the research literature. A number of questionnaires have been developed to assess people's attitudes to robots. These are often used in research with older people, although they have not necessarily been validated with this age group or for the cultures in which they are being used.

The most widely used set of questionnaires in the general field of human-robot interaction is the strangely named *Godspeed questionnaires* (Bartneck et al. 2009; Bartneck 2023). Although they appear to be one questionnaire with a set of sub-scales, the parts were developed separately, so they can be used as stand-alone questionnaires if this is needed. The questionnaires are: Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety. These questionnaires drew on earlier individually validated questionnaires, but subsequently considerable work has been undertaken to validate their use in robotics research.

Two other widely used questionnaires were developed in Japan by Nomura and colleagues (Nomura et al. 2006a, 2006b), the Negative Attitudes Towards Robots Scale (NARS) and the Robot Anxiety Scale (RAS). These scales were initially validated by conducting an experiment with 38 Japanese university students in which they completed both scales before and after an interaction with a humanoid robot. It is not clear whether they have been validated with more diverse samples in other cultures, for example in Europe or North America. The NARS contains three sub-scales: Negative Attitudes toward Situations of Interaction with Robots, Negative Attitudes toward the Social Influence of Robots, and Negative Attitudes toward Emotions in Interaction with Robots. The RAS also contains three sub-scales: Anxiety toward Communication Capability of robots, Anxiety toward Behavioural Characteristics of Robots, and Anxiety toward Discourse with Robots.

The Robot Attitudes Scale (also abbreviated to RAS) was developed by Broadbent et al. (2010) which they have used in a number of studies about robots for older people. This scale consists of 12 semantic differential pairs, which participants rate on eight-point scales, with the attribute opposites as anchors, for example friendly (1) - unfriendly (8).

The most developed framework for understanding attitudes to robots by older people was developed by Heerink and colleagues (Heerink et al. 2008, 2009, 2010). Their Almere model was based on the Technology Acceptance Model (TAM) developed by Davis (Younghwa, Kozar, and Larsen 2003) and the extension of TAM, the Unified Theory of Acceptance and Use of Technology (UTUAT) model (Venkatesh, Morris, and Davis 2003). The Almere model questionnaire includes 41 items divided into 12 different constructs (see Table 1). Different parts of the model were validated in four experiments with older adults and different social robots. The authors argued that the final model showed predictive strength and solid constructs, being able to reliably predict the acceptance of assistive social robots. Many studies about robots for older people have used or adapted the Almere model, sometimes selecting only specific constructs that are of interest.

Table 1 Almere model constructs (from Heerink et al. 2010)

Construct	Definition
Anxiety ANX	Evoking anxious or emotional reactions when using the system
Attitude ATT	Positive or negative feelings about the appliance of the technology
Facilitating Conditions FC	Objective factors in the environment that facilitate using the system
Intention to Use ITU	The outspoken intention to use the system over a longer period of time
Perceived Adaptability PAD	The perceived ability of the system to be adaptive to the changing needs of the user
Perceived Enjoyment PENJ	Feelings of joy or pleasure associated by the user with the use of the system
Perceived Ease of Use PEOU	The degree to which the user believes that using the system would be free of effort
Perceived Sociability PS	The perceived ability of the system to perform sociable behaviour
Perceived Usefulness PU	The degree to which a person believes that using the system would enhance his or her daily activities
Social Influence SI	The user's perception of how people who are important to him/her think about him/her using the system
Social Presence SP	The experience of sensing a social entity when interacting with the system
Trust	The belief that the system performs with personal integrity and reliability

4 Research on personal robots for older people living independently

There is a large body of research on the development and evaluation of robots for older people. There have already been numerous reviews of this research over the years, trying to encapsulate different aspects of the research (Abdi et al. 2018; Conti, Di Nuovo, and Di Nuovo 2021; Frennert and Östlund 2014; Guerra et al. 2022; Kachouie et al. 2014; Pedersen, Reid, and Aspevig 2018; Petrie and Darzentas 2017; Robinson, MacDonald, and Broadbent 2014; Shishehgar, Kerr, and Blake 2018; Vandemeulebroucke, Dzi, and Gastmans 2021). We are in the process of undertaking our own up-to-date review of the research on robots to support older people living independently, so in the following sections, we present a reasonably representative sample of the research on personal robots for older people living independently. We have excluded research to support older people with dementia and other severe cognitive and physical disabilities, as these important topics need separate consideration. We also restrict ourselves to reasonably recent research, conducted in the last decade (2013 – 2023).

4.1 Older people's needs and desires in relation to personal robots and attitudes towards them

This section will consider research which has investigated older people's needs and desires in relation to personal robots, and their attitudes to robot technology, in situations in which the participants do not actually have any experience with robots. They may have simply been asked their wishes or views, they may have been given a verbal description of a type of robot or shown photos or videos, but they did not experience interacting with a robot as part of the study. This is of course a typical first step in user- or human-centred design lifecycles (International Organization for Standardization 2019). In relation to the overall programme of research on robots for older people, it has both advantages and disadvantages. On the one hand it is important to understand what older people want robots to do for them, as developing such functionality should increase acceptability and use. On the other hand, due to the perhaps somewhat unrealistic portrayal of robots in the mass media, older people may have misconceptions about them until they are able to interact with them in-depth. Thus, we are caught in something of a vicious circle, of potentially developing robot functionality, which is not desired by older people (as noted by Søraa et al. 2023), which might lead to rejection of robots or failure to dispel misconceptions about robots which might also lead to rejection.

Thirteen research studies on older people's needs, desires and attitudes about personal robots are summarized in Table 2. One of the strengths of recent research in this area is that it is conducted in many parts of the world, thus reflecting the diversity of situations of older people in different cultures. These 13 studies were conducted in 10 different countries, and although there is some bias towards the English speaking countries perhaps because we only reviewed papers published in English. However, there is representation from a range of European countries (Germany, Sweden, and Switzerland) and East Asian countries (China, Japan, and Korea). However, the weakness is there is such a variety of methods and topics of investigation, that it is very hard to make any direct comparisons between studies.

Table 2 Research on older people's needs and desires for personal robots and attitudes to robots (Participants is abbreviated to P for brevity)

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Smarr et al. 2014 USA	Structured group interviews including 8 minute video of robot (PR2) performing tasks and demonstrating its capabilities Brainstorming on assistance robots could provide in the home	Assistance Preference Checklist (compared preferences for a human or a robot doing 48 home-based tasks) Developed 12 item Robot Opinion Questionnaire (based on TAM) to measure perceived usefulness, perceived ease of use (7-point Likert items) Analysis of brainstorming of assistance (type of analysis not described)	21 63 – 95 (mean: 80.25) 71.4 % F Living independently	Ps positive about robots in general: medians of 5 or 6 on ratings perceived usefulness and perceived ease of use. Ps generated 121 tasks they wanted a robot to perform, most common categories: Clean, Remind, Straighten/organise, bring, pick up, select/pick, connect, make, play, walk. Robot vs Human preferences – preferred robot for a range of object manipulation tasks, information management tasks and household chores; preferred human for more personal tasks (e.g. eating, brushing teeth), social tasks (being entertained, call family/friends), and health tasks (e.g. exercise, take medicine)

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Lazar et al. 2016 USA	Focus groups with initial drawing/description of ideal robotic pet Discussion of what Ps thought of the idea of having a robotic pet, whether they would consider having one, whether they would want to interact with one, and how they would want to interact with it, any perceived concerns such as privacy, maintenance, and pets replacing human contact Midway, handling of 6 robotic pets, not designed specifically for older people (the pets were handled, but there was no other interaction with the pets)	Thematic analysis of discussions No separate analysis of the drawings/descriptions of the ideal robotic pet	41 61 – 92 (mean: 77) 83.4 % F Living independently, varied income levels	Themes which emerged: (1) deriving comfort and companionship from a robotic pet requires giving into the fiction of it, which is a choice (2) rather than alleviating loneliness and social isolation, robotic pets may provide social entertainment and facilitate opportunities for social interaction (3) the functional support of robotic pets is appealing, but participants valued reciprocity inherent in caring for a pet and the relationship that it creates.

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Leong and Johnston 2016 Australia	Group 1: Interviews, followed by 3 co-design workshops Group 2: two workshops presenting the outcome of Group 1 work	Group 1: interviews and 1st workshop identified a robot dog as a possible focus; 2nd and 3rd workshops developed scenarios of use for the robot dog. Group 2: qualitative evaluation of the scenarios	Group 1: 8 Group 2: 16 Group 1: 65 – 75 Group 2: 65 – 90 Group 1: 50 % F, Group 2: no information given No further information	87.5 % of Group 2 were positive about the robot dog, 25 % wanted one immediately Many felt owning such a dog would give them admiration from their peers and more importantly, their grandchildren Many of them could also imagine different ways in which a robot dog might be useful in their everyday lives, e.g. strengthen a sense of security when they are home alone.

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Lehoux and Grimard 2018 Canada	Workshops with 3 minute video of 3 scenarios of an older person interacting with a robot Discussion of how robots could help older people	Comments on video made immediately, group discussion, comments made after workshop	Total: 46 18 – 29: 9 30 – 39: 6 40 – 49: 3 50 – 59: 7 60 – 69: 17 70 +: 4 No gender breakdown by age, but overall 72 % F Variety of educational levels, incomes	Wide range of tasks proposed that a robot could help with: monitoring and safety, activities of daily living, social activities and emotional support. Did not want to anthropomorphize a non-sentient entity
Backonja et al. 2018 also discussed in: Hall et al. 2019 USA	Questionnaire distributed in public spaces and community centres for older people 20 closed questions, 1 open-ended question. Only a text explaining the term robot.	Thematic analysis of open-ended questions.	Total: 499 Young: 322; Middle-aged: 50; Older: 102 Young: 18 - 44; Middle-aged: 45 - 64; Older: 65 – 98 Older: 69.6 % F	Older participants are most comfortable with these roles for a robot: Acting as companionship, for example, telling stories, Acting as social companions, for example, a robotic pet dog or cat, Providing medical advice, Escorting you around a town or city, for example to stores

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Lugrin, Rosenthal-von der Pütten, and Hahn 2019 Germany	Individual interviews with 8 videos showing different interaction contexts (e.g. a birthday party, two friends playing a card game, two friends chatting about the good old times)	For each context, analysed whether Ps thought a robot should deliver a reminder (4 different kinds of reminder: message delicate/non-delicate, appointment urgent/non-urgent), and if so how should the reminder be delivered	8 No range (mean: 75) 62. 5% F Supported living home	The different contexts and message types both had effects on the answers, as well as other contextual factors such as level of background noise, ability to concentrate in a particular context and relationship to other people in the situation. Difficult to generate general principles from this set of contexts/messages.
Park et al. 2019 Korea	Survey: 8 items (scored 0 – 10) about acceptance and need for robot technology in areas such as: early detection of emergency situations and reacting to emergency situations in time, locating objects, assisting with mobility, recording and recalling memories.	Quantitative analysis of survey data. Thematic analysis of focus group discussions.	Survey: 234 Focus groups: 23 (sampled from the survey respondents) Survey: 65 – 96 (mean: 75.7) Focus groups: 66 – 85 (mean: 75.5) Survey: 70.9 % F Focus groups: Community-dwelling	Need for and acceptance of robots to assist in daily living were high (scores of 7.2 and 7.9). Also important: timely reaction to emergency situations, early detection of emergency situations, help to locate objects, assistance with mobility, assistance in memory recall.

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
	No mention of explanation of robots, photos or videos. Focus groups: included 3 video clips - Pepper, Paro and exoskeleton robots. Discussion topics included aspects of daily life most requiring another person's assistance, if a robot were capable of assisting daily life, what aspect would Ps prioritize, how could a robot can help in regard to most pressing needs.			Analysis of focus group discussion found a 'mismatch between desires and functional capacity' was the core characteristic of living as an older person and 'being a friend and helper' was the most desired trait of a robot service.
Biswas et al. 2020 UK	Survey with 6 videos of an actor interacting with a robot (Metralabs SCITOS G5), some successful interactions, some not; interaction with robot was through voice or a tablet computer.	12 item questionnaire (7 open questions, 5 closed) asking about their choice for a multimodal interface in these situations. General questions e.g. possible uses for robots in the home	Total: 114 21 and under: 24; 22 – 64:72; 65 and over: 18 No means No gender information Older Ps were living in sheltered housing	Older Ps preferred voice interaction to tablet (72.2 %) and were more likely to want a robot for their household compared to younger participants (83.3 % vs 55.2 %). The most popular use of a robot was for household tasks

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
	General questions e.g. possible uses for robots in the home			e.g. vacuum cleaning the floor, and personal tasks, e.g. reminding Ps to take their medicine. Some (mostly younger) people suggested robots could help communicate with other people, organize email etc.
Frennert and Östlund 2020 Sweden	Focus groups including video of a robot	Thematic type analysis of discussion, questionnaire about perceptions of the robot	31 70 – 85 (mean: 76.8) 55 % F	4 themes emerged from discussions: (1) potential of using robots in health and elderly care (2) concerns about using robots in health and elderly care (3) pre-conditions for using a robot 4) barriers to using a robot
Lehmann, Ruf, and Misoch 2020 Switzerland	Presentations of vignettes with pictures of 4 robots (human-like, machine-like, mechanical-human-like, android) and video of 2	Questionnaire to measure emotions and attitudes	142 58 – 87 (mean: 73.2) 54.2 % F	In a service situation (e.g. receiving a drink from a robot), more positive emotions but in a care situation (being washed by a

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	different robot interaction types (service, care)			robot) more negative emotions were reported. The android robot did not evoke more negative emotions than the machine-like, the mechanical-human-like, or the human-like robot
Noguchi, Kamide, and Tanaka 2020 Japan	Session in a lab. Ps watched 4 videos of a robot (small, cartoon/human-like) showing different personalities (high/low extroversion, high/low neuroticism)	Japanese Ten-Item Personality Inventory (Oshio, Abe, and Cutrone 2012), applied to the robot, personality of participants measured. Level of self-disclosure to the robot measured by a rating of how much participants wanted to talk to the robot.	589 Over 60 (mean: 69.8) 50 % F Living independently alone or with spouse only	Participants self-disclosed more to the low neuroticism robot than the high neuroticism robot. Participant personality and gender also had effects on self-disclosure levels.

Authors **Year** **Location**	**Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants Other inclusion criteria	**Key Results**
Samaddar and Petrie 2020 UK	Semi-structured interviews in a HomeLab about what participants want from a robot, then photos of 5 types of robot and related technology (robots: humanoid, pet, tabletop; plus virtual assistants and virtual agents), reactions and preferences	Thematic analysis of answers	24 66 – 82 (no mean) 50 % F	Ps want help with: reminders, with tasks dexterity and mobility (e.g. getting out of bed), cooking, home security, finding and fetching objects, games and exercise. Preferences: 32 % no preference; 27 % - pet robot; 41 % did not want a humanoid robot.
Liu, Shen, and Hancock 2021 China	Survey with photos of 18 robots	Likert scales to measure warmth and competence of each robot 12 Likert items about concerns about robots derived from previous research	730 Over 60 (mean: 72.36) 42.9 % F Living independently or in nursing homes in rural area	Ps perceived small, animal shaped robots as having high warmth, they perceived android and steel-made machine-like robots had high competence. Ps had three main areas of concern about robots: technical and financial concerns, privacy concerns, and psychological concerns.

Six of the studies conducted large scale surveys with substantial numbers of respondents (from 102 to 730 respondents, an average of over 300 respondents). Four studies conducted focus groups, again with substantial numbers of participants for this method (from 23 to 46, average 35 participants). Three studies conducted individual or group interviews with reasonable number of participants (8 to 24, average 17 participants). Finally, one study involved co-design workshops with 8 participants. The age ranges of the studies are also good, with some participants in their 90s. There is often a gender bias toward women participants (46 % of studies have more than 60 % women), which is understandable given that life expectancy is somewhat longer for women, and this effect becomes stronger in older cohorts of people. In addition, women are often more likely to volunteer to help in research than men (Rosnow and Rosenthal 2021). Six of the studies showed participants videos of personal robots, four showed a range of photos of robots, one study gave a text description, and one gave participants a range of pet robots to handle, but not interact with. Thus, participants were given a wide range of initial information about what personal robots might do for them, which might also counteract any initial conceptions they had.

Across all these studies, one can conclude that older people in a range of countries, given a range of information, in a range of research contexts, were largely positive about the idea of personal robots to support them in daily life. This ranged from 21 participants in the USA (Smarr et al. 2014) who gave high rating of usefulness and ease of use to the PR2 robot, having watched a video of it, to 730 participants in China (Liu, Shen, and Hancock 2021) who perceived small pet robots as very warm, and android and machine-like robots as highly competent, on the basis of photos of a range of robots. However, only five of the studies investigated what older people want robots to support them with, although the other studies investigated a range of other interesting and important topics, such as how older people want to interact with a robot (e.g., Biswas et al. 2020) and in what contexts they want a robot to intervene (Lugrin, Rosenthal-von der Pütten, and Hahn 2019). A wide range of types of support did emerge, with many practical activities of daily living, particularly reminder functions, as well as entertainment and companionship.

However, as noted above, these results are based on older people having potentially little knowledge of the current capabilities of robots and possible misconceptions. Thus, we will now compare this body of research with research in which participants have at least a brief experience of interacting with a personal robot.

4.2 Research on older people's reactions to personal robots after brief experience

Eleven research studies on older people's reactions to personal robots after brief experiences with them are summarized in Table 3. As with the previous set of studies, these are conducted in a wide range of countries, showing the cultural diversity of the findings. These studies are often done in a laboratory setting, which is understandable, given the technical infrastructure required to deploy a robot. But does mean they may lack ecological validity, as these would not be the settings in which these robots would be used. A striking example is the study by Chen et al. (2017) investigating the use of a robot for partner dancing. This is a fascinating study, but the laboratory is far from the natural setting for this activity, although clearly, it is quite appropriate to conduct a first evaluation in that setting. At the other end of the spectrum is the study by Karunarathne et al. (2019) investigating the use of a robot as an outdoor walking companion to encourage older people to take gentle exercise. This study was largely conducted in an outdoor location on a university campus which would be the kind of setting for the real use of this robot. The functionality being assessed in these studies is often quite specific, which is understandable, as they usually require the deployment of a fully functioning robotic system, although a Wizard of Oz simulation of the functionality could sometimes be used (e.g. Thunberg, Arnelid, and Ziemke 2022).

Table 3 Research on older people's reactions to personal robots after brief experience

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
Körtner et al. 2014 also discussed in: Fischinger et al. 2016 Austria Greece Sweden	HOBBIT Robot Took place in a lab set up as a living room. Ps undertook 5 tasks with the robot.	NASA TLX (Hart and Staveland 1988) SUS (Brooke 1996) Debriefing questionnaire with rating items and open-ended questions	49 70 – 88 (no mean) 71.4 % F Living independently, alone	Usability was satisfactory Task speed was considered to be rather slow, but tasks were considered easy to undertake. Ps preferred voice input to gesture or touchscreen. Picking up objects considered the most important task. Help in standing up and walking also useful. Ps were sceptical of buying a robot, but would be willing to rent one. 57.2 % of Ps could imagine having the robot at home for a longer period of time. 65.3 % could imagine the robot taking care of them.

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
				49 % of the Ps considered the robot as rather or very helpful at home, but 44.9 % were sceptical about its helpfulness.
Louie, McColl, and Nejat 2014 Canada	Took place in a lab. Ps watched live interaction between robot and researcher using two different scenarios.	Robot Acceptance Questionnaire (based on Almere model)	46 62 – 91 (mean: 76) 80.4 % F	Attitude (ATT) – positive, Anxiety (ANX) – low, perceived ease of use (PEOU) – neutral (perhaps because Ps did not interact with the robot personally) 70 % liked the idea of the companionship the robot could provide; 65 % like the expressions of emotion (tone of voice, facial expression), but only 35 % liked its life-like appearance. Authors note that “human-like communication is preferred over human-like appearance”. Tasks desired: Reminders, play games, tell stories, guide exercise.

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
McGlynn et al. 2014, 2017 USA	PARO seal robot. Took place in a lab. PARO was introduced to Ps in one of three scenarios (pet, robot, toy). After presenting PARO but before turning it on, initial reactions were sought. It was turned on and again reactions were sought. Researcher demonstrated possible interactions with PARO.	Perceived Ease of Use, Perceived Usefulness (from TAM/Almere model). Pet experience questionnaire. PANAS Positive Affect Negative Affect Schedule (Watson, Clark, and Tellegen 1988). Interview about PARO.	30 67 – 80 (mean: 72.17) 50 % F	Interviews showed that Ps had positive attitudes towards PARO, thought it would be easy to use, and perceived potential uses for both themselves and others. Ps varied in their frequency of active engagement with PARO. Engagement frequency uniquely predicted post-interaction positive affect.
Stafford et al. 2014b New Zealand	Study conducted in an office at the university. Ps conversed for 5 minutes each with 6 animated robot faces with appropriate speech (3 M, 3 F; 2 machine-like, 2 human-like, 2 just voice). Input was via keyboard, robot spoke with synthetic speech.	Robot Attitudes Scale (RAS) Rating of whether they would use the robot	20 65 – 93 (mean: 80.25) 65 % F Living independently	No differences between the different robot versions, ratings of all were low. Men rated all robots more positively than women.

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
Shen and Wu 2016 Singapore	No information about location for study. NAO robot performed two tasks with Ps: exercise guidance and information about healthy living. Plus human control condition.	Effectiveness of exercise performance by video analysis. Effectiveness of information by quiz taken by participants. Subjective evaluation on 10 semantic differential items (e.g. dangerous-safe) (appears to be RAS from Broadbent et al, 2010, but not acknowledged)	41 67 – 86 (mean: 73) 61 % F Living independently	Robot was more effective and better preferred by Ps over human instructor on instructing physical exercise; similar levels of effectiveness and acceptance on information task. Perception of robot improved after the robot session.
Boumans et al. 2018, 2020 Netherlands	Took place in an interview room. Pepper robot collected information about health outcomes from Ps using voice interaction and screen presentation of options. Collected information from a range of standard patient outcome measures.	Duration compared to human interview. Effectiveness of obtaining information. Questionnaire (short form of Almere model)	31 Over 70 (mean: 76.2) 45 % F Community-dwelling	Robot was as effective, as efficient as a human, and scored highly on Almere ratings from participants.
Chen et al. 2017 USA	Took place in a lab. Ps led a human-scale wheeled robot with arms in a simple dance.	Questionnaire based on Almere Model	16 65 – 79 (mean: 71.5) 56.25 % F Able to walk without an assistive device	Ps generally accepted the robot as dance partner for exercise, perceived it as useful (PU), easy to use (PU), and enjoyable (PENJ).

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
				Ps perceived the robot as easier to use after dancing with it
Di Nuovo et al. 2018 Italy	Took place in a lab. Study 1: Ps undertook several tasks in one of 6 scenarios: shopping, communication, laundry, reminding, garbage, food delivery.	Questionnaire to measure attitudes toward the robot (based on Almere model) SUS (12) ad hoc questionnaire	72 63 – 97 (mean: 77.6) 70.8 % F Living independently	Robot seen as useful, did not make Ps anxious (ANX), they showed moderate to high intention to use (ITU) in the future. SUS had median scores of 85 or above for the different scenarios.
Karunarathne et al. 2019 Japan	Conducted outdoors when possible at university campus (when raining or snowing conducted indoors). Robovie-R3 robot walked side-by-side with Ps for 80m (60m when indoors). Control condition of walking alone. Interview.	Objective measurement of walking side-by-side. Three measures from Almere Model: Perceived Enjoyment (PENJ), Perceived ease of walking (PEOU), intention to walk (ITU)	Total: 20 Outdoors: 7 Indoors: 13 60 – 73 (mean: 67.50) 50 % F	90 % of Ps sustained a side-by-side formation. 35 % initially walked side-by-side, but eventually led the robot slightly. No difference in enjoyment (PENJ) between robot and walking alone, however, ease of walking with robot (PEOU) was significantly lower than walking alone. However, intention to walk with robot (ITU), particularly outside was high.

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
Olde Keizer et al. 2019 Netherlands	NAO robot questioned Ps about their frailty status and guide them through 4 physical exercises. Control condition of a tablet computer.	Performance on the exercises. SUS, perceived usability (3 5-point Likert items), 2 user experience measures (Enjoyment – 4 Likert items, Control – 3 Likert items). Which version did Ps prefer and why.	20 Over 70 (mean: 78.5) 40 % F No physical impairments, but need to be frail or pre-frail	Both robot and tablet received average usability scores. Perceived usefulness and enjoyment were rated as very positive for both; control was scored positively. Main usability issues for NAO were related to speech interaction (e.g., NAO's limited speech library, NAO's difficulty to cope with Dutch dialect), Ps' difficulties with taking their proper role in human-robot interaction, and a lack of affordances of NAO. 35% Ps preferred NAO: it was easier to use and more personal.
Avioz-Sarig et al. 2021 Israel	Study took place in lab. 2 robots (Nao, Poppy) acted as exercise coaches for strength exercises. One session with each coach.	Comfort (heart rate change) Understanding (reaction time) Engagement (eye contact with robot) Whether Ps continued exercise after robot stopped) Adherence (success rate).	32 70 – 88 (mean: 77.4) 56.25 % F healthy	Most Ps rated the robots as very useful, easy to use, had a positive attitude towards the overall system and noted their intention to use it. Most Ps preferred the more mechanical looking

Authors **Year** **Location**	**Robot** **Study design**	**Measures taken**	**Participants** Number Age – range (mean) % female participants	**Key results**
		Questionnaires: Negative Attitudes toward Robots Scale (NARS) Technology Adoption Propensity (TAP) (Ratchford and Barnhart 2012)		robot (Poppy) to the toy-like robot (Nao).
Thunberg, Arnelid, and Ziemke 2022 Sweden	Took place in a quiet room in a community centre. Furhat robot (robot head-only with realistic animated male face) had a 10 minute conversation with P (created by Wizard of Oz)	NARS and Godspeed questionnaires	19 Over 65 (No mean) Living independently	Ps have a negative attitude towards robots after interacting with the Furhat robot, especially towards robot emotions. Ps did not perceive the robots as alive or human-like but they are to be safe to be around.

The number of participants involved in these studies is also impressive, given the complexity of the research. The number ranged from 16 to 72, with an average number of 34. As with the previous set of studies, there tended to be a gender bias towards women participants, although not quite as strong as in the previous set (37 % of studies have more than 60 % women), perhaps because in these kinds of studies researchers have some more control in participant recruitment and can attempt to balance their samples. The design of the studies is also somewhat more homogeneous than the previous set, typically with participants having some kind of experience with the robot and then measures, both objective and subjective, of their reactions to the experience and the robot. Some studies measure reactions to the robot both before and after the experience and some studies have one or more control conditions to compare the experience with the robot to other appropriate situations.

For example, Karunarathne et al. (2019) compared walking with the robot to walking alone, Olde Keizer et al. (2019) compared an interview with a robot to completing the same questions on a tablet computer.

There was also an interesting range of objective measures appropriate to the situation. For example, a number of the studies investigated the use of a robot to guide exercise (Avioz-Sarig et al. 2021; Olde Keizer et al. 2019; Shen and Wu 2016) or other physical activities (dancing – Shen and Wu 2016; walking – Karunarathne et al. 2019) and took objective measures of the performance of these activities with the robot, and sometimes in comparison with a control condition. For example, Shen and Wu (2016) compared exercising with a NAO robot with exercising with a human coach (and found the exercises were more effectively followed with the robot). Studies also used an interesting range of subjective measures to assess reaction to the robot experience. Over half the studies (55 %) used versions of the Almere model questionnaire, two studies used the NARS, and one used the Godspeed questionnaires. Other studies used mainstream human-computer interaction measures, the NASA TLX and the System Usability Scale (SUS), self-developed questions and open-ended interviews. The overall impression one gains from this set of studies is that older people are a little more cautious about personal robots than one might expect from the first set of studies. For example, the studies with the Hobbit robot (Fischinger et al. 2016; Körtner et al. 2014; Pripfl et al. 2016) found that participants were equally split between thinking the robot would be helpful or not. Louie, McColl, and Nejat (2014) found that although participants had a positive attitude and were not anxious about the robot, they were neutral about its ease of use and only 35 % liked its life-like appearance. In some cases in which there was a control condition, there were no differences between the robot and the control condition. For example, Karunarathne et al. (2019) found no difference in enjoyment between walking with the robot and walking alone (an interesting and more appropriate control condition might be walking with a friend). Olde Keizer et al. (2019) found no differences between answering questions with a robot or a tablet computer, although both were considered useful, usable and enjoyable. Only one study reported quite negative reactions to the robot, that by Thunberg, Arnelid, and Ziemke (2022) in which participants interacted with a robot head with a realistic animated face. This is quite an unusual configuration for a personal robot, very different from those used in other research, so one should be very cautious about generalising from this study. It would be very helpful to investigate further why the participants were so negative about this robot form. Other studies showed far more positive reactions to the robot. Avioz-Sarig et al. (2021) compared two robots (NAO and Poppy) as exercise coaches and found that participants rated both as useful, easy to use and intended to use them in future, although most participants preferred the mechanical-looking robot (Poppy) to NAO. Di Nuovo et al. (2018), which was one of the studies which was able to demonstrate a wide range of functionality with the robot, found very positive reactions from participants.

One of the limitations of this kind of research is that participants only have a short experience with a robot, and as noted, often in an artificial setting in the researchers' location rather than their own home. This may create novelty effects and social desirability effects (as the participants want to please the researchers). The experience does not necessarily give participants much understanding of what it would be like to use a robot long term, usually in their homes, which is the ultimate goal of all this programme of research. Therefore, the final set of studies to be reviewed are those which have undertaken longer term studies of the use of personal robots by older people.

4.3 Evaluation of longer-term use of personal robots by older people

Eight research studies on the longer-term use of personal robots by older people are summarised in Table 4. There does seem to be a smaller number of studies of this nature, which is not surprising, given the complexity and cost of organizing this type of research. As with the previous set of studies, these are conducted in a wide range of countries, although as of yet, we have found no longer-term studies in East Asia. We may not have found relevant studies yet, and there has definitely been work in Japan, although not in the time period of this review (e.g. (Sabelli, Kanda, and Hagita 2011; Shibata, Kawaguchi, and Wada 2012; Wada et al. 2002, 2003) and often that work has concentrated on older people with dementia and other cognitive issues (as do a number of longer-term studies in Europe and North America, e.g. Chang, Ŝabanović, and Huber 2014; Hebesberger et al. 2016; Schroeter et al. 2013).

Table 4 Studies of older people's longer term experience with personal robots

Authors **Date** **Location**	**Study design**	**Measures**	**Participants (Ps)** **Number** **Ages** **Gender** **Other criteria**	**Key Results**
Stafford et al. 2014a New Zealand	HealthBots Robot could perform a number of tasks: Take vital signs (e.g. blood pressure) Give reminders about medication, Make telephone calls, Play songs Play memory games Ps were invited to use the robot as much as they	RAS (Broadbent et al. 2010) 11 items from the 18 item Dimensions of Mind Perception Scale (H. M. Gray, K. Gray, and Wegner 2007) Self-developed questionnaire about how much the robot had been used, quality of overall experience with the robot, how much	23 78 – 95 (mean: 86.12) 72 % F Living in a retirement village, be taking medication daily	Ps who held significantly more positive attitudes towards robots, and perceived robot minds to have less agency (ability to do things) were more likely to use the robot. Attitudes towards robots improved over time for Ps using the robot.

Authors **Date** **Location**	**Study design**	**Measures**	**Participants (Ps)** **Number** **Ages** **Gender** **Other criteria**	**Key Results**
	wished for a 2 week period, either in their own apartment (for up to 30 minutes a day) or in the public area of their building	Ps would like to use the robot again.		
Graaf, Allouch, and Klamer 2015 UK	Nabaztag (later know as Karotz) small rabbit-like robot was installed in Ps home for 30 days. Robot asked P: (1) if they were adhering to their activity plan (2) to reflect on their feelings after a day that had involved some activity, (3) to weigh themselves to keep track of their own weight as an indication of their long-term health and fitness. It also provided weather reports and recommendations for local events.	Interviews every 10 days (3 per P in total) Content analysis of the interview material	6 50 – 76 (no mean) 66.7 % F Healthy, not known conditions which placed restrictions on exercise	Themes which emerged from the analysis included: (1) utilitarian factors – usefulness, ease of use, adaptability and intelligence. Only on the third interview did Ps find the robot was useful. Adaptability was considered important. By the third interview Ps thought that robot had some form of intelligence. (2) Hedonic factors – enjoyment, attractiveness, anthropomorphism, sociability, and companionship. Some Ps enjoyed having the robot, some did not. Some Ps thought the robot looked attractive, some

Authors **Date** **Location**	**Study design**	**Measures**	**Participants (Ps)** **Number** **Ages** **Gender** **Other criteria**	**Key Results**
				were unconcerned about appearance. Some participants began to think of the robot as a person, others thought of it as a real rabbit. Sociability – Ps thought the robot would behave more realistically and be more social. All participants spoke to the robot and talked to it more as the study progressed Companionship – most Ps saw the robot as a companion, or its potential for companionship. (3) Usage context – social influence, privacy, trust, control. Social influence – most Ps mentioned other people's opinions of the robot. Privacy and trust – Ps were concerned about the privacy and trust involved in the interactions with the robot.

Authors Date Location	Study design	Measures	Participants (Ps) Number Ages Gender Other criteria	Key Results
				(4) Continued use. Only 2 Ps could imagine having the robot in the future.
Gross et al. 2015 Germany	SCITOS G3 robot was deployed in Ps apartments for up to three days. Ps were instructed to freely use the robot as they wished, while sticking to their usual routines. The robot provided cognitive support – reminders, calendar management, communication support – making video calls, exercise support, health support – vital signs monitoring, fall detection.	Log data of use. Ps were asked to complete a short questionnaire after the first use of each function. Interview at the end of the study.	9 68 – 92 (mean: 80.9) 66.7 % F	Positive ratings of usability and enjoyment, but limited usefulness due to the restricted functionality. 8 of the 9 Ps reported strong intentions to use a health robot in the future. Ps felt safe, but kept an eye on the robot to prevent it from undertaking unwanted activities, and were hesitant to leave it alone in their apartment. All but one P treated the robot as a social being, when interacting with it or talking about it, although they were well aware it was not alive. All but one P named the robot. They felt it helped with feelings of loneliness and boredom.

Authors Date Location	Study design	Measures	Participants (Ps) Number Ages Gender Other criteria	Key Results
Zsiga et al. 2018 Hungary	Study took place in Ps homes (without any modification) for approximately three months (average 94.9 day). Kompaï humanoid robot with voice and touchscreen interface provided a range of services: cognitive and memory assistance (such as agenda, medication reminder, and shopping list management), safety- and health-related functions (emergency signal, health check report, blood pressure, and body weight measurement), information inquiry services (weather forecast, time, date), communication services (Skype, email), speech recognition and synthesis, entertainment	Log files of use of robot.	8 70 – 83 (mean: 77.125) 75 % F Living alone, able to move indoors without assistance, able to communicate with the robot by voice and touch	The most useful and the least reliable robot functions according to the users were the navigation and the verbal communication. Entertainment, locomotion, and weather forecast were the most frequently used functions, while the shopping list was the least popular. The companion robot used in the test was accepted enthusiastically by the senior subjects. Specific robot functions (mainly navigation in the apartment and the speech recognition) require improvement to better accommodate real circumstances.

Authors **Date** **Location**	**Study design**	**Measures**	**Participants (Ps)** **Number** **Ages** **Gender** **Other criteria**	**Key Results**
	opportunities (web-browser, games), and some essential robotic functions (navigation in the apartment including obstacle detection and avoidance, automatic docking to the charger, carrying small objects on a tray).			
Portugal et al. 2019 Netherlands	Bespoke robot (SocialRobot, nearly human height, animated head, no arms, touchscreen and voice interface) was deployed in the public areas of a care centre for older people for one week. Approached people, initiated interaction, offered a small range of services (e.g. taking a photo, making a Skype call, showing person's appointments). People who interacted with the robot were given a questionnaire to complete.	Short questionnaire covering usability, appearance and satisfaction with the robot. Likert items with ratings from 1 to 10. Plus 3 open-ended questions.	Approximately 100 people interacted with the robot, 30 completed a questionnaire. No demographic data were collected, not all Ps were older people.	Ps found the robot useful, friendly, safe, fun and non-invasive and believe that the robot could help them to become more active thus becoming more sociable. Ps assigned an average score of 8.07 to the performance of the robot during the demo and found the robot easy and simple to use, and it made them feel happier and less concerned.

Authors Date Location	Study design	Measures	Participants (Ps) Number Ages Gender Other criteria	Key Results
				They found the robot intelligent as well as respectful of their wishes. Ps felt that the robot was more machine-like than human-like, however this did not affect the likeability of the robot. The animacy of the robot was rated low, means that Ps did not consider the robot particularly lively, finding it somewhat stagnant.
Pripfl et al. 2016 also discussed in: Bajones et al. 2019 Austria Greece Sweden	Study took place in Ps own home for approximately 21 days. Hobbit robot could perform a number of tasks: Help support Safety check Pick up/bring objects Reminders Exercises Two modes of using the robot were studied: device-like (first 11 days of study) and companion (second 10	Questionnaires: Falls efficacy scale (Yardley et al. 2005) Self-efficacy scale (Schwarzer and Jerusalem 1995) NARS Self-developed items on emotional attachment and perceived reciprocity Interviews on Day 11, at end of study and one week post study. Log of use of the robot.	16 (Austria: 7; Greece: 4; Sweden: 7). 75 – 89 (mean: 79.75) 87.5 % F Living alone in own home Possibly receiving home care Possible impairments but sufficient mental capacity to understand the project	All Ps interacted with Hobbit daily, rated most functions as well working, and reported that they believe that Hobbit will be part of future elderly care. Hobbit's adaptive behaviour approach towards Ps increasingly eased the interaction between the users and the robot.

Authors Date Location	Study design	Measures	Participants (Ps) Number Ages Gender Other criteria	Key Results
	day) – participants were not informed of the change.			
Ruf, Lehmann, and Misoch 2020 Switzerland	Study took place in Ps own homes, after a briefing and training session at the study centre. NAO robot presented 6 exercises, taking 36 minutes to complete. Control conditions were a booklet or a video presentation of the exercises. Ps were asked to complete the exercises 3 times during a one-week period in each condition.	Questionnaire covering: Regularity of exercise during the study Difficulties with the system. Fun Motivation Operation Own experience Recommendations Interviews at the end of the study.	7 67 – 84 (mean: 74) 28.6 % F No physical or cognitive restrictions	Ps enjoyed the robot, but some technical difficulties such as slowness, communication, face recognition, stability, and acoustic problems occurred. Ps experienced the robot as motivating, but they expected habituation effects.

Authors **Date** **Location**	**Study design**	**Measures**	**Participants (Ps)** **Number** **Ages** **Gender** **Other criteria**	**Key Results**
Tkatch et al. 2021 USA	Ps received robotic pet of their choice (cat or dog), only instructions to treat it like a pet. Follow up with voice reminders twice a week for first month to interact with the robot. Questionnaires when receiving the robot, one month and two months after receiving the robot.	10-item version UCLA Loneliness Scale (Russell 1996) 12 item Quality of Life questionnaire Brief Resilience Scale (BRS) (Smith et al. 2008) Meaning and Purpose Scale Age 18 (Hedberg, Gustafson, and Brulin 2010) Life Orientation Test-Revised (LOT-R) (Herzberg, Glaesmer, and Hoyer 2006).	125 65 – over 85 (no mean) 56.8 % F Screened as being lonely, not currently owning a live pet	At the end of the study, Ps loneliness had decreased, while mental wellbeing, resilience, and purpose in life improved. Frequent interactions with the pets were associated with greater improvement in mental well-being and optimism.

Seven of these studies deployed the robots in the homes of the older people, one (Stafford et al. 2014a) deployed the robot in the older participants' apartment for 30 minutes a day if they wished, and participants could also use the robot in the public foyer of their apartment building during a three-hour period each day. The final study (Portugal et al. 2019) was rather different in that it deployed a robot in the public spaces of a care centre for older people which many people visit during the day. In this very interesting study, the robot moved around and *looked for* people to interact with (not all of whom would have been older people, but many would have been). The researchers estimated that the robot interacted with approximately 100 people over a five-day period. Wherever possible, the researchers gave people a questionnaire to complete after such an interaction and 30 were returned. As with the other sets of studies, there was a good range of ages of older people (19 being a slight exception, with rather young participants from 50 to 76 years) and a bias towards women participants (on average 67% women participants). For the studies in older people's homes, the robots were deployed for between 3 days and 3 months, an average of just over one month (33 days). In four of the studies, the robot stayed with the participant continuously for at least three weeks (Bajones et al. 2019; Graaf, Allouch, and Klamer 2015; Pripfl et al. 2016; Tkatch et al. 2021; Zsiga et al. 2018), giving the older people a very in-depth experience of having a personal robot in their home.

In general, the results from these longer-term studies were very positive, with participants finding the robots easy to use and having positive attitudes towards them. Interestingly, two studies (Bajones et al. 2019; Pripfl et al. 2016; Stafford et al. 2014a) found that the more/longer participants interacting with the robot, the more positive they became, a very encouraging sign. Only one study (Graaf, Allouch, and Klamer 2015) had quite negative results, with the small number of participants rather split in their attitude to the Nabaztag robot. At the end of the study, only two of the six participants could imagine using the robot in the future.

5 Conclusions

This chapter has reviewed some of the research on personal robots for older people. There is now an impressive body of research on this topic, in many cultural contexts, using a range of methodologies and theoretical approaches. The sample sizes in studies are often impressive, although often with a bias towards women participants (which does reflect the demographic makeup of the age group). There have been criticisms in the past that research in this area has been methodologically weak and that the views of older people are not taken into account (Frennert and Östlund 2014). The impression gained from reviewing the past decade of research is that both these criticisms are less valid now. Many of the studies reviewed employed appropriate methodologies and researchers are listening to participants and noting their views.

The review highlights a number of weaknesses which need to be considered in future research. There have been surprisingly few studies which have investigated what older people actually want from robots in terms of support. Too often, researchers appear to have an idea which they then present to older people for evaluation. This type of study may be open to socially desirable responses, as older people do not wish to offend keen young researchers who have come up with an idea for a robot. There are methods for avoiding this problem, for example by the evaluation being conducted by a different team to the development and explaining that to participants. There may be problems with asking older people about what they want from technologies of which they have no experience. Nonetheless, it is important that more studies explore actual needs and wishes of older people in a wide range of cultural contexts. Researchers could use low fidelity prototypes of ideas for robots to explore possible functions and aspects of the robot form and interaction style with older people. This type of study is uncommon in robotics research.

Another weakness highlighted by this review is perhaps inevitable. Some studies have taken a holistic approach, investigating reactions to a complete robot, which may provide a specific service or a range of services. Other studies have investigated very particular aspects of how a robot should look or how it should interact with an older person. Both types of studies are valid and necessary, but many more studies of both kinds are needed. This is a perennial problem in research on human-technology interaction, there are many aspects to be investigated – a holistic approach is appropriate, but it can be difficult to identify the sources of problems in a complex system, so studies of individual aspects are also needed, but there are very many of them.

There is also only a small body of research on the long-term use of robots by older people in their homes. This is not surprising, as deploying reliable working robots with sufficient functionality in private homes is very time-consuming and costly research. The studies which have been conducted, particularly those of the Hobbit robot (Frennert and Östlund 2014; Pripfl et al. 2016) and the Kompaï robot (Zsiga et al. 2018) are substantial in what they have achieved. There are many studies which stop at the point of measuring intention to use a robot and do not investigate the relationship between intention to use and actual use. We definitely need a body of studies exploring actual use. Hopefully, further studies about actual long-term use are in the pipeline. Overall, a growing and important body of research knowledge is developing about how we can best support coming generations of older people with personal robots in ways that they find useful and usable and therefore they will use them happily.

References

Abdi, Jordan, Ahmed Al-Hindawi, Tiffany Ng, and Marcela P. Vizcaychipi. 2018. "Scoping Review on the Use of Socially Assistive Robot Technology in Elderly Care." *BMJ open* 8 (2): e018815. https://doi.org/10.1136/bmjopen-2017-018815.

Ambient Assisted Living Association. n. d. "Aging Well in the Digital World." http://www.aal-europe.eu/.

Avioz-Sarig, Omri, Samuel Olatunji, Vardit Sarne-Fleischmann, and Yael Edan. 2021. "Robotic System for Physical Training of Older Adults." *International journal of social robotics* 13 (5): 1109–24. https://doi.org/10.1007/s12369-020-00697-y.

Backonja, Uba, Amanda K. Hall, Ian Painter, Laura Kneale, Amanda Lazar, Maya Cakmak, Hilaire J. Thompson, and George Demiris. 2018. "Comfort and Attitudes Towards Robots Among Young, Middle-Aged, and Older Adults: A Cross-Sectional Study." *Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing* 50 (6): 623–33. https://doi.org/10.1111/jnu.12430.

Bajones, Markus, David Fischinger, Astrid Weiss, Paloma De La Puente, Daniel Wolf, Markus Vincze, Tobias Körtner et al. 2019. "Results of Field Trials with a Mobile Service Robot for Older Adults in 16 Private Households." *ACM Transactions on Human-Robot Interaction* 9 (2): 1–27. https://doi.org/10.1145/3368554.

Bartneck, Christoph. 2023. "Godspeed Questionnaire Series: Translations and Usage." In *International Handbook of Behavioral Health Assessment*, edited by Christian U. Krägeloh, Mohsen Alyami, and Oleg N. Medvedev, 1–35. Cham: Springer International Publishing.

Bartneck, Christoph, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. 2009. "Measurement Instruments for the Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety of Robots." *International journal of social robotics* 1 (1): 71–81. https://doi.org/10.1007/s12369-008-0001-3.

Biswas, Mriganka, Marta Romeo, Angelo Cangelosi, and Ray Jones. 2020. "Are Older People Any Different from Younger People in the Way They Want to Interact with Robots? Scenario Based Survey." *Journal on Multimodal User Interfaces* 14 (1): 61–72. https://doi.org/10.1007/s12193-019-00306-x.

Boumans, Roel, Fokke van Meulen, Koen Hindriks, Mark Neerincx, and Marcel Olde Rikkert. 2018. "Proof of Concept of a Social Robot for Patient Reported Outcome

Measurements in Elderly Persons." In *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, edited by Takayuki Kanda, Selma Ŝabanović, Guy Hoffman, and Adriana Tapus, 73–74. New York, NY, USA: ACM.

Boumans, Roel, Fokke van Meulen, Koen Hindriks, Mark Neerincx, and Marcel Olde Rikkert. 2020. "A Feasibility Study of a Social Robot Collecting Patient Reported Outcome Measurements from Older Adults." *International journal of social robotics* 12 (1): 259–66. https://doi.org/10.1007/s12369-019-00561-8.

Broadbent, Elizabeth, I. Han Kuo, Yong in Lee, Joel Rabindran, Ngaire Kerse, Rebecca Stafford, and Bruce MacDonald. 2010. "Attitudes and Reactions to a Healthcare Robot." *Telemedicine journal and e-health : the official journal of the American Telemedicine Association* 16 (5): 608–13. https://doi.org/10.1089/tmj.2009.0171.

Brooke, John. 1996. "SUS: A 'Quick and Dirty' Usability Scale." In *Usability Evaluation in Industry*, edited by Patrick W. Jordan, B. Thomas, Ian L. McClelland, and Bernard Weerdmeester, 207–12: CRC Press.

Central Intelligence Agency. 2021. "The World Factbook." https://www.cia.gov/the-world-factbook/about/archives/2021.

Chang, Wan-Ling, Selma Ŝabanović, and Lesa Huber. 2014. "Observational Study of Naturalistic Interactions with the Socially Assistive Robot PARO in a Nursing Home." In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication*, 294–99: IEEE.

Chen, Tiffany L., Tapomayukh Bhattacharjee, Jenay M. Beer, Lena H. Ting, Madeleine E. Hackney, Wendy Rogers, and Charles C. Kemp. 2017. "Older Adults' Acceptance of a Robot for Partner Dance-Based Exercise." *PloS one* 12 (10): e0182736. https://doi.org/10.1371/journal.pone.0182736.

Christensen, Henrik, Nancy Amato, Holly Yanco, Maja Mataric, Howie Choset, Ann Drobnis, Ken Goldberg et al. 2021. "A Roadmap for US Robotics – from Internet to Robotics 2020 Edition." *Foundations and Trends® in Robotics* 8 (4): 307–424. https://doi.org/10.1561/2300000066.

Conti, Daniela, Santo Di Nuovo, and Alessandro Di Nuovo. 2021. "A Brief Review of Robotics Technologies to Support Social Interventions for Older Users." In *Human Centred Intelligent Systems*. Vol. 189, edited by Alfred Zimmermann, Robert J. Howlett, and Lakhmi C. Jain, 221–32. Smart Innovation, Systems and Technologies. Singapore: Springer Singapore.

Di Nuovo, Alessandro, Frank Broz, Ning Wang, Tony Belpaeme, Angelo Cangelosi, Ray Jones, Raffaele Esposito, Filippo Cavallo, and Paolo Dario. 2018. "The Multi-Modal Interface of Robot-Era Multi-Robot Services Tailored for the Elderly." *Intelligent Service Robotics* 11 (1): 109–26. https://doi.org/10.1007/s11370-017-0237-6.

Dix, Alan. 2008. "Tales From/for Berlin - Appropriation, Adaption and Physicality." https://alandix.com/blog/2008/03/02/tales-fromfor-berlin-appropriation-adoption-and-physicality/.

European Commission. 2023. "Rolling Plan for ICT Standardisation: Robotics and Autonomous Systems." https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/robotics-and-autonomous-systems-rp-2023.

Fischinger, David, Peter Einramhof, Konstantinos Papoutsakis, Walter Wohlkinger, Peter Mayer, Paul Panek, Stefan Hofmann et al. 2016. "Hobbit, a Care Robot Supporting Independent Living at Home: First Prototype and Lessons Learned." *Robotics and Autonomous Systems* 75:60–78. https://doi.org/10.1016/j.robot.2014.09.029.

Frennert, Susanne, and Britt Östlund. 2014. "Review: Seven Matters of Concern of Social Robots and Older People." *International journal of social robotics* 6 (2): 299–310. https://doi.org/10.1007/s12369-013-0225-8.

Frennert, Susanne, and Britt Östlund. 2020. "How Do Older People Think and Feel About Robots in Health- and Elderly Care?" In *Inclusive Robotics for a Better Society*. Vol. 25, edited by José L. Pons, 167–74. Biosystems & Biorobotics. Cham: Springer International Publishing.

Gonyea, Judith G., and Kathy Burnes. 2013. "Aging Well at Home: Evaluation of a Neighborhood-Based Pilot Project to "Put Connection Back into Community"." *Journal of Housing For the Elderly* 27 (4): 333–47. https://doi.org/10.1080/02763893.2013.813425.

Graaf, Maartje M.A. de, Somaya Ben Allouch, and Tineke Klamer. 2015. "Sharing a Life with Harvey: Exploring the Acceptance of and Relationship-Building with a Social Robot." *Computers in Human Behavior* 43:1–14. https://doi.org/10.1016/j.chb.2014.10.030.

Gray, Heather M., Kurt Gray, and Daniel M. Wegner. 2007. "Dimensions of Mind Perception." *Science* 315 (5812): 619. https://doi.org/10.1126/science.1134475.

Gross, Horst-Michael, Steffen Müller, Christof Schroeter, Michael Volkhardt, Andrea Scheidig, Klaus Debes, Katja Richter, and Nicola Doering. 2015. "Robot Companion for Domestic Health Assistance: Implementation, Test and Case Study Under Everyday Conditions in Private Apartments." In *2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 5992–99: IEEE.

Guerra, Sara, Catarina Rosa, Liliana Sousa, António Neves, Gabriel Pestana, Maria José Hernández, Raquel Losada, Susana Pires, and Oscar Ribeiro. 2022. "The Use of Robotic Pets by Community-Dwelling Older Adults: A Scoping Review." *International journal of social robotics* 14 (6): 1481–92. https://doi.org/10.1007/s12369-022-00892-z.

Haase, Kristen R., Theodore Cosco, Lucy Kervin, Indira Riadi, and Megan E. O'Connell. 2021. "Older Adults' Experiences with Using Technology for Socialization During the COVID-19 Pandemic: Cross-Sectional Survey Study." *JMIR aging* 4 (2): e28010. https://doi.org/10.2196/28010.

Hall, Amanda K., Uba Backonja, Ian Painter, Maya Cakmak, Minjung Sung, Timothy Lau, Hilaire J. Thompson, and George Demiris. 2019. "Acceptance and Perceived Usefulness of Robots to Assist with Activities of Daily Living and Healthcare Tasks." *Assistive technology* 31 (3): 133–40. https://doi.org/10.1080/10400435.2017.1396565.

Hart, Sandra G., and Lowell E. Staveland. 1988. "Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research." *Advances in Psychology* 52:139–83. https://doi.org/10.1016/S0166-4115(08)62386-9.

Hebesberger, Denise, Tobias Körtner, Christoph Gisinger, Jürgen Pripfl, and Christian Dondrup. 2016. "Lessons Learned from the Deployment of a Long-Term Autonomous Robot as Companion in Physical Therapy for Older Adults with Dementia a Mixed Methods Study." 2016, 27–34.

Hedberg, Pia, Yngve Gustafson, and Christine Brulin. 2010. "Purpose in Life Among Men and Women Aged 85 Years and Older." *International journal of aging & human development* 70 (3): 213–29. https://doi.org/10.2190/ag.70.3.c.

Heerink, Marcel, Ben Kröse, Vanessa Evers, and Bob Wielinga. 2008. "The Influence of Social Presence on Acceptance of a Companion Robot by Older People." *Journal of Physical Agents* 2 (2): 33–40. https://doi.org/10.14198/JoPha.2008.2.2.05.

Heerink, Marcel, Ben Kröse, Vanessa Evers, and Bob Wielinga. 2009. "Measuring Acceptance of an Assistive Social Robot: A Suggested Toolkit." In *RO-MAN 2009 - the 18th IEEE International Symposium on Robot and Human Interactive Communication*, 528–33: IEEE.

Heerink, Marcel, Ben Kröse, Vanessa Evers, and Bob Wielinga. 2010. "Assessing Acceptance of Assistive Social Agent Technology by Older Adults: The Almere Model." *International journal of social robotics* 2 (4): 361–75. https://doi.org/10.1007/s12369-010-0068-5.

Herzberg, Philipp Yorck, Heide Glaesmer, and Jürgen Hoyer. 2006. "Separating Optimism and Pessimism: A Robust Psychometric Analysis of the Revised Life Orientation Test (LOT-R)." *Psychological assessment* 18 (4): 433–38. https://doi.org/10.1037/1040-3590.18.4.433.

Ilinca, Stefania, Kai Leichsenring, and Ricardo Rodrigues. 2015. "From Care in Homes to Care at Home: European Experiences with (De)Institutionalisation in Long-Term Care: Policy Brief 12/2015." https://www.euro.centre.org/publications/detail/420.

International Organization for Standardization. 2019. "Ergonomics of Human-System Interaction. Part 210: Human-Centred Design for Interactive Systems." https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-2:v1:en.

Kachouie, Reza, Sima Sedighadeli, Rajiv Khosla, and Mei-Tai Chu. 2014. "Socially Assistive Robots in Elderly Care: A Mixed-Method Systematic Literature Review." *International Journal of Human-Computer Interaction* 30 (5): 369–93. https://doi.org/10.1080/10447318.2013.873278.

Karunarathne, Deneth, Yoichi Morales, Tatsuya Nomura, Takayuki Kanda, and Hiroshi Ishiguro. 2019. "Will Older Adults Accept a Humanoid Robot as a Walking Partner?" *International journal of social robotics* 11 (2): 343–58. https://doi.org/10.1007/s12369-018-0503-6.

Körtner, Tobias, Alexandra Schmid, Daliah Batko-Klein, and Christoph Gisinger. 2014. "Meeting Requirements of Older Users? Robot Prototype Trials in a Home-Like Environment." In *Universal Access in Human-Computer Interaction. Aging and Assistive Environments*. Vol. 8515, edited by Constantine Stephanidis and Margherita Antona, 660–71. Lecture Notes in Computer Science. Cham: Springer International Publishing.

Kydd, Angela, Anne Fleming, Isabella Paoletti, and Simona Hvalič Touzery. 2020. "Exploring Terms Used for the Oldest Old in the Gerontological Literature." *The Journal of Aging and Social Change* 10 (2): 53–73. https://doi.org/10.18848/2576-5310/CGP/v10i02/53-73.

Lazar, Amanda, Hilaire J. Thompson, Anne Marie Piper, and George Demiris. 2016. "Rethinking the Design of Robotic Pets for Older Adults." In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, edited by Marcus Foth, Wendy Ju, Ronald Schroeter, and Stephen Viller, 1034–46. New York, NY, USA: ACM.

Lee, Younghwa, Kenneth A. Kozar, and Kai R.T. Larsen. 2003. "The Technology Acceptance Model: Past, Present, and Future." *Communications of the Association for Information Systems* 12. https://doi.org/10.17705/1CAIS.01250.

Lehmann, Stephanie, Esther Ruf, and Sabina Misoch. 2020. "Emotions and Attitudes of Older Adults Toward Robots of Different Appearances and in Different Situations." In Ziefle, Guldemond, and Maciaszek 2020, 21–43.

Lehoux, Pascale, and Daniela Grimard. 2018. "When Robots Care: Public Deliberations on How Technology and Humans May Support Independent Living for Older Adults." *Social science & medicine* 211:330–37. https://doi.org/10.1016/j.socscimed.2018.06.038.

Leong, Tuck W., and Benjamin Johnston. 2016. "Co-Design and Robots: A Case Study of a Robot Dog for Aging People." In *Social Robotics*. Vol. 9979, edited by Arvin Agah, John-John Cabibihan, Ayanna M. Howard, Miguel A. Salichs, and Hongsheng He, 702–11. Lecture Notes in Computer Science. Cham: Springer International Publishing.

Liu, Sunny Xun, Qi Shen, and Jeff Hancock. 2021. "Can a Social Robot Be Too Warm or Too Competent? Older Chinese Adults' Perceptions of Social Robots and Vulnerabilities." *Computers in Human Behavior* 125:106942. https://doi.org/10.1016/j.chb.2021.106942.

Louie, Wing-Yue Geoffrey, Derek McColl, and Goldie Nejat. 2014. "Acceptance and Attitudes Toward a Human-Like Socially Assistive Robot by Older Adults." *Assistive technology* 26 (3): 140–50. https://doi.org/10.1080/10400435.2013.869703.

Lugrin, Birgit, Astrid Rosenthal-von der Pütten, and Svenja Hahn. 2019. "Identifying Social Context Factors Relevant for a Robotic Elderly Assistant." In *Social Robotics*. Vol. 11876, edited by Miguel A. Salichs, Shuzhi S. Ge, Emilia I. Barakova, John-John Cabibihan, Alan R. Wagner, Álvaro Castro-González, and Hongsheng He, 558–67. Lecture Notes in Computer Science. Cham: Springer International Publishing.

Marek, Karen Dorman, Frank Stetzer, Scott J. Adams, Lori L. Popejoy, and Marilyn Rantz. 2012. "Aging in Place Versus Nursing Home Care: Comparison of Costs to Medicare and Medicaid." *Research in gerontological nursing* 5 (2): 123–29. https://doi.org/10.3928/19404921-20110802-01.

McGlynn, Sean A., Shawn Kemple, Tracy L. Mitzner, Chih-Hung King, and Wendy Rogers. 2014. "Understanding Older Adults' Perceptions of Usefulness for the Paro Robot." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 58 (1): 1914–18. https://doi.org/10.1177/1541931214581400.

McGlynn, Sean A., Shawn Kemple, Tracy L. Mitzner, Chih-Hung King, and Wendy Rogers. 2017. "Understanding the Potential of PARO for Healthy Older Adults." *International journal of human-computer studies* 100:33–47. https://doi.org/10.1016/j.ijhcs.2016.12.004.

Monekosso, Dorothy N., Francisco Florez-Revuelta, and Paolo Remagnino. 2015. "Guest Editorial Special Issue on Ambient-Assisted Living: Sensors, Methods, and Applications." *IEEE Trans. Human-Mach. Syst.* 45 (5): 545–49. https://doi.org/10.1109/THMS.2015.2458019.

Noguchi, Yohei, Hiroko Kamide, and Fumihide Tanaka. 2020. "Personality Traits for a Social Mediator Robot Encouraging Elderly Self-Disclosure on Loss Experiences." *ACM Transactions on Human-Robot Interaction* 9 (3): 1–24. https://doi.org/10.1145/3377342.

Nomura, Tatsuya, Tomohiro Suzuki, Takayuki Kanda, and Kensuke Kato. 2006a. "Measurement of Anxiety Toward Robots." In *ROMAN 2006 - the 15th IEEE International Symposium on Robot and Human Interactive Communication*, 372–77: IEEE.

Nomura, Tatsuya, Tomohiro Suzuki, Takayuki Kanda, and Kensuke Kato. 2006b. "Measurement of Negative Attitudes Toward Robots." *Interaction Studies. Social*

Behaviour and Communication in Biological and Artificial Systems 7 (3): 437–54. https://doi.org/10.1075/is.7.3.14nom.

Olde Keizer, Richelle A. C. M., Lex van Velsen, Mathieu Moncharmont, Brigitte Riche, Nadir Ammour, Susanna Del Signore, Gianluca Zia, Hermie Hermens, and Aurèle N'Dja. 2019. "Using Socially Assistive Robots for Monitoring and Preventing Frailty Among Older Adults: A Study on Usability and User Experience Challenges." *Health and Technology* 9 (4): 595–605. https://doi.org/10.1007/s12553-019-00320-9.

Oshio, Atsushi, Shingo Abe, and Pino Cutrone. 2012. "Development, Reliability, and Validity of the Japanese Version of Ten Item Personality Inventory (TIPI-J)." *The Japanese Journal of Personality* 21 (1): 40–52. https://doi.org/10.2132/personality.21.40.

Park, Yeon-Hwan, Hee Kyung Chang, Min Hye Lee, and Seong Hyeon Lee. 2019. "Community-Dwelling Older Adults' Needs and Acceptance Regarding the Use of Robot Technology to Assist with Daily Living Performance." *BMC geriatrics* 19 (1): 208. https://doi.org/10.1186/s12877-019-1227-7.

Pedersen, Isabel, Samantha Reid, and Kristen Aspevig. 2018. "Developing Social Robots for Aging Populations: A Literature Review of Recent Academic Sources." *Sociology Compass* 12 (6). https://doi.org/10.1111/soc4.12585.

Peng, Xizhe. 2021. "Coping with Population Ageing in Mainland China." *Asian Population Studies* 17 (1): 1–6. https://doi.org/10.1080/17441730.2020.1834197.

Petrie, Helen. 2023. "Talking 'Bout My Generation … or Not?" In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, edited by Albrecht Schmidt, Kaisa Väänänen, Tesh Goyal, Per O. Kristensson, and Anicia Peters, 1–9. New York, NY, USA: ACM.

Petrie, Helen, and Jenny Darzentas. 2017. "Older People and Robotic Technologies in the Home." In *Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments*, 29–36. New York, NY, USA: ACM.

Petrie, Helen, Jenny Darzentas, and Stefan Carmien. 2018. "Intelligent Support Technologies for Older People: An Analysis of Characteristics and Roles." In *Breaking down Barriers*, edited by Pat Langdon, Jonathan Lazar, Ann Heylighen, and Hua Dong, 89–99. Cham: Springer International Publishing.

Portugal, David, Paulo Alvito, Eleni Christodoulou, George Samaras, and Jorge Dias. 2019. "A Study on the Deployment of a Service Robot in an Elderly Care Center." *International journal of social robotics* 11 (2): 317–41. https://doi.org/10.1007/s12369-018-0492-5.

Pripfl, Jürgen, Tobias Körtner, Daliah Batko-Klein, Denise Hebesberger, Markus Weninger, Christoph Gisinger, Susanne Frennert et al. 2016. "Results of a Real World Trial with a Mobile Social Service Robot for Older Adults." 2016, 497–98.

Ratchford, Mark, and Michelle Barnhart. 2012. "Development and Validation of the Technology Adoption Propensity (TAP) Index." *Journal of Business Research* 65 (8): 1209–15. https://doi.org/10.1016/j.jbusres.2011.07.001.

Robinson, Hayley, Bruce MacDonald, and Elizabeth Broadbent. 2014. "The Role of Healthcare Robots for Older People at Home: A Review." *International journal of social robotics* 6 (4): 575–91. https://doi.org/10.1007/s12369-014-0242-2.

Rosnow, Ralph L., and Robert Rosenthal. 2021. *Beginning Behavirol Research: A Conceptual Primer.* 7.th ed. Upper Saddle River: Pearson Prentice Hall.

Ruf, Esther, Stephanie Lehmann, and Sabina Misoch. 2020. "Use of a Socially Assistive Robot to Promote Physical Activity of Older Adults at Home." In Ziefle, Guldemond, and Maciaszek 2020, 78–95.

Russell, Daniel. 1996. "UCLA Loneliness Scale (Version 3): Reliability, Validity, and Factor Structure." *Journal of personality assessment* 66 (1): 20–40. https://doi.org/10.1207/s15327752jpa6601_2.

Sabelli, Alessandra Maria, Takayuki Kanda, and Norihiro Hagita. 2011. "A Conversational Robot in an Elderly Care Center." In *Proceedings of the 6th International Conference on Human-Robot Interaction*, edited by Aude Billard, Peter Kahn, Julie A. Adams, and Greg Trafton, 37–44. New York, NY, USA: ACM.

Samaddar, Sanjit, and Helen Petrie. 2020. "What Do Older People Actually Want from Their Robots?" In *Computers Helping People with Special Needs*. Vol. 12376, edited by Klaus Miesenberger, Roberto Manduchi, Mario Covarrubias Rodriguez, and Petr Peňáz, 19–26. Lecture Notes in Computer Science. Cham: Springer International Publishing.

Schroeter, Christof, Steffen Müller, M. Volkhardt, Erik Einhorn, Claire Huijnen, Herjan van den Heuvel, A. van Berlo, A. Bley, and Horst-Michael Gross. 2013. "Realization and User Evaluation of a Companion Robot for People with Mild Cognitive Impairments." In *2013 IEEE International Conference on Robotics and Automation*, 1153–59: IEEE.

Schulz, Richard, Hans-Werner Wahl, Judith T. Matthews, Annette de Vito Dabbs, Scott R. Beach, and Sara J. Czaja. 2015. "Advancing the Aging and Technology Agenda in Gerontology." *The Gerontologist* 55 (5): 724–34. https://doi.org/10.1093/geront/gnu071.

Schwarzer, Ralf, and Matthias Jerusalem. 1995. "General Self-Efficacy Scale." In *Measures in Health Psychology: A User's Portfolio. Beliefs and Knowledge About Health and Illness*, edited by Stephen Wright, Marie Johnston, and John Weinman: NFER-Nelson.

Sharkey, Amanda, and Noel Sharkey. 2012. "Granny and the Robots: Ethical Issues in Robot Care for the Elderly." *Ethics and Information Technology* 14 (1): 27–40. https://doi.org/10.1007/s10676-010-9234-6.

Shen, Zhuoyu, and Yan Wu. 2016. "Investigation of Practical Use of Humanoid Robots in Elderly Care Centres." In *Proceedings of the Fourth International Conference on Human Agent Interaction*, edited by Wei Y. Yau, Takashi Omori, Giorgio Metta, Hirotaka Osawa, and Shengdong Zhao, 63–66. New York, NY, USA: ACM.

Shibata, Takanori, Yukitaka Kawaguchi, and Kazuyoshi Wada. 2012. "Investigation on People Living with Seal Robot at Home." *International journal of social robotics* 4 (1): 53–63. https://doi.org/10.1007/s12369-011-0111-1.

Shishehgar, Majid, Donald Kerr, and Jacqueline Blake. 2018. "A Systematic Review of Research into How Robotic Technology Can Help Older People." *Smart Health* 7-8:1–18. https://doi.org/10.1016/j.smhl.2018.03.002.

Sixsmith, Andrew, Becky R. Horst, Dorina Simeonov, and Alex Mihailidis. 2022. "Older People's Use of Digital Technology During the COVID-19 Pandemic." *Bulletin of science, technology & society* 42 (1-2): 19–24. https://doi.org/10.1177/02704676221094731.

Sixsmith, Andrew, and Judith Sixsmith. 2008. "Ageing in Place in the United Kingdom." *Ageing International* 32 (3): 219–35. https://doi.org/10.1007/s12126-008-9019-y.

Skirbekk, Vegard, Joseph L. Dieleman, Marcin Stonawski, Krystian Fejkiel, Stefanos Tyrovolas, and Angela Y. Chang. 2022. "The Health-Adjusted Dependency Ratio as a New Global Measure of the Burden of Ageing: A Population-Based Study." *The lancet. Healthy longevity* 3 (5): e332-e338. https://doi.org/10.1016/S2666-7568(22)00075-7.

Smarr, Cory-Ann, Tracy L. Mitzner, Jenay M. Beer, Akanksha Prakash, Tiffany L. Chen, Charles C. Kemp, and Wendy Rogers. 2014. "Domestic Robots for Older Adults: Attitudes, Preferences, and Potential." *International journal of social robotics* 6 (2): 229–47. https://doi.org/10.1007/s12369-013-0220-0.

Smith, Bruce W., Jeanne Dalen, Kathryn Wiggins, Erin Tooley, Paulette Christopher, and Jennifer Bernard. 2008. "The Brief Resilience Scale: Assessing the Ability to Bounce Back." *International journal of behavioral medicine* 15 (3): 194–200. https://doi.org/10.1080/10705500802222972.

Søraa, Roger Andre, Gunhild Tøndel, Mark W. Kharas, and J. Artur Serrano. 2023. "What Do Older Adults Want from Social Robots? A Qualitative Research Approach to Human-Robot Interaction (HRI) Studies." *International journal of social robotics* 15 (3): 411–24. https://doi.org/10.1007/s12369-022-00914-w.

Stafford, Rebecca, Bruce MacDonald, Chandimal Jayawardena, Daniel M. Wegner, and Elizabeth Broadbent. 2014a. "Does the Robot Have a Mind? Mind Perception and Attitudes Towards Robots Predict Use of an Eldercare Robot." *International journal of social robotics* 6 (1): 17–32. https://doi.org/10.1007/s12369-013-0186-y.

Stafford, Rebecca, Bruce MacDonald, Xingyan Li, and Elizabeth Broadbent. 2014b. "Older People's Prior Robot Attitudes Influence Evaluations of a Conversational Robot." *International journal of social robotics* 6 (2): 281–97. https://doi.org/10.1007/s12369-013-0224-9.

Teti, Andrea, Ulrike Grittner, Adelheid Kuhlmey, and Stefan Blüher. 2014. "Residential mobility in old age. Age-appropriate housing as a primary preventive strategy." [Residential mobility in old age. Age-appropriate housing as a primary preventive strategy]. *Zeitschrift fur Gerontologie und Geriatrie* 47 (4): 320–28. https://doi.org/10.1007/s00391-013-0538-0.

Thunberg, Sofia, Maria Arnelid, and Tom Ziemke. 2022. "Older Adults' Perception of the Furhat Robot." In *Proceedings of the 10th International Conference on Human-Agent Interaction*, edited by Christoph Bartneck, Takayuki Kanda, Mohammad Obaid, and Wafa Johal, 4–12. New York, NY, USA: ACM.

Tkatch, Rifky, Lizi Wu, Stephanie MacLeod, Rachel Ungar, Laurie Albright, Daniel Russell, James Murphy, James Schaeffer, and Charlotte S. Yeh. 2021. "Reducing Loneliness and Improving Well-Being Among Older Adults with Animatronic Pets." *Aging & mental health* 25 (7): 1239–45. https://doi.org/10.1080/13607863.2020.1758906.

United Nations. 2022. "World Population Prospects 2022: Summary of Results." https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf.

Vandemeulebroucke, Tijs, Kevin Dzi, and Chris Gastmans. 2021. "Older Adults' Experiences with and Perceptions of the Use of Socially Assistive Robots in Aged Care: A Systematic Review of Quantitative Evidence." *Archives of gerontology and geriatrics* 95:104399. https://doi.org/10.1016/j.archger.2021.104399.

Vasunilashorn, Sarinnapha, Bernard A. Steinman, Phoebe S. Liebig, and Jon Pynoos. 2012. "Aging in Place: Evolution of a Research Topic Whose Time Has Come." *Journal of aging research* 2012:120952. https://doi.org/10.1155/2012/120952.

Venkatesh, Viswanath, Michael Morris, and Fred Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS Quarterly* 27 (3): 425. https://doi.org/10.2307/30036540.

Wada, Kazuyoshi, Takanori Shibata, Tomoko Saito, and Kazuo Tanie. 2002. "Analysis of Factors That Bring Mental Effects to Elderly People in Robot Assisted Activity." In *IEEE/RSJ International Conference on Intelligent Robots and System*, 1152–57: IEEE.

Wada, Kazuyoshi, Takanori Shibata, Tomoko Saito, and Kazuo Tanie. 2003. "Effects of Robot Assisted Activity to Elderly People Who Stay at a Health Service Facility for the Aged." In *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003) (Cat. No.03CH37453)*, 2847–52: IEEE.

Watson, David, Lee Anna. Clark, and Auke Tellegen. 1988. "Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales." *Journal of personality and social psychology* 54 (6): 1063–70. https://doi.org/10.1037//0022-3514.54.6.1063.

Wright, James. 2023. "Inside Japan's Long Experiment in Automating Elder Care: MIT Technology Review." www.technologyreview.com/2023/01/09/1065135/japan-automating-eldercare-robots/.

Yardley, Lucy, Nina Beyer, Klaus Hauer, Gertrudis Kempen, Chantal Piot-Ziegler, and Chris Todd. 2005. "Development and Initial Validation of the Falls Efficacy Scale-International (FES-I)." *Age and ageing* 34 (6): 614–19. https://doi.org/10.1093/ageing/afi196.

Ziefle, Martina, Nick Guldemond, and Leszek A. Maciaszek, eds. 2020. *Information and Communication Technologies for Ageing Well and E-Health.* Communications in Computer and Information Science. Cham: Springer International Publishing.

Zsiga, Katalin, András Tóth, Tamás Pilissy, Orsolya Péter, Zoltán Dénes, and Gábor Fazekas. 2018. "Evaluation of a Companion Robot Based on Field Tests with Single Older Adults in Their Homes." *Assistive technology* 30 (5): 259–66. https://doi.org/10.1080/10400435.2017.1322158.

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