Assistive social robots in elderly care: a review

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J. Broekens, M. Heerink, H. Rosendal. Assistive social robots in elderly care: a review. Gerontechnology 2009; 8(2):94-103; doi: 10.4017/gt.2009.08.02.002.00. Assistive social robots, a particular type of assistive robotics designed for social interaction with humans, could play an important role with respect to the health and psychological well-being of the elderly. **Objectives** Assistive social robots are believed to be useful in eldercare for two reasons, a functional one and an affective one. Such robots are developed to function as an interface for the elderly with digital technology, and to help increase the quality of life of the elderly by providing companionship, respectively. There is a growing attention for these devices in the literature. However, no comprehensive review has yet been performed to investigate the effectiveness of such robots in the care of the elderly. Therefore, we systematically reviewed and analyzed existing literature on the effects of assistive social robots in health care for the elderly. We focused in particular on the companion function. **Data Sources** A systematic search of MEDLINE, CINAHL, PsycINFO, The Cochrane Library databases, IEEE, ACM libraries and finally Google Scholar was performed for records through December 2007 to identify articles of all studies with actual subjects aimed to assess the effects of assistive social robots on the elderly. This search was completed with information derived from personal expertise, contacts and reports. **Study Selection and Data Extraction** Since no randomized controlled trials (RCT)'s have been found within this field of research, all studies reporting effects of assistive robotics in elderly populations were included. Information on study design, interventions, controls, and findings were extracted for each article. In medical journals only a few articles were found, whereas about 50 publications were found in literature on ICT and robotics. **Data Synthesis** The identified studies were all published after 2000 indicating the novelty of this area of research. Most of these publications contain the results of studies that report positive effects of assistive social robots on health and psychological well-being of elders. Solid evidence indicating that these effects can indeed be attributed to the actual assistive social robot, its behavior and its functionality is scarce. **Conclusions** There is some qualitative evidence as well as limited quantitative evidence of the positive effects of assistive social robots with respect to the elderly. The research designs, however, are not robust enough to establish this. Confounding variables often cannot be excluded. This is partly due to the chosen research designs, but also because it is unclear what research methodology is adequate to investigate such effects. Therefore, more work on methods is needed as well as robust, large-scale studies to establish the effects of these devices.

Key words: Assistive robotics, companion robot, Aibo, Paro, Huggable, iCat

Because of the graying of our western population, there is a growing necessity for new technologies that can assist the elderly in their daily living. There are two main arguments for this. First, it is expected that western countries will face a tremendous shortage on staff and qualified healthcare personnel in the near future[1]. Second, people prefer more and more to live in their own homes as long as possible instead of being institutionalized in sheltered homes, or nursery homes when problems related to ageing appear. To address these issues, we not only need sufficient health care personnel, but also the presence and appliance of high-tech devices[2]. ICT-technology and robotics are developing quickly nowadays, resulting in products that have the potential to play an important role in assisting the elderly[3]. In order to use new technology in an effective and efficient way, robust information with respect to their effects is needed, especially when used in health-care.

In this review we focus on health- and psychological well-being-related effects of assistive social robots on the elderly. Robot research in eldercare concerns assistive robots that can be both rehabilitation robots and social robots (*Figure 1*). The first type of research features physical assistive technology that is not primarily communicative and is not meant to be perceived as a social entity. Examples are smart wheelchairs[4], artificial limbs and exoskeletons[5]. The field of social robotics concerns systems that can be perceived as social entities that communicate with the user. Of course there are also projects with social robots aimed at rehabilitation[6] and vice versa.

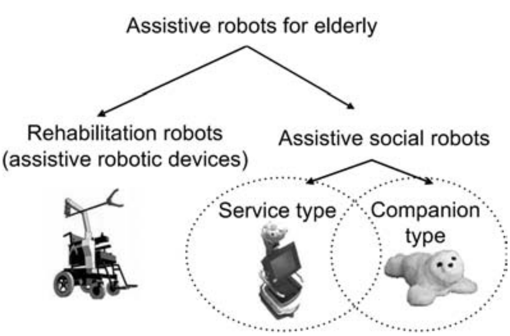

Figure 1. Categorization of assistive robots for elderly

Studies on social robots in eldercare feature different robot types. First, there are robots that are used as assistive devices which we will refer to as service type robots. Functionalities are related to the support of independent living by supporting basic activities (eating, bathing, toileting and getting dressed) and mobility (including navigation), providing household maintenance, monitoring of those who need continuous attention and maintaining safety. Examples of these robots are 'nursebot' Pearl[7], the Dutch iCat (although not especially developed for eldercare) and the German Care-o-bot[8]. Also categorized as such could be the Italian Robocare project, in which a robot is developed as part of an intelligent assistive environment for elderly people[9]. The social functions of such service type robots exist primarily to facilitate interfacing with the robot. Studies typically investigate what different social functions can bring to the acceptance of the device in the living environment of the elder, as well as how social functions can facilitate actual usage of the device.

Second, there are studies that focus on the pet-like companionship a robot might provide. The main function of these robots is to enhance health and psychological well-being of elderly users by providing companionship. We will refer to these robots as *companion type robots*. Examples are the Japanese seal-shaped robot Paro[10], the Huggable[11] (both specifically developed for experiments in eldercare) and Aibo (a robot dog by Sony, see below). Social functions implemented in companion robots are primarily aimed at increasing health and psychological well-being. For example, studies investigate whether companion robots can increase positive mood in elderly living in nursery homes.

However, not all robots can be categorized strictly in either one of these two groups. For example, Aibo is usually applied as a companion type robot, but can also be programmed to perform assistive activities[12] and both Pearl and iCat can provide companionship.

This review aims to provide a first overall overview of studies that investigate the effects of assistive social robots on the health and well-being of the elderly. Since the majority of the assistive social robot studies with actual elderly people as subjects involve the robots Aibo, Paro, iCat and 'nursebot' Pearl, these robots are briefly highlighted next.

Aibo

Aibo is an entertainment robot developed and produced by Sony (*Figure 2a*)[13]. It is currently out of production. It has programmable behavior, a hard plastic exterior and has a wide set of sensors and actuators. Sensors include a camera, touch sensors, infrared and stereo sound. Actuators include four legs, a moveable tail, and a moveable head. Aibo is mobile and autonomous. It can find its power supply by itself and it is programmed to play and interact with humans. It has been used extensively in studies with the elderly in order to try to assess the

Figure 2. Assistive social robots; (a) Aibo, (b) Pearl, (c) Robocare with screen, (d) Robocare without screen, (e) Care-o-bot I, (f) Care-o-bot II, (g) Care-o-bot III, (h) Homie, (i) iCat, (j) Paro and (k) Huggable

effects on the quality of life and symptoms of stress. In this article we will review these studies.

Paro

Paro is a soft seal robot (*Figure 2j*)[10,14]. It has been developed by the Intelligent Systems Research Institute (ISRI) of the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, and is produced by Intelligent System Co. Ltd. It is developed to study the effects of Animal Assistive Therapy with companion robots, and is targeted at the elderly. It has programmable behavior as well as a set of sensors. Sensors include a touch sensor over the complete body, an infrared sensor, stereoscopic vision and hearing. Actuators include eyelids, upper body motors, front paw and hind limb motors. Paro is not mobile. It has been used extensively in studies with the elderly to assess the effects of robot therapy.

iCat

The iCat has been developed and is produced by Philips Electronics (*Figure 2i*)[15]. Its design aim is to be a research platform for human-robot interaction. It is made of hard plastic and has a cat-like appearance. Furthermore, it has a face that is able to express emotions. Studies typically investigate how users perceive the iCat as interface to new technology. The iCat is not particularly aimed at being a companion (i.e., affective assistance) but more at functional assistance (classified as service type). However, it is included in this study as some studies involving the elderly typically measure acceptance under the influence of different social iCat behaviors. Therefore the iCat strongly relates to social interaction between the elderly and robots as well.

Pearl

Of the four most-cited and studied robots, Pearl is targeted most heavily on functional assistance. Pearl is the second generation of nursebots developed by Carnegie Mellon University (*Figure 2b*)[7,16]. It is a mobile robot that can help the elderly to navigate through the nursing facility. It does have a user-friendly interface with a face, and can also provide advice and cognitive support for the elderly.

Other eldercare robots that have only briefly been included in this review are the Care-o-bot (*Figure 2e*)[8] and Robocare (*Figure 2c*)[9]. Their effects have been measured, but not directly related to health or psychological well-being. Finally, for the Huggable (*Figure 2k*)[11], a good example of a companion robot, we did not find any publications on user studies at the time of collecting the data for the review. Many of the health- and psychological well-being-related effects on the elderly have been found in studies with the four devices described above (*Table 1*).

Methodology

The data collection process consisted of three steps (*Figure 3*). First, a systematic search of MEDLINE, CINAHL, PsycINFO, The Cochrane Library databases, IEEE, ACM libraries and finally Google Scholar was performed for records through December 2007 to identify articles of all studies with actual subjects aimed to assess the effects of assistive social robots on the elderly. These databases were searched using the following search terms: Companion robot, Aibo, Paro, iCat, Pearl, nursebot, Care-o-bot, Homie, Huggable and Robocare combined in all possible ways with elderly, assistive robotics, health care or health and care. This particular use of search terms ensured that no study involving companion robots and elderly was missed. Further, our use of particular robot names in combination with their use in the area of health care ensured that we also included all studies with robots that are often used as companion robot, but that do not employ this exact term in the article. The search was restricted to publications in English, with no limitations on dates of publication or venue. All three researchers independently screened the initial set of results. Studies were selected for inclusion if they actually reported studies that related assistive social robotics to elderly people. This first step in the data collection process resulted in an initial list of 229 studies (*Figure 3a*).

Second, this list of potentially relevant full-text articles was reviewed by all three of the reviewers separately according to the main criterion for this review: the publication delivers empirical data on the effects of assistive robotics in health care for the elderly. Key criterion for inclusion was that the study involved real elderly subjects. Since this is a relatively new field, we preferred a complete overview of the field and therefore included all study-designs in this review. This selection process resulted in a list of 68 studies (*Figure 3b*).

Third, disagreements about the inclusion of articles were resolved in a face to face discussion and a study was included in the final list of to be reviewed publications (*Figure 3c*) if two out of three researchers agreed to include it.

Subsequently, the final set of 43 studies were reviewed with respect to the robustness of evidence, the chosen study design, the number of patients involved, the outcome measures, the period of follow-up, and the results.

Results

In total, 43 citations were included in our review (*Table 1*). For each study, we report on research design, type of assistive social robot, main outcome measures used in the study to measure the effects of the intervention, number of participants in the study, whether or not the results were positive, negative or mixed and the time period the study spanned. We also included our main observations.

A variety of effects or functions of assistive social robots have been studied, including (i) increased health by decreased level of stress, (ii) more positive mood, (iii) decreased loneliness, (iv) increased communication activity with others, and (v) rethinking the past. Most studies report positive effects (*Table 1*). With regards to mood, companion robots are reported to increase positive mood, typically measured using evaluation of facial expressions of elderly people as well as questionnaires. Further, elderly people are reported to become less lonely with the intervention of companion robots as measured with loneliness measurement scales. With regards to health status, companion robots are reported to alleviate stress (for instance, measured by stress hormones in urine) and increase immune system response. Some studies report a decrease on existing dementia measurement scales. One study explicitly reports that a companion robot (the My Real Baby in this case) elicited memories about the past. Many studies report positive findings with regards to social ties between the elderly in homes (measured by the frequency of contact between the elderly) as well as between the elderly and family. Typically, the companion is the topic of conversation.

With regards to the perception of the companion robot, narrative records present in a large portion of these studies show that most elderly actually report liking the robots (or their controls, such as a pet toy).

Four patterns emerge that limit the strength of the evidence for the positive effects reported. The first pattern is that the majority of studies are with the Aibo and Paro companion robots. This means that little has been published on experimentation with different forms of assistive social robots. This is interesting, as it has been concluded that form and material does matter a lot to the acceptance and effects of assistive social robots[23,42].

Second, the majority of the studies are done in Japan. As it has been shown that robot perception is culturally de-

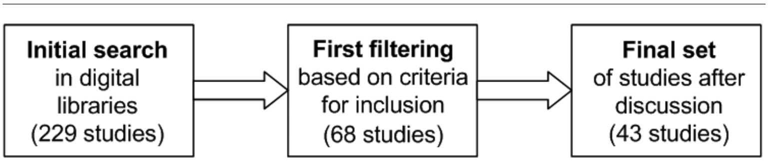

Figure 3. Flow diagram outlining the review process

Table 1. Companion robot studies assessed; ?=unknown / not reported; ***Design****: 1=RCT, 2=Comparative cohort, 3= Case series, 4=Narrative/opinion, 5=Other, 6=Focus group;* ***Outcome****: 1=Health status, 2=Mood, 3=Communication, 4=Loneliness, 5=Other / design criteria, 6=Rethinking the past;* ***Result****: +=positive, ±=undetermined, -=no effect,* ***Ref****: Reference*

Companion	n	Design	Outcome	Result	Term	Ref	Remarks
Aibo	?	3	3	±	5 min	19	Both Aibo and toy-dog increased activity in demented patients; Aibo not perceived as puppy-dog
	46	3	5	+	several hrs	29	Study in clinic waiting room; exact measure unclear from abstract
	?	?	?	?	?	30	Overview article
	3	3	1,5	+	20x	31	20 sessions; decreased stress and loneliness; confounding factors not clear
	5	3	1,3,4,5	+	20x in 7 wks	32	20 sessions; confounding factors not clear
	10,12	6	5	?	?	33	Finding companion robot design criteria
	23	3	1	+	2 months	34	Positive immune system response; Aibo use unclear; causality not attributable
	8	3	3,5	+	30 min	35	No control; no statistics
	15	3?	1	+	?	36	No control; study design unclear
Aibo, My real baby	2	3	5,6	+	several months	37	Robot pet acceptance depends on form and behavior; social interaction increased for My real baby
Care-o-bot	6	3	5	+	?	8	Results with walking aid robot and grabber; elderly can work with robot
Homie	2	3	3,5	+	?	39	Ideas about design
iCat	40	2	5	±	minutes	25	Robot acceptance and design guidelines
	40	2	5	±	minutes	26	Robot acceptance and design guidelines
	40	2	5	±	minutes	27	Robot acceptance and design guidelines
	40	2	5	±	minutes	28	Conversational behavior
	6	6	5	±	< 1hr	38	Interface design guidelines
Paro	4,3,9	3	1,2	+	3 wks 1hr 4 days/wk	10	No effect on immune system (n=4); Paro (n=3) and fake (n=9) decreased depression
	12	3	1,3	+	1 mnth 9 hrs/day	14	Participants played without caregivers or researchers intervening; control not clear
	12,11	3	1	-	3 wks 1hr 4 days/wk	18	Less demented (n=12): less active Paro: increased stress; demented (n=11): active Paro: no effect
	7,11,12,9	3	2	+	3 wks 1hr 4 days/wk	20	Happier with real Paro (n=7) than fake (n=11); continued to like fake (n=12) better than real Paro (n=9)
	4,7,11	3	1,2	+	3 wks	21,22	Emotion change and familiarity correlated(n=4); same interest for fake(n=11) and real Paro (n=7)
	18	2	3	+	20 min	23	Form influences expectations; acceptance important; less active Paro: fewer reactions
	5	3	3	?	1 month 2x wk	40	Demented started talking about and to Paro; no control group; no clear effect measure
	12,11	3	2	±	3 wks 1hr 4 days/wk	41	As 18; different effect measure; no statistics; no difference between Paro and fake Paro
	23	2	2,3	+	4 months	42	Paro-on: more lively communication; no statistics; My real baby calms down residents, but is often a care burden
	1	3	3	+	once	43	Introduced by therapist; demented patient accepted Paro and talked about it
	20	3	1		6 wks	44	Lower stress level
	11	3	2	±	3 wks 20 min 1-3x/wk	45,46	Vigour (item on mood scale) bettered after intervention; no control group
	10	3	1	+	14 wks	47	No effect on dementia scale; no control; degree of involvement of researcher unclear
	12,11	3	2	+	5 wks 20 min 1-3x/wk	48,49	Mediated intervention; measured before and after; increase in mood and emotion faces test
	23	3	2	+	1 yr	50	Longer term study; 8 subjects; statistical power & researchers interaction unclear
	?	3	3	?	1 yr	51	As 50, plus: silent Paro provokes less utterances than normal Paro
	14	3	5	+	20 min	52	Strong intervention; dubious interpretation of cortical neuron activation; short term effect
	8	3	2	+	17 months	53	Long term study; no new insights in addition to other work by same group
	14	3	2	+	10 wks	54	
	11	3	1,3	?	1 month 9hrs/day	55	Participants played without caregivers intervening; no control; social network increased; stress hormone indicated better immune system
Pearl	6	3	5	+	5 days	16,56	Robot guidance, not companionship
Robocare	123	?	5	?	?	24	Evaluation of robot perception amongst elderly

pendent[17] results should therefore not be generalized too easily to other cultures.

Third, practically all of the studies are done with elderly people in nursery homes, not with elderly people still living in their own house, even though there is a growing number of elderly people that get support in their own home. We do not know if the effects of social assistive robots are the same in these two cases.

Fourth, and most importantly, the research methods used to derive effects are not robust from a methodological point of view. Good control conditions are rare. When present, the results are often difficult to interpret because the control condition, such as a fake Paro, has an effect that is similar to the effect of the experimental condition, or because the number of participants is too small to conclude much.[10,18,22]. Some studies are even contradictory in terms of their outcome[18,23]. Also, many studies are not long-term enough to exclude novelty effects. Further, the exact way of interacting with the elderly is often not described in enough detail to make it possible to repeat the study. Therefore, we should be careful to conclude that the cause of any effect is really due to the robot, since a Hawthorne effect (a temporary change to behavior in response to a change in the environment) can not be excluded in several studies. Notable exceptions to this are recent studies by Kidd et al.[42] and Wada and Shibata[14] where participants could play with the robot without intervention by the researchers. Other exceptions to this are studies that investigate robot acceptance and design criteria that include a larger number of participants and generally allow subjects to play with the robot by themselves without intervention of the researchers[24-29]. However, it should be noted that this latter type of research is aimed at extracting requirements for robot design and understanding robot acceptance and as such does not focus on physical and mental health as treatment effects of robots.

Conclusion

Many different studies report positive reactions of the elderly to assistive social robots. As a wide variety of research designs has been used, and many of these studies indicate a positive effect of companion robots on the elderly, we conclude that there is some evidence that companion type robots have positive effects in health care for the elderly with respect to at least mood, loneliness and social connections with others. However, the strength of this evidence is limited, since (i) most studies have been done in Japan, with (ii) a limited set of companion robots, i.e., Aibo and Paro, and (iii) research designs are not robust enough, usually not described in enough detail to repeat, and confounding causal variables cannot be excluded. However, as several studies mention subjective reports from elderly people indicating that they like the companion robots, we conclude that it is worth-while to invest in research methods that are able to attribute the causality of the beneficial effects to the robot as well as invest in robust, large-scale cross-cultural studies to better establish the effects of these devices.

Future research

Given the large number of studies that show positive effects of either the robot or its placebo version, such as a non-functional robot or a pet toy, we believe this type of devices hasmerits in elder care. Further, and of importance, the elderly seem to be open to this kind of technology[25-28].

We consider it necessary to address the methodological problems, or at the very least vagueness regarding methodology often encountered in these studies. It is a little unfair to judge so harsh these studies, as they attempt to do something quite difficult and novel: experiment with a novel form of treatment in a real life situation without having the benefit of being able to set up randomized blind trials, as the placebo version of the robot is also perceptually different. This is obviously not the case with drug-research, for example. However, we surely think that several of the experimental design issues need to, and can be improved.

First, it is absolutely necessary to have a control group that is not in contact with the experimental group. Secondly, researchers need to start replicating results of each other, and for this to be possible they need to have access to the methods used, the same control conditions and preferably the same robots. This implies that all studies should describe their research design and methods clearly and in such a way that the research can be completely repeated somewhere else. Third, studies must be long-term. The novelty value of something that enters the life of an elderly person may take some time to wear off. Fourth, many studies attempt to derive statistically significant results from far too small a number of subjects. This is problematic, because of sample group selection bias and lack of statistical power.

In summary, we need large-scale experiments that are rigorously set up, and an adequate methodology by which these studies are done and compared to each other. Further, we need more variation in the form and function of these robots to figure out what parts actually contribute to the beneficial effects. Setting up a large scale, international (for instance, EU-based) program to establish the merits of these, and related, devices could be of great importance for the elderly as well as for health care in general.

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