///VSP///
Advanced Robotics 23 (2009) 1909–1923
ADVANCED ROBOTICS
www.brill.nl/ar

Full paper

Influence of Social Presence on Acceptance of an Assistive Social Robot and Screen Agent by Elderly Users

Marcel Heerink [a,*], **Ben Kröse** [a,b], **Vanessa Evers** [b] **and Bob Wielinga** [b]

[a] Instituut voor Information Engineering, Amsterdam University of Applied Sciences, P. J. Oudweg 25, 1314 CH Almere, The Netherlands

[b] Informatics Institute, University of Amsterdam, Science Park 107, 1098 XG Amsterdam, The Netherlands

Received 21 April 2009; accepted 23 June 2009

Abstract

When using a robot or a screen agent, elderly users might feel more enjoyment if they experience a stronger social presence. In two experiments with a robotic agent and a screen agent (both $n = 30$) this relationship between these two concepts could be confirmed. In addition, both studies showed that social presence correlates with the Intention to Use the system, although there were some differences between the agents. This implicates that factors that influence social presence are relevant when designing assistive agents for elderly people.

Keywords

Assistive robots, technology acceptance, eldercare companions, human–robot interaction, social agents

1. Introduction

Exploring the possibilities for using robots and screen agents in eldercare [1], we face not only technological issues, but also challenging questions concerning the way elderly people are coping or not coping with this new technology [2–5]. In our research, we address some of those questions by exploring the factors that may influence acceptance of a conversational robot by elderly users [6]. We not only have to deal with the fact that the user characteristics of elderly people differ from the user groups that are addressed in most technology acceptance studies, we are also facing a type of technology that brings about different characteristics [7]. For example, for many users a robot or screen agent may be experienced as a personality

* To whom correspondence should be addressed. E-mail: m.heerink@hva.nl

 DOI:10.1163/016918609X12518783330289

that one might or might not appreciate, rather than a piece of technology. In addition, robots and screen agents could have 'hedonic' aspects — users might actually feel the same enjoyment they would feel when playing a game or having a pleasant conversation with a person. It might very well be that, the more natural and 'human like' this conversation is, the more enjoyment a user would feel and the more this user would feel encouraged to actually use this technology.

In technology acceptance models, enjoyment is sometimes incorporated as 'Perceived Enjoyment', defined as 'the extent to which the activity of using the system is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated' [8]. Most acceptance models however, are developed within the context of utilitarian or productivity-oriented systems and Perceived Enjoyment is usually not incorporated as a major influence. However, for hedonic, or pleasure-oriented, systems it seems to be a crucial factor [9]. In the context of acceptance of an assistive social robot by elderly users [10] we found strong indications that Perceived Enjoyment is a major influence on the Intention to Use the robot.

If this enjoyment can be related to the feeling of really having contact with a mechanical but social entity, this would mean that a stronger sense of Social Presence would lead to a stronger feeling of enjoyment.

The goal of this paper is to try to establish these relationships: Social Presence being a determinant of enjoyment and enjoyment being a determinant of acceptance. This acceptance is to be measured both by the Intention to Use the system and by actual use of it. After describing related research and theoretical concepts, we will explain how we set up experiments with a robot and a screen agent to gather data on Social Presence, Perceived Enjoyment, Intention to Use and actual usage of the technology. After analyzing the results of these experiments, we will establish the preliminary position of Social Presence and Perceived Enjoyment in an acceptance methodology, and set out a path for further development of an appropriate model.

2. Theoretical Framework

In this section we will explore the theoretical concepts used by discussing related research. We will subsequently discuss robotic technology as it is being used in eldercare, acceptance methodology applied to robots, and finally the concepts of Perceived Enjoyment and Social Presence.

2.1. Robots and Screen Agents in Eldercare

Projects addressing the development of assistive social robots for experiments in eldercare generally either focus on possibilities and requirements or on measuring the responses to it by performing experiments with specific robots. An example of the latter is the research done with a seal shaped robot (Paro) [11, 12]. These experiments showed that a robot could have the same beneficial effect on elders that a pet can have, making them feel happier and healthier. A more recently developed robot with similar pet-like functionalities is the Huggable [13]. Another example of a robot developed specifically for eldercare experiments is 'nursebot' Pearl — a robot that could actually provide advanced assistance to elders, although its functionalities were merely simulated [14, 15]. A more recently developed robot to be applied in eldercare is Care-o-bot [16]. This robot is intended to provide assistance in many ways, varying from being a walking aid to functioning as a butler. Some projects concern an assistive social robot that is developed as an integrated part of an intelligent home. Examples are the Italian Robocare project [17, 18] and the Intelligent sweet home at KAIST, South Korea [19, 20].

The type of robots we refer to as assistive social robots are robots that are both socially interactive [21] and developed or used as assistive agents. They can be assistive by their social interaction, like Paro, which we refer to as a companion-type robot (also sometimes called socially assistive robots [22]), or by providing monitoring or physical assistance like Care-o-bot, which we refer to as a service type-robot. Of course an assistive social robot can be a mixture of those two.

These different examples suggest that robots could both perform as social actors and fulfill practical functions, although the focus obviously differs within the different projects.

2.2. *Technology Acceptance and Robots*

Related research on acceptance of a conversational robot is described by De Ruyter *et al.* [7]. It concerned a robotic interface (the iCat made by Philips), which was tested in a Wizard of Oz experiment where the robot was controlled remotely by an experimenter while the participants perceived it to be autonomous. This experiment was done in a laboratory setting, with adult, but not elderly participants.

The results showed that the extravert iCat was perceived to be more socially intelligent and was also more likely to be accepted by the user than a more introvert version. The same robot was used in an experiment by Looije *et al.* [23] where it featured as a personal assistant for a small group of people with diabetes. Results showed that participants appreciated a more socially intelligent agent more and had a higher intention of using it than a less socially intelligent agent.

It seems that perceived social abilities of a robotic system are indeed appreciated as they would be in a human conversational partner and research on screen agents indicates that this is also the case for two-dimensional artificial personalities [24, 25].

2.3. *Social Presence*

Since it is not unusual for humans to treat systems and devices as social beings [26] it seems likely that humans treat embodied agents as such. The extent to which they do so seems to be related to a factor that is often referred to as either Presence or, more specifically, Social Presence. Many research projects that are related to our research incorporate this concept [25, 27, 28].

Originally, the term presence refers to two different phenomena. First, it relates to the feeling of really being present in a virtual environment and can be defined as ‘the sense of being there’ [29]. Second, it can relate to the feeling of being in the company of someone: ‘the perceptual illusion of non-mediation’ [30]. In our context, the second definition is relevant.

Although there is no direct indication that technology acceptance can be related to a certain degree of Social Presence, there is in fact some indication that it influences the attitude towards technology [28, 31, 32]. Regarding the close connection between social abilities and the sense of presence, there could be a crucial role for presence in the process of acceptance of embodied agent technology. Therefore, we intend to incorporate measuring Social Presence in our experiments to research its role.

2.4. Technology Acceptance Models and Enjoyment

Since the first introduction of the Technology Acceptance Model (TAM) in 1986 [33], it has become one of the most widely used theoretical models in behavioral psychology. In its most basic form it states that Perceived Usefulness and Perceived Ease of Use determine the behavioral Intention to Use a system and it assumes that this behavioral intention is predicting the actual use [34–37]. The model has been used for many different types of technology and has been extended with other factors that supposedly influenced Intention to Use or usage. In 2003, Venkatesh *et al.* [37] published an inventory of all current models and factors, and presented a new model called UTAUT in which all relevant factors would be incorporated.

In these models, the main instrument to measure these influences is by using questionnaires. These questionnaires consist of a number of items, which can be questions or statements. Items that measure the same influence can be grouped as a measure of more general constructs. The validation of a model typically includes an observation of the actual use of technology, which makes it possible to relate scores on Intention to Use to actual usage.

The original TAM, related models and UTAUT were merely developed for and validated in a context of utilitarian systems in a working environment. Robotic technology used outside a working environment provides systems that might be experienced as more than this: users might have a sense of entertainment when using it. Van der Heijden [9] points out that in ‘hedonic systems’, the concept of enjoyment is a crucial determinant for the Intention to Use it.

Of course, robotic technology in eldercare will hardly be developed just to entertain — it will be partly utilitarian, partly hedonic. However, even if just partly hedonic, enjoyment could prove to be a construct that needs to be part of an acceptance model for robotic technology in eldercare.

In addition, Perceived Enjoyment can also be of importance in utilitarian systems, as pointed out in an extensive study by Sun and Zhang [38]. The study mainly supports the claims by Venkatesh *et al.* [37] and Yi and Hwang [39] that Perceived Enjoyment has no direct influence on Intention to Use, but that it can influence Ease of Use and Usefulness. Still, the study also recognizes that this is not a general claim for all types of systems. Indeed, this could work very differently for robotic systems used by elderly people.

An acceptance study also including Perceived Enjoyment concerned the use of Lego Mindstorms development environment by Mindstorms hobbyists [40]. The study, based on the viewpoint that this concerns a partly hedonic, partly utilitarian type of system, confirms Perceived Enjoyment having just an indirect effect on Intention to Use.

We may conclude that literature on acceptance models in general does attribute some influence to Perceived Enjoyment in systems that are partly or totally hedonic. Since socially interactive robots may be experienced as hedonic systems, this means Perceived Enjoyment could be of some influence. When we consider social acceptance also to be a factor, especially with conversational robots, this means robotic systems differ from the systems described in acceptance model literature so far and the strength of the influence of Perceived Enjoyment is still very much uncertain, especially in the context of eldercare.

3. Method

Relating the concept of Social Presence to Perceived Enjoyment and Perceived Enjoyment to the Intention to Use a conversational robot brings us to another acceptance model issue that is of interest to us. As stated above, an important aspect of these models is that the assumption that Intention to Use determines actual use is found to be correct. This has not been confirmed for this type of technology and for this particular user group yet. This means that we have to set up an experiment in which we will not only measure Perceived Enjoyment, Social Presence and Intention to Use a system, but also actual usage. In this section we will present two experiments that have been set up for this purpose

3.1. Hypotheses

There are three hypotheses we want to test in an experiment:

H1 The more elderly users experience Social Presence when interacting with an assistive social robot or screen agent, the more they perceive it to be enjoyable.

H2 The more elderly users perceive an assistive social robot or screen agent to be enjoyable, the more they intend to use it.

H3 The more elderly users indicate they intend to use an assistive social robot or screen agent, the more they will actually use it.

As Fig. 1 shows, we expect (i) Social Presence to be a determinant of Perceived Enjoyment, (ii) Perceived Enjoyment be a determinant of Intention to Use and (iii) Intention to Use be a determinant of Usage.

Measuring Social Presence, Perceived Enjoyment and Intention to Use demands a setup in which there is a small test in which people get a first impression after which they can be subject to a questionnaire. Measuring usage demands a setup in which people can be observed using or not using the system over a certain period.

3.2. Experimental Setup for the Robotic Agent

3.2.1. System

The robotic agent we used in our experiment is the iCat ('interactive cat'), developed by Philips, also used in the experiments by De Ruyter *et al.* [7] and Looije *et al.* [23], and within our own project [41]. The iCat is a research platform for studying social robotic user-interfaces. It is a 38-cm tall immobile robot with movable lips, eyes, eyelids and eyebrows to display different facial expressions to simulate emotional behavior. There is a camera installed in the iCat's nose that can be used for different computer vision capabilities.

For this experiment, we used a setup in which the robot was connected to a touch screen as shown in Fig. 2.

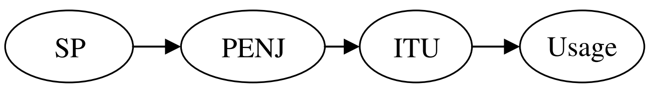


Figure 1. Tested model. SP, Social Presence; PENJ, Perceived Enjoyment; ITU, Intention to Use.

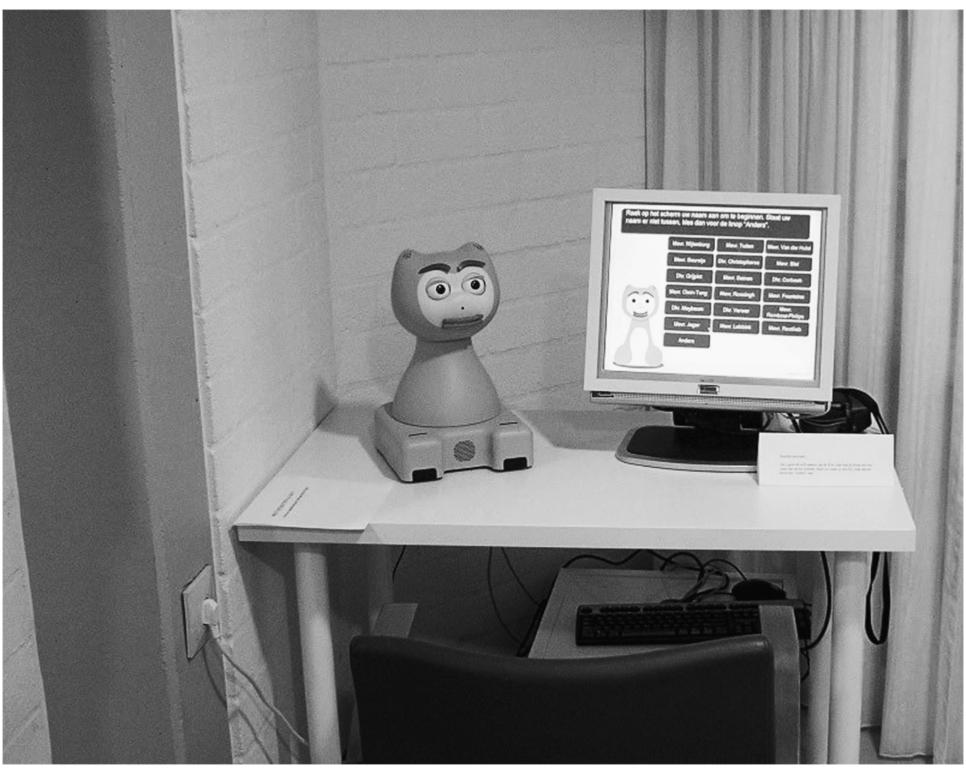


Figure 2. iCat setup with touch screen.

It could be used for information and for fun — the participants could ask for weather forecast, a television program overview or a joke by pressing the appropriate choices from a menu on the screen. The information was then given with pre-recorded speech by the iCat, for which we used a female voice. The recording was done with a text-to-speech engine.

3.2.2. Experiment

We designed an experiment in two eldercare institutions in the city of Almere (The Netherlands) with the first part consisting of a short test, during which participants were to meet a robot and work with it for a few minutes individually.

3.2.3. Subjects

There were 30 participants, recruited both by eldercare personnel and by students. Their age ranged from 65 to 94 years, while 22 of them were female and eight were male. Some of them lived inside the eldercare institutions and some lived independently in apartments next to the institutions.

3.2.4. Procedure

Participants were brought into a room where they were instructed to simply play with the robot for about 3 min. Subsequently, they were brought to another room where they were given a questionnaire. They could ask for help if they were unable to read the statements.

After these sessions were completed, we left the robot for public use in a tea room. On the screen were buttons with the names of the test session participants and one extra button saying ‘I’m not listed’. Passers-by were informed by a note that anyone could use the robot and that they could start a session by pressing the button with their name on it or the ‘I’m not listed’ button if their name was not on the screen.

3.3. Experimental Setup for the Screen Agent

3.3.1. System

Steffie (Fig. 3) is a screen agent designed in Flash and developed as a part of a website (www.steffie.nl) where she features as a talking guide, explaining the internet, e-mail, health insurance, cash dispensers and railway ticket machines. She has been developed by a consortium of commercial and non-commercial participants, as a part of a project to facilitate the use of the internet by older adults. Steffie lectures on the subject chosen by the user and gives a few phrases at a time, after which the user can choose to let her repeat what she just said or to go on. She uses her (lip synchronized) voice with facial expressions and hand/arm gestures.

We used an offline version of the application (kindly provided to us by the developers) that we installed on the PCs of the participants. We added an entrance page on which there were the names of possible users. If the user chose a name, it was recorded in a log file and if the user ended the session, it wrote the ending time in the log file. Also, if the user did not use the application for 90 s, it closed and wrote the time in the log file.

Figure 3. Screen shot of Steffie.

3.3.2. Participants

Participants were 30 elderly users who owned a PC. Their age ranged from 65 to 89 years and they were all living independently. Of the 30 participants, 14 were female and 16 were male.

3.3.3. Procedure

The participants were visited by a researcher who installed the Steffie application on their PC. Subsequently, they were to try out the application for a minimum of 2 min a maximum of 3 min. After this they were to fill out our questionnaire. After 10 days, the researcher returned, copied the log file and deleted the application from the PC.

3.4. Instruments

In both experiments we used a questionnaire that consisted of a list of statements that participants could reply to in a five-point Likert scale (totally disagree–disagree–don't know–agree–totally agree). Table 1 shows the used statements on Intention to Use, Perceived Enjoyment and Social Presence. The statements were not grouped by construct, but mixed.

The usage data for both systems was collected by using the log. For the iCat, the log was compared to video footage to check if the users were the person they claimed to be when logging in.

Table 1.
Statements used for Intention to Use, Perceived Enjoyment and Social Presence

Construct	Statement
Intention to Use	I'm thinking of using the agent the next few days
	I am certainly going to use the agent the next few days
	I am planning to use the agent the next few days
	I think I will use the agent for . . . minutes
Received Enjoyment	I enjoy it when the agent is talking to me
	I enjoy working with the agent
	I find the agent enjoyable
	I find the agent interesting
Social Presence	When working with the agent, I felt like working with a real person
	I occasionally felt like the agent was actually looking at me
	I can imagine the agent as a living creature
	I often realized the agent is not a real person
	Sometimes it seemed as if the agent had real feelings

Table 2.
Cronbach's α for the constructs used for screen agent Steffie and robot iCat

Construct	Items	Steffie	iCat
Intention to Use	4	0.948	0.947
Perceived Enjoyment	4	0.802	0.801
Social Presence	5	0.816	0.866

4. Results

We first calculated Cronbach's α for the constructs used to see if they were consistent. In psychology, an α of 0.7 and higher is considered acceptable [42]. As Table 2 shows, the constructs had high scores and can be considered reliable. Regarding the usage data of the experiment with iCat, we analyzed the video footage and the log, and compared these to find out if users pressed the button with their name. We found that there were 78 full sessions of which 38 were from test session participants. Users that did not belong to this group did not always use the 'I'm not listed' button: 17 of 40 of their sessions were started by them using the name of one of the participants. The test session participants, however, always started their session with their own name.

Tables 3 and 4 show first of all a correlation between Intention to Use and the actual use measured in the number of sessions, and a strong correlation between Intention to Use and actual use measured in minutes for both systems. There is also a strong correlation between Social Presence and Perceived Enjoyment, and between

Table 3.
Correlations of iCat robot for Intention to Use (ITU), Perceived Enjoyment (PENJ), Social Presence (SP) and usage in number of sessions and minutes

		PENJ	SP	ITU	Sessions
PENJ	Pearson correlation	1	0.606**	0.420*	0.290
	Sig (two-tailed)		0.000	0.021	0.120
SP	Pearson correlation	0.606**	1	0.599**	0.552**
	Sig (two-tailed)	0.000		0.000	0.002
ITU	Pearson correlation	0.420*	0.599**	1	0.413*
	Sig (two-tailed)	0.021	0.000		0.023
Minutes	Pearson correlation	0.363*	0.646**	0.625**	0.861**
	Sig (two-tailed)	0.049	0.000	0.000	0.000

* $P < 0.05$, ** $P < 0.01$.

Table 4.
Correlations for screen agent Steffie for Intention to Use (ITU), Perceived Enjoyment (PENJ), Social Presence (SP) and usage in number of sessions and minutes

		PENJ	SP	ITU	Sessions
PENJ	Pearson correlation	1	0.514**	0.604**	0.072
	Sig (two-tailed)		0.004	0.000	0.706
SP	Pearson correlation	0.514**	1	0.193	0.116
	Sig (two-tailed)	0.004		0.308	0.541
ITU	Pearson correlation	0.604**	0.193	1	0.622**
	Sig (two-tailed)	0.000	0.308		0.000
Minutes	Pearson correlation	0.039	0.078	0.623**	0.934**
	Sig (two-tailed)	0.839	0.681	0.000	0.000

* $P < 0.05$, ** $P < 0.01$.

Perceived Enjoyment and Intention to Use. We performed a regression analysis to estimate the probability of prediction. Often a multiple regression analysis and path analysis is used when modeling several constructs, but since we have just a few constructs and only one predicting factor per hypothesis, we performed a simple linear regression analysis.

Tables 5 and 6 show the results of our analysis for both systems, with the independent variable in the first column predicting the dependent variable in the second column. The scores show that indeed Social Presence is predictive towards Perceived Enjoyment, Perceived Enjoyment is predictive towards Intention to Use and Intention to Use is predictive towards both Usage items (sessions and minutes).

Table 5.
Linear regression for iCat robot: t scores and significance for predicting constructs

Independent variable	Dependant variable	β	t	p
Intention to Use	Usage (sessions)	0.420	2.449	0.021*
Intention to Use	Usage (min)	0.413	2.400	0.023*
Perceived Enjoyment	Intention to Use	0.625	4.236	0.000**
Social Presence	Perceived Enjoyment	0.606	4.033	0.000**

$^{*}P < 0.05$, $^{**}P < 0.01$.

Table 6.
Linear regression for screen agent Steffie: t scores and significance for predicting constructs

Independent variable	Dependant variable	β	t	p
Intention to Use	Usage (sessions)	0.622	4.202	0.000**
Intention to Use	Usage (min)	0.623	4.213	0.000**
Perceived Enjoyment	Intention to Use	0.604	4.008	0.000**
Social Presence	Perceived Enjoyment	0.514	3.174	0.004**

$^{*}P < 0.05$, $^{**}P < 0.01$.

5. Discussion and Conclusions

For both systems all three hypotheses were supported by a simple linear regression analysis. Regarding Intention to Use and Usage, this means the acceptance model assumption of the first being predictive towards the second is likely to be applicable to robotic systems and screen agents used by elderly people. The high correlation and regression scores between Perceived Enjoyment and Intention to Use indicate that this influence is strong and there is a strong influence of Social Presence on Perceived Enjoyment. This means both constructs can be part of a technology acceptance model for robotic and screen companions that are developed for elderly users. However, such a model would incorporate other constructs like Perceived Usefulness and Perceived Ease of Use that are typical for existing TAM's and moderating influences like age, gender and (computer) experience (in earlier research we found both gender and computer experience to be significant influences [6]). Future work needs to address the relationships between classical and new constructs.

Although the hypotheses were confirmed for both systems, there are some remarkable differences. First, both correlation and regression scores show a stronger relationship between Intention to Use and Usage for Steffie than for iCat. Second, the scores for Social Presence correlate with Perceived Enjoyment, Intention to Use and Usage for iCat, but only with Perceived Enjoyment for Steffie. Since both systems are different in more than one aspect, it is not possible to explain these differences.

If we consider the implications on the design of interactive robots and screen agents, these results show the importance of non-functional aspects that may raise the level of enjoyment and the sense of Social Presence for elderly participants. Further research might focus on the design aspects that increase enjoyment and Social Presence for elderly users. In addition, further research could establish the relationship between these non-functional aspects and functional aspects of the systems, and find out if one of these types contributes to the perception of the other.

Nevertheless, when applying these findings we need to realize that the robot in our experiment has only been available for 5 days and the screen agent only for 10 days. It would be interesting to see the results of a study that measures usage over a period of a few months. In addition, although for an eldercare field study the number of participants in our experiments is relatively high, statistical analysis would leave us with more conclusive findings if numbers were much higher.

Finally, although it is tempting to generalize our findings, we realize that this study concerns elderly users, which is a very specific group when it comes to dealing with new technology. It would be interesting to see how other user groups would respond to robots and screen agents, and research the influence of enjoyment and their sense of Social Presence.

Acknowledgements

We would like to express our gratitude to the staff and caretakers as well as the test participants of 'De Kiekendief' and 'De Overloop' in Almere for their cooperation. Also, we like to thank Willem Notten, Bas Terwijn and Rogier Voors for their work on programming the system, and Rick van Midde, Albert van Breemen and Martin Saerbeck for their support. Furthermore, we thank Rabobank Foundation Nederland and Netrex Solutions for their support of our research on Steffie.

References

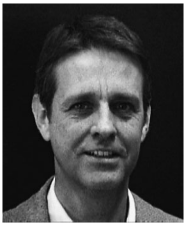
1. M. Pollack, Intelligent technology for an aging population: the use of AI to assist elders with cognitive impairment, *AI Mag. Summer* **26**, 9–24 (2005).
2. J. Forlizzi, C. DiSalvo and F. Gemperle, Assistive robotics and an ecology of elders living independently in their homes, *J. Human Comput. Interact.* **19**, 25–59 (2004).
3. J. Forlizzi, Robotic products to assist the aging population, *Interactions* **12** (2), 16–18 (2004).
4. M. S. Giuliani and F. Fornara, Coping strategies and technology in later life, in: *Proc. AISB 2005 — Symposium Robot Companions: Hard Problems and Open Challenges in Robot–Human Interaction*, Hatfield, pp. 46–53 (2005).
5. W. Taggart, S. Turkle and C. Kidd, An interactive robot in a nursing home: preliminary remarks, in: *Proc. Towards Social Mechanisms of Android Science*, Stresa, pp. 56–61 (2005).
6. M. Heerink, B. J. A. Kröse, B. J. Wielinga and V. Evers, Studying the acceptance of a robotic agent by elderly users, *Int. J. Assist. Robotics Mechatron.* **7**, 33–43 (2006).
7. B. de Ruyter, P. Saini, P. Markopoulos and A. J. N. van Breemen, Assessing the effects of building social intelligence in a robotic interface for the home, *Interact. Comput.* **17**, 522–541 (2005).

8. F. D. Davis, R. P. Bagozzi and P. R. Warshaw, Extrinsic and intrinsic motivation to use computers in the workplace, *J. Appl. Soc. Psychol.* **22**, 1111–1132 (1992).
9. H. Van der Heijden, User acceptance of hedonic information systems, *MIS Q.* **28**, 695–704 (2004).
10. M. Heerink, B. J. A. Kröse, B. J. Wielinga and V. Evers, Enjoyment, intention to use and actual use of a conversational robot by elderly people, in: *Proc. 3rd ACM/IEEE Int. Conf. on Human–Robot Interaction*, Amsterdam, pp. 113–120 (2008).
11. T. Shibata, K. Wada and K. Tanie, Statistical analysis and comparison of questionnaire results of subjective evaluations of seal robot in Japan and UK, in: *Proc. IEEE Int. Conf. on Robotics and Automation*, Taipei, pp. 3152–3157 (2003).
12. K. Wada and T. Shibata, Robot therapy in a care house — results of case studies, in: *Proc. RO-MAN*, Hatfield, pp. 581–586 (2006).
13. W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, R. Cooper, H. Knight, L. Lalla, A. Maymin and S. Purchase, The huggable: a therapeutic robotic companion for relational, affective touch, in: *Proc. IEEE Consumer Communications and Networking Conf.*, Las Vegas, NV, pp. 1290–1291 (2006).
14. M. Montemerlo, J. Pineau, N. Roy, S. Thrun and V. Verma, Experiences with a mobile robotic guide for the elderly, in: *Proc. AAAI Natl Conf. on Artificial Intelligence*, Edmonton, pp. 587–592 (2002).
15. M. E. Pollack, L. Brown, D. Colbry, C. Orosz, B. Peintner, S. Ramakrishnan, S. Engberg, J. T. Matthews, J. Dunbar-Jacob, C. E. McCarthy, S. Thrun, M. Montemerlo, J. Pineau and N. Roy, Pearl: a mobile robotic assistant for the elderly, in: *Proc. AAAI Workshop on Automation as Eldercare*, Edmonton, AB, pp. 1–7 (2002).
16. C. Parlitz, W. Baum, U. Reiser and M. Hagele, Intuitive human–machine interaction and implementation on a household robot companion, *Lecture Notes Comp. Sci.* **4557**, 922–929 (2007).
17. A. Cesta, G. Cortellessa, F. Pecora and R. Rasconi, Supporting interaction in the RoboCare intelligent assistive environment, in: *Proc. AAAI Spring Symp. on Interaction Challenges for Intelligent Assistants*, Stanford, CA, pp. 18–25 (2007).
18. A. Cesta and F. Pecora, The RoboCare project: intelligent systems for elder care, in: *Proc. AAAI Fall Symp. on Caring Machines: AI in Elder Care*, Washington, DC, pp. 1–4 (2005).
19. H. E. Lee, Development of a steward robot for intelligent sweet home, *Int. J. Human-friendly Welfare Robotic Syst.* **6**, 57–64 (2005).
20. K. H. Park, H. E. Lee, Y. Kim and Z. Z. Bien, A steward robot for human-friendly human–machine interaction in a smart house environment, *IEEE Trans. Automat. Sci. Eng.* **5**, 21–25 (2008).
21. T. Fong, I. Nourbakhsh and K. Dautenhahn, A survey of socially interactive robots, *Robotics Autonomous Syst.* **42**, 143–166 (2003).
22. D. Feil-Seifer and M. J. Mataric, Defining socially assistive robotics, in: *Proc. Int. Conf. on Rehabilitation Robotics*, Chicago, IL, pp. 465–468 (2005).
23. R. Looije, F. Cnossen and M. A. Neerincx, Incorporating guidelines for health assistance into a socially intelligent robot, in: *Proc. Int. Symp. on Robot and Human Interactive Communication*, Hatfield, pp. 515–520 (2006).
24. T. Bickmore, L. Caruso and K. Clough-Gorr, Acceptance and usability of a relational agent interface by urban older adults, in: *Proc. ACM SIGCHI Conf. on Human Factors in Computing Systems*, Portland, OR, pp. 1212–1215 (2005).
25. T. Bickmore and D. Schulman, The comforting presence of relational agents, in: *Proc. CHI*, Montreal, pp. 550–555 (2006).
26. B. Reeves and C. Nash, *The Media Equation: How People Treat Computers, Televisions, and New Media as Real People and Places*. Cambridge University Press, New York (1996).

27. C. F. DiSalvo, F. Gemperle, J. Forlizzi and S. Kiesler, All robots are not created equal: the design and perception of humanoid robot heads, in: *Proc. Conf. on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, London, pp. 321–326 (2002).
28. K. M. Lee and C. Nass, Designing social presence of social actors in human computer interaction, in: *Proc. SIGCHI Conf. on Human Factors in Computing Systems*, Fort Lauderdale, FL, pp. 289–296 (2003).
29. B. G. Witmer and M. J. Singer, Measuring presence in virtual environments: a presence questionnaire, *Presence* **7**, 225–240 (1998).
30. M. Lombard and T. B. Ditton, At the heart of it all: the concept of presence, *J. Computer-Mediated-Commun.* **3**, available online at: http://www.ascusc.org/jcmc/vol3/issue2/lombard.html (1997).
31. F. Biocca, C. Harms and J. K. Burgoon, Toward a more robust theory and measure of social presence: review and suggested criteria, *Presence* **12**, 456–480 (2003).
32. F. Davide and R. Walker, Engineering presence: an experimental strategy, in: *Being There: Concepts, Effects and Measurements of User Presence in Synthetic Environments*, G. Riva, F. Davide and W. IJsselsteijn (Eds), pp. 42–59. IOS Press, Amsterdam (2003).
33. F. D. Davis, Technology acceptance model for empirically testing new end-user information systems theory and results, *Doctoral Dissertation*, MIT, Cambridge, MA (1986).
34. I. Ajzen, The theory of planned behavior, *Organizat. Behav. Hum. Decision Process.* **50**, 179–211 (1991).
35. B. H. Sheppard, J. Hartwick and P. R. Warshaw, The theory of reasoned action: a meta-analysis of past research with recommendations for modifications and future research, *J. Consumer Res.* **15**, 325–343 (1988).
36. S. Taylor and P. A. Todd, Understanding information technology usage: a test of competing models, *Inform. Syst. Res.* **6**, 144–176 (1995).
37. V. Venkatesh, M. G. Morris, G. B. Davis and F. D. Davis, User acceptance of information technology: toward a unified view, *MIS Quart.* **27**, 425–478 (2003).
38. H. Sun and P. Zhang, Causal relationships between perceived enjoyment and perceived ease of use: an alternative approach, *J. Ass. Inform. Syst.* **7**, 618–645 (2006).
39. M. Y. Yi and Y. Hwang, Predicting the use of web-based information systems: self-efficacy, enjoyment, learning goal orientation, and the technology acceptance model, *Int. J. Hum.-Comp. Stud.* **59**, 431–449 (2003).
40. T. Chesney, An acceptance model for useful and fun information systems, *Hum. Technol.* **2**, 225–235 (2006).
41. M. Heerink, B. J. A. Kröse, B. J. Wielinga and V. Evers, The influence of a robot's social abilities on acceptance by elderly users, in: *Proc. Int. Symp. on Robot and Human Interactive Communication*, Hatfield, pp. 521–526 (2006).
42. J. Decoster and H. M. Claypool, A meta-analysis of priming effects on impression formation supporting a general model of informational biases, *Personal. Soc. Psychol. Rev.* **8**, 2–27 (2004).

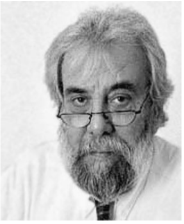
About the Authors

Marcel Heerink is a Senior Lecturer and Researcher at the Information Engineering Institute of the Amsterdam University of Applied Sciences. He teaches HCI and research methodology, and his research interests are in the fields of human–robot interaction, technology acceptance and gerontechnology.



Ben Kröse is an Associate Professor at the University of Amsterdam, where he leads a group in Computational Intelligence and Autonomous Systems. He teaches courses on Interactive Systems and Machine Learning, and supervises three PhD students. As of 2004 he is Part-time Lector at the Amsterdam University of Applied Science, where he leads a group in the field of Digital Life and Smart Homes. He is member of the IEEE, Dutch Pattern Recognition Association and Dutch AI Association.

Vanessa Evers is an Assistant Professor at the Human Computer Studies Lab at the University of Amsterdam. Her research focuses on cultural aspects of HCI and human interaction with autonomous agents such as robots or systems that learn. She is active in the HRI and CHI communities.



Bob Wielinga is a Full Professor of Social Science Informatics at the University of Amsterdam. His research focus has been the methodology of knowledge-based system design and knowledge acquisition. He was and is team leader of several research projects, including KADS, ACKnowledge, REFLECT and KADS-II. He was one of the main contributors to the development of the KADS methodology for knowledge-based system development.