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Psychological Implications of Domestic Assistive Technology for the Elderly

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ABSTRACT

The ROBOCARE Domestic Environment (RDE) is the result of a three-year project aimed at developing cognitive support technology for elderly people. Specifically, the domestic environment is equipped with sensors, intelligent software components and devices which cooperate to provide cognitive support to the assisted person. The ROBOCARE interaction capabilities have been concentrated in a robotic mediator who acts as the main communication channel between the users and the intelligent domestic environment. This paper presents an evaluation of elderly people's perception of assistive robots and smart domotic environments. Results show how the acceptability of robotic devices in home setting does not depend only on the practical benefits they can provide, but also on complex relationships between the cognitive, affective and emotional components of people's images of robot. Specially, we analyzes a number of evaluation criteria related to the robot's aspect, the way in which it communicates with the user, and the perceived usefulness of its support services. Among these criteria, the paper proposes and reports an evaluation of how perceived frailty, with reference to both health in general and fear of cognitive weakening, more specifically, can influence the evaluation of a potential aid in everyday life, namely the robotic assistant. The paper also provides a discussion which can be useful for the design of future assistive agents and socially interactive robotic.

Keywords: *socially assistive robots, intelligent sensorised environments, evaluation of human-robot interactions, acceptability, perceived health.*

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1. Introduction

The use of intelligent technology for supporting elderly people at home has been addressed in various research projects in the last years (Pineau, Montemerlo, Pollack, Roy, & Thrun, 2003; Pollack, 2005). In addition, recent research has been increasingly focusing on Cognitive Systems to produce aids that enhance human cognition capabilities (Myers, 2006). The state-of-the-art in robotics allows now an increasing emphasis on human-robot interaction in general and on social assistive robotics in particular. The emphasis in the latter is to support human users through social rather than physical interaction (Feil-Seifer & Mataric', 2005). A key aspect of social assistive robots consists in social interaction between human users and robotic agents. For example, Sabanovic, Michalowski and Simmons (2006) highlighted how observation and behavioural analysis of human-robot social interaction in real environments is necessary in order to take into consideration all the divergent factors pertaining to the design of social robots. The design of social robots also raises a number of ethical issues that need to be discussed within the research community to provide guidance to system designers. Turkle, Taggart, Kidd and Daste (2006) considered some of the ethical implication of human-robot interaction, mainly related to the kind of authenticity we require to our technology as well as to the choice of the most appropriate relationship between children/elders and relational artefacts.

The ROBOCARE project is in line with several of the mentioned projects and examines some of the relevant factors for the design of assistive robots. The project has involved research groups with different backgrounds with the goal of investigating how state of the art AI (Artificial Intelligence) and robotics techniques can be combined to create new domestic services for elderly people (Cesta & Pecora, 2006). The project has produced a prototype of integrated home environment, called RDE (ROBOCARE Domestic Environment), composed of a robotic interactive agent, some sensors for continuous monitoring, and additional intelligent systems that store and reason upon knowledge about the assisted elder's scheduled activities. A multi-agent coordination algorithm guarantees the coherence of the behaviour of the whole environment. This provides a functional cohesive which invokes the smart home's services so as to preserve safeness of the person and provide suggestions. How the different interactive functionalities are obtained is described in Cesta, Cortellessa, Pecora and Rasconi (2007).

The RDE includes a mobile robotic platform with interaction capabilities. This robot provides an interface between the RDE and the user: indeed, the entire smart home is accessible to the user in the form of an assistive robotic companion. In the spirit described in (Feil-Seifer & Mataric', 2005) the RDE is an example of Social Assistive Robot, a concept which can be distinguished from Social Interactive Robot (Fong, Nourbakhsh, & Dautenhahn, 2003) because its main task is to monitor and assist the elder user rather than simply interacting with him/her. Since its beginning, ROBOCARE has raised numerous challenges. In particular one, also reported in Tapus, Mataric' and Scassellati (2007) has been paramount in our work: "what are the circumstances in which people accept an assistive robot in their environment?". Other important questions we have strived to answer (or at least investigated) are ``how should an elder user communicate with a robot?", "should the robot look like a human being?", and, last but not least, "are robots useful in the domestic environment?". This paper comes after three years of development in which we have attempted to realize a prototypical domestic environment equipped with an assistive robot. The aim of the paper is to describe an *a-posteriori* evaluation of the intelligent environment. In particular, we present experiments aimed at understanding the perception of older people towards the assistance that this robot is able to offer at the moment. Specifically, the analysis of psychological implications in the interaction between the user and the intelligent environment; in other words, how the robotic mediator is perceived by the elder user.

2. The ROBOCARE Assistive Domain

The ROBOCARE Domestic Environment is aimed at demonstrating instances in which the coordinated operation of multiple household agents can provide complex support services for the elder user. For instance, suppose the assisted person is in an abnormal posture-location state (e.g., lying down in the kitchen). The intelligent home should recognize this situation and react to the contingency by dispatching the robot to the person's location. The robot should then ask if all is well, and if necessary sound an alarm. A meaningful example: the smart environment detects that the time bounds within which to take a medication are jeopardized by an unusual activity pattern (e.g., the assisted person starts to have lunch very late in the afternoon); as a consequence, the system should verbally alert the assisted person of the possible future inconsistency. An even more advanced form of reasoning-driven interaction could be the following: the assisted person asks the intelligent environment (e.g., verbally) whether he/she should take a walk now or wait till after dinner; the request is forwarded to a specialized reasoner which propagates the two scenarios (walk now or walk after dinner) in its temporal representation of the daily schedule, and the result of this deduction is relayed to the assisted in the form of verbal advice (e.g., ``if you take a walk now, you will not be able to start dinner before 10:00 pm, and this is in contrast with a medication constraint''). The objective of our prototype is to show how a collection of service-providing and very diverse agents (namely, in our specific case, artificial reasoners, robots and smart sensors) can be integrated into one functionally coherent system which provides more added value than the sum of its parts (see Figure 1). The type of elementary services deployed in the RDE mirrors the domotic components that will be available on the market in the near future. In this context, a special focus of ROBOCARE has been to explore the role of an embodied agent which provides an interface between the assisted person and his or her smart home environment. Our integration effort has yielded an integrated environment that interacts with the assisted person through what we have called a *robotic mediator* (see Figure 1). The base on top of which the robotic mediator is built consists in a Pioneer platform. The mobile platform is equipped with additional sensors, namely a laser range finder, a stereo camera and an omni-directional camera, as well as additional computational resources consisting in two laptops, one for on-board sensor processing and navigation and one for human-robot interaction. The robot is endowed with verbal user□interaction skills: speech recognition is achieved with the Sonic speech recognition system (University of Colorado)[1], while speech synthesis is driven by a simple text-to-speech system.

The objective of the RDE is to provide on-demand as well as proactive support in the management of an elderly person’s daily activities. To this end, the RDE is composed of two fundamental subsystems. On one hand, an “intelligent observer” of the assisted person: information coming from environmental sensors is used for maintaining an updated representation of what is happening in the environment. The sequence of observations from the artificial vision sensors allows following the evolution of the activities of the observed person. Based on the synthesis of these observations, the system is able to generate a report that underscores when the person’s activities have been performed within “reasonable” temporal boundaries or when important anomalies

[1] For details, see \url{cslr.colorado.edu/beginweb/speech_recognition/sonic.html

or even violations on their execution have been detected. In this light, the RDE's basic functionality is an example of home Activity Monitor grounded on scheduling technology. Notice that, on its own, the domestic activity monitor acts as a "silent observer" and does not take initiative with respect to the elder person in any way.

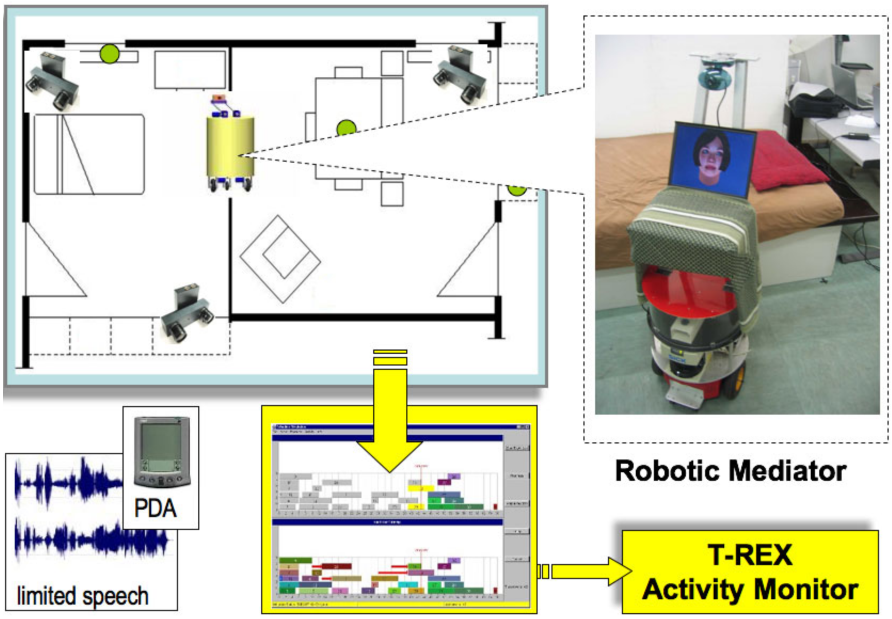

Figure 1. The ROBOCARE heterogeneous ingredients

On the other hand, the RDE also provides an interface with the assisted elder through an interactive subsystem. This subsystem is essentially a "proactive assistant" which closes the loop between the elder user and the intelligent environment, enabling the system to take initiatives based on Activity Monitor inference.

As a central component for the activity management we have employed an AI-based schedule management environment called T-REX – Tool for schedule Representation and Execution (Pecora, Rasconi, Cortellessa, & Cesta, 2006). T-REX allows representing a set of activities and their quantitative temporal connections (i.e., a schedule of activities that the user is expected to carry out). These temporal constraints represent the behavioural requirements to which the assisted person should adhere.

An "ideal schedule" is an enactment of these activities which does not violate any temporal constraint. Broadly speaking, the objective of the Activity Monitor is to recognize deviations from the ideal situation. Specifically, the system should assess the extent to which the elder user's behaviour deviates from this situation. This equates to assessing which temporal constraints are progressively violated during the day. In a nutshell, system interventions are driven by constraint violations: warnings, alarms and suggestions result from violated constraints, which are processed by the interactive subsystem on board the robotic mediator.

2.1. Managing Interaction with the User

As already mentioned, interaction within ROBOCARE relies on an embodied robotic assistant as the focal point between the user and the system. Communication between the user and the robotic mediator occurs verbally. We implemented two forms of interaction based on who takes the initiative to start a dialogue:

On-Demand interaction in which the user takes the initiative first. The assisted person commences interaction, for instance, by querying the system's knowledge base: "have I taken my pills?", or "can I make an appointment for tomorrow at 5 PM?".

Proactive interaction in which the intelligent environment commences interaction guided by its internal reasoning. Within ROBOCARE, constraint violations have been considered as a trigger for the system to take the initiative and perform some actions: issue an alarm in case of illness, or verbalize warnings and suggestions.

We categorize as On-Demand interaction the "Question/Answer" category of dialogues. This activity is triggered by a speech input from the assisted person. The generation of the answer is managed mostly internally to the manager that has information on the activities' history and/or on the current state of the environment, to answer questions like. "Have I had lunch?" or "What time is it?", etc. Instances of Proactive interaction are "Danger" and "Warning" scenarios. Undoubtedly, one of the important tasks for assistance is to recognize emergencies for the monitored person. The emergency trigger is fired by particular combinations of the input provided by the sensors that monitor the environment and the assisted person. As an example we can discriminate as a dangerous situation the case in which a person is "laying down on the kitchen floor" or "laying down in bed half and hour after usual wake up", rather than "laying down in bed within an expected period" which is recognized as a regular situation. The danger trigger is dealt with by a specific behaviour of the multi-agent system that interrupts the usual flow of activities and undertakes an action: the robot is sent to the assisted person, a specific dialogue is attempted, and if no answer from the assisted person is obtained, an Alarm is immediately fired to the external world (call to a relative, to an emergency help desk, etc.).

A warning scenario is one in which constraint violations are detected by the T-REX activity monitor. Broadly speaking, the activity monitor decides the values for the variables that are used by the interaction manager to trigger a proactive dialogue with the assisted person. The content of the dialog is synthesized on the basis of the monitor's internal knowledge.

3. Acceptability Requirements of Domestic Robots: Empirical Evidences

The issue of acceptability of technology and domestic robots by elderly people was addressed in literature in different studies.

Scopelliti, Giuliani and Fornara (2005) analysed preferences and basic requirements of domestic robots from the point of view of final users. This evaluation specifically addressed a variety of topics: the users' expectations with respect to the robot's capabilities to perform different everyday activities at home; their emotional response to a domestic robot; the image of the robot, referring to shape, size, colour, cover material, speed; preferences and expectancies about the robot's personification (given name, etc.) and the modalities of human-robot communication and interaction. Results showed that people underestimate cognitive capabilities and overestimate manipulative abilities of the robot, probably because such a device is still too far away from everyday life experience of laypeople, and their representations may be biased by science fiction. In addition, people at different stages of their lifespan showed very divergent opinions and preferences. In particular, elderly people clearly indicated a preference for a small robot, hardly resembling a human being, which has to intrude as less as possible in personal and domestic life; a device which is not autonomously free to move in the domestic environment and simply responding to tasks to be performed. Its practical utility was clearly recognized, yet the robot emerged as a potential source of worry at home, and the idea of a non-autonomous device seemed to be useful to reduce apprehension.

Another issue to be considered has to do with the context in which the device is expected to operate. The use of new technologies and domestic robots in the home environment is not only a matter of general human-technology interaction, but depends on the specific activity domain in which assistance is needed. In addition, the deep involvement of people with the home place (Giuliani, 1991; Rowles & Chaudhury, 2005) rises the question of possible reactions to modifications in the domestic environment. In this respect Giuliani, Scopelliti and Fornara (2005) clearly outlined different levels of perceived utility and acceptability of a technological aid supporting the elderly in performing everyday activities. Elderly people showed a rather positive attitude towards a technological modification in the domestic environment, yet the inclination to use technological devices is strongly associated to the problem they have to cope with. In some situations, a technological aid seemed to be unrealistic, or unpractical, or it would have better been replaced by a more common alternative. Conversely, when health and personal/environmental safeness are implied, it emerged as a suitable solution to cope with losses imposed by ageing. Furthermore, Cesta Cortellessa, Pecora, & Rasconi (2007) highlighted in an experimental study a different evaluation of a domestic robot performing On-demand vs. Proactive activities in the home environment.

On the whole, the acceptability of a specific support is probably influenced by the coping strategies (Brandtstadter & Renner, 1990; Slangen-de Kort, Midden, & van Wagenberg, 1998) elderly people commonly utilize to manage the weakening of their competences, ranging from assimilative - involving an active modification of the environment in order to reach personal goals - to accomodative - involving a more passive acceptance of life circumstances and obstacles, and a personal adaptation to the environment. The choice among different strategies, far from being a matter of individual preference, is deeply influenced by how people perceive themselves and their personal control on the environment; in other words, it is a matter of perceived self-efficacy (Bandura, 1977). With increasing age and the weakening of personal resources, elderly people are more likely to experience a condition of psychological frailty (Rockwood, 2005; Strandberg & Pitkälä, 2007), that showed to be associated with a variety of behavioural modifications. For example, frailty caused by fear of falling is associated with an increase in social isolation (Rockwood et al., 2004) and an avoidance of activities (Delbaere, Crombez, Vanderstraeten, Willems, & Cambier, 2004; Li, Fisher, Harmer, McAuley, & Wilson, 2003; Zijlstra, van Haastregt, van Eijk, van Rossum, Stalenhoef, & Kempen, 2007). From our perspective, it is important to address the issue of how perceived frailty, with reference to both health in general and fear of cognitive weakening, more specifically, can influence the evaluation of a potential aid in everyday life, namely the robotic assistant.

3.1. Experiments with Elder Users

Apart from the research by Cesta, Cortellessa, Pecora, & Rasconi (2007), the studies on users' evaluations on domestic robots previously mentioned were mainly focussed on attitudes toward a purely imaginary assistive device, with unspecified abilities and not operating in a real domestic environment. For this reason, differences in users' reactions might have been related to both diverse knowledge and bias toward technologies.

The final prototype achieved by the ROBOCARE project allows us to overcome this limitation. In this article, we specifically aimed at understanding the psychological implications of older people-RDE interaction in a real environment, thus focusing on the evaluation of the assistance that the robot (and thus the assistive environment as a whole) is able to offer at the moment.

Figure 2a. Robot showing a human speaking face

Figure 2b. Non anthropomorphic version of the robot

Figure 2. The two experimental conditions of the robot.

Through the evaluation of the RDE prototype it is possible to draw specific conclusions on the prototype itself, and also to investigate some general issues relative to the challenges of assistive technology for elderly people. The approach we adopted is in line with recent recommendations for the evaluation of complex assistive technology. For instance, Hutchins (1995) recognized that human-robot interaction is to be evaluated on socio-culturally constituted activities outside the design laboratory. In this light, the aim of our research is to analyze the potential reactions of final users to real life interactions between elderly people and an assistive robot.

In this exploratory study eight different scenarios were considered, which were meant to be representative of daily situations in which elderly people may be involved. The situations were selected with reference to previous research on this topic (Giuliani, Scopelliti, & Fornara, 2005), ranging from the most emotionally involving to less critical and emotionally neutral, with the aim of exploring elderly people's evaluations of the potential role of a domestic robot as a useful support in everyday life. Scenarios were arranged in order to cover a wide range of interactive situations: we specifically included both "On-demand" and "Proactive" scenarios (Cesta, Cortellessa, Pecora, & Rasconi, 2007).

On the whole, the present study focused on psychological reactions of potential elderly users to the RDE with reference to two main aspects.

First, we aimed at investigating users' preferences with respect to the robotic agent's resemblance to human beings. Even though in our RDE the robotic agent is not properly humanlike, we explored potential reactions of final users to two different versions of the same agent, in which this variable was manipulated (see Figure 2). Given its key role in elderly people's attitudes and preferences towards a domestic robot (Scopelliti, Giuliani, & Fornara, 2005) we proposed a version in which the robot has a 3D facial representation (whose lip movement is synchronized with the speech synthesizer), and one without a facial representation.

Second, we addressed the issue of elderly people attitudes towards the robot's features, interaction modalities and general suitability in the domestic environment (e.g., size, mobility, integration with the home), with particular emphasis on the potential influence of psychological characteristics of respondents on evaluations. Specifically, our aim was to explore the role of perceived frailty of the elderly on the acceptability of the robotic in the domestic environment. Are different levels in perceived health and worry about future cognitive losses predictive of a change in the evaluation of the robot's features and utility? If so, what is the direction assumed by this relationship?

3.2. Materials

Eight short movies (ranging from about 30 seconds to little more than one minute) were developed. The movies show potential interactions occurring in a real domestic environment between an elderly person and the RDE's robotic agent. An experimental manipulation of the features of the robotic agent was employed, according to two different conditions: in the first condition ("Face") the movies show a robot having a human speaking face on a notebook monitor; in the second ("No-face"), we used a robot with no kind of human features (see Figure 3). In the eight scenarios we presented common everyday life situations in which the robot provides cognitive support to the elderly person. Scenarios referred to critical areas, as highlighted by Giuliani, Scopelliti and Fornara (2005): (a) management of personal/environmental safety, (b) healthcare, (c) reminding events/deadlines, (d) support to activity planning, (e) suggestions. In the following, the eight scenarios are shortly described[2]:

1. *Environmental safety*. The robot warns the assisted person of a potentially dangerous situation within the domestic environment.
2. *Personal safety*. This scenario depicts a medical emergency for the assisted person. The system detects the dangerous situation and issues an alarm to the assisted person's family.
3. *Finding objects*. This is an example of *on-demand* interaction where the assisted person relies on the robot's help to find objects within the environment.
4. *Reminding analyses*. In this scenario the robotic assistant reminds the user of a medical appointment he had forgotten.
5. *Activity planning*. In this scenario, the system supports the activity planning of the assisted person.
6. *Reminding medication*. This scenario describes an *on-demand* interaction in which the assisted person does not remember whether or not he/she took his/her medicine after lunch, and asks the robot.
7. *Suggestions*. This scenario depicts an example of system's initiative in making suggestions to the user regarding non-critical situations.
8. *Reminding events*. This is an example of cognitive support provided by the system in case of events not related to the assisted person's medical care.

3.3. Tools

We developed a questionnaire for data collection, consisting of three sections, plus a final part referring to psychological variables (perceived health and worry about loss of

[2] Samples of the videos are available at the web site: http://robocare.istc.cnr.it/

cognitive competence) and socio-demographics. The sections are briefly presented below:

Section 1. Eight fill-in papers, each of them referring to one of the eight scenarios, were presented. For each scenario, questions about the likelihood of the situation for the elderly person, the utility and acceptability of the robot were asked.

Section 2. An attitude scale, consisting of 45 Likert-type items, referring to the physical aspect of the robot, interactive behavior and communication modalities, the level of integration with the domestic environment, the degree of perceived intrusion/disturbance of the robot in everyday life and routines, the personal advantages and disadvantages of having such a device at home.

Section 3. An emotional scale, consisting of sixteen adjectives through which respondents have to evaluate the possible presence of the robot in their home.

Section 4. Two Likert-type items were presented, referring to perceived health ("On the whole, how much are you satisfied with your health conditions?") and worry about loss of cognitive competence ("How much are you afraid of cognitive impairments associated to aging?"). Finally, we asked socio-demographic data.

In Sections 1 and 4, respondents had to express their evaluations on a scale ranging from 0 ("Not at all") to 4 ("Very much"). In Sections 2 and 3, respondents had to express their level of agreement/disagreement on a scale ranging from 0 ("I totally disagree") to 4 ("I completely agree").

3.4. Participants and Procedure

We recruited forty elderly people (aged 56-88; mean age = 70.3 years) for this exploratory study. Participants were 13 males and 27 females; as for their educational level, 17.9% attended primary school, 43.6% attended middle school, 25.6% attended high school, and 12.9% have a degree. Most of them (82.5%) are retired. Before retirement, 22.5% were teachers, 15% were office workers.

Subjects were randomly assigned to one of the two experimental conditions (Face/No-face). In order to control for the potential influence of administration procedure on results, the movies were either projected on a notebook monitor, in a face-to-face administration, or on a larger screen, in a small-group administration. In addition, two different sequences of presentation of scenarios were employed, in order to avoid an order effect of episodes on results. After the vision of each scenario, participants were asked to fill the paper specifically referring to it (Section 1 of the questionnaire). At the end of the whole presentation, subjects were asked to give general evaluations of the robot (Sections 2 and 3 of the questionnaire), and to fill the final part of the questionnaire (Section 4), referring to psychological variables and socio-demographics.

4. Results

A variety of quantitative analyses (ANOVA, Chi-square and Pearson's correlation) were conducted for this study and integrated with a more qualitative evaluation of the user's responses.

First, we checked for the possibility of an influence of procedure administration on judgements. Results from the monitor and the small-group administration were compared, and no significant difference emerged between procedures with respect to all areas of evaluation we considered.

Then, preliminary analyses were performed in order to assess the effectiveness of our selection of scenarios as meaningful in elderly people's experience. On the whole, results showed that proposed scenarios were significant in everyday life of respondents (M = 2.38, sd = .55), and the RDE's support was evaluated as both useful (M = 2.43, sd = .75) and appreciated (M = 2.32, sd = .75). In particular, we found a higher level of perceived utility for Personal safety (M = 3.10, sd = 1.01), and a lower level for Suggestions (M = 1.85, sd = 1.14). A more detailed analysis of scenarios, specifically focussing on the difference between On-demand and Proactive situations is discussed in Cesta, Cortellessa, Pecora, & Rasconi (2007).

4.1. Acceptability Requirements

General evaluation of the robot. Mean scores referring to key features of the robot (physical aspect, interactive behaviour and communication modalities, integration with the home, potential intrusion/disturbance in everyday routines, personal advantages provided) were calculated. On the whole, the robot emerged to be positively evaluated with respect to physical aspect (M = 2.21, sd = .78), interactive behaviour and communication modalities (M = 2.37, sd = .61), level of integration with the domestic environment (M = 2.34, sd = .91), absence of perceived intrusion/disturbance in everyday life and routines (M = 2.50, sd = 1.10), and personal advantages of having such a device at home (M = 2.27, sd = .65).

Similarity to human beings. A comparison between experimental conditions showed a stronger preference for the No-face version of the robot (see Figure 3). In particular, a significant difference in favour of the No-face robot emerged with respect to physical aspect ($F_{(1,38)} = 7.45$, $p < .01$), integration with the home environment ($F_{(1,38)} = 5.65$, $p < .05$), advantages provided by the robot at home ($F_{(1,38)} = 4.58$, $p < .05$). No significant difference between the Face and the No-face versions emerged with reference to interactive behaviour and communication modalities ($F_{(1,38)} = .97$, n.s.) and level of perceived intrusion/disturbance ($F_{(1,38)} = 1.55$, n.s.).

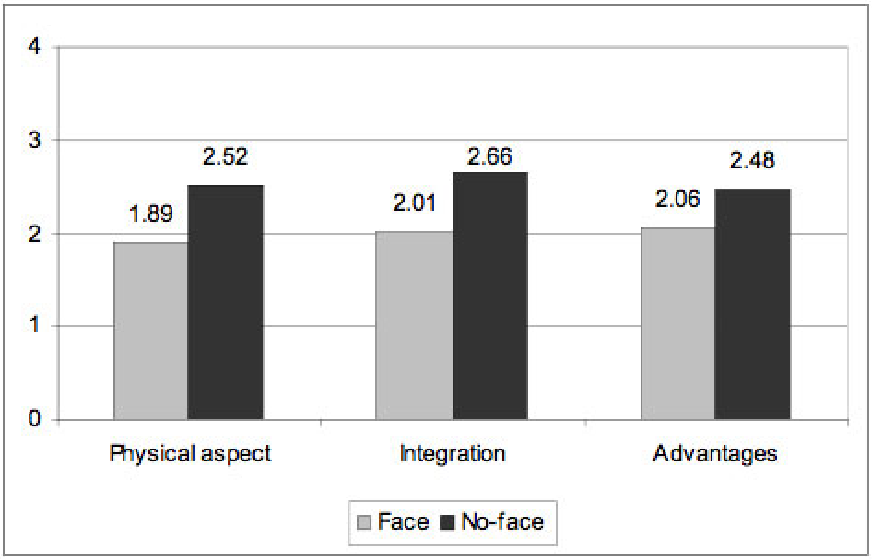

Figure 3. Evaluation of the Face and No-face robot.
Users were asked to evaluate on a scale from 0 to 4.

In addition, elderly people seemed to be more likely to develop a psychological attachment towards the No-face robot than towards the Face robot ($\chi^2 = 6.11$, df = 2, $p < .05$).

Influence of psychological variables. Our analyses outlined a clear influence of both perceived health and worry about loss of cognitive competence on evaluations expressed by elderly people.

The level of perceived health did not show any influence on utility and acceptability of the robot in the evaluation of scenarios. Conversely, elderly people perceiving better health conditions expressed more positive evaluations about the integration of the robot in the domestic environment ($F_{(1,38)} = 4.11$, $p < .05$), and the level of intrusion/disturbance of the robot in everyday life and routines ($F_{(1,38)} = 4.54$, $p < .05$)

than elderly people complaining for worst health conditions (see Fig. 4). No significant difference emerged with respect to physical aspect ($F_{(1,38)}$ = .50, n.s.), interactive behaviour and communication modalities ($F_{(1,38)}$ = 1.31, n.s.) and advantages provided by the robot at home ($F_{(1,38)}$ = 1.55, n.s.).

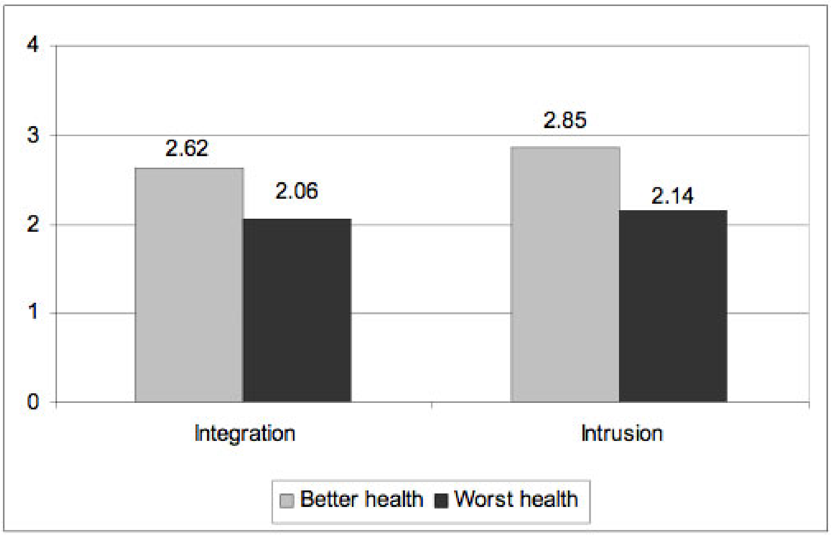

Figure 4. Influence of perceived health conditions.
Users were asked to evaluate on a scale from 0 to 4.

In particular, the perception of better health conditions was found to lead to a more positive evaluation of the robot's ability to move without crashing objects ($F_{(1,38)}$ = 6.07, $p < .05$), a stronger personal willingness to teach the robot what to do at home ($F_{(1,38)}$ = 7.89, $p < .01$), a higher preference for the possibility for the robot to autonomously give suggestions ($F_{(1,38)}$ = 4.68, $p < .05$) and take decisions ($F_{(1,38)}$ = 4.64, $p < .05$).

In addition, elderly people perceiving better health conditions showed a more positive emotional reaction to the robot, being it evaluated as less scary ($F_{(1,38)}$ = 4.46, $p < .05$) and cumbersome ($F_{(1,38)}$ = 7.75, $p < .01$)

Interestingly, elderly people perceiving better health conditions were also more confident to have the robot available in the market in the near future ($F_{(1,38)}$ = 5.92, $p < .05$).

Personal worry about loss of cognitive competence showed a significant influence on utility and acceptability of the robot in the evaluation of scenarios. Elderly people showing a stronger apprehension for personal cognitive impairments expressed more positive evaluations on both variables with reference to Finding objects ($F_{(2,37)}$ = 5.68, $p < .01$ for utility and $F_{(2,37)}$ = 3.30, $p < .05$ for acceptability, respectively), Reminding analyses ($F_{(2,37)}$ = 3.95, $p < .05$ for utility and $F_{(2,37)}$ = 3.88, $p < .05$ for acceptability, respectively), Activity planning ($F_{(2,37)}$ = 9.92, p < .01 for utility and $F_{(2,37)}$ = 8.55, p < .01 for acceptability, respectively), Suggestion ($F_{(2,37)}$ = 3.48, p < .05 for utility and $F_{(2,37)}$ = 7.93, p < .01 for acceptability, respectively), and Reminding events ($F_{(2,37)}$ = 14.33, p < .01 for utility and $F_{(2,37)}$ = 20.99, p < .01 for acceptability, respectively), on utility with reference to Environmental safety ($F_{(2,37)}$ = 4.33, p < .05), and on acceptability with reference to Reminding medication ($F_{(2,37)}$ = 4.85, p < .05).

Moreover, elderly people showing higher anxiety about cognitive impairments expressed more positive evaluations about the physical aspect of the robot ($F_{(2,37)}$ = 5.11, p < .05), interactive behaviour and communication modalities ($F_{(2,37)}$ = 4.45, p < .05) and advantages provided by the robot at home ($F_{(2,37)}$ = 6.54, p < .05) (see Fig. 5). No significant difference emerged with respect to integration of the robot in the domestic environment ($F_{(2,37)}$ = 2.88, n.s.), and the level of intrusion/disturbance of the robot in everyday life and routines ($F_{(2,37)}$ = 2.10, n.s.).

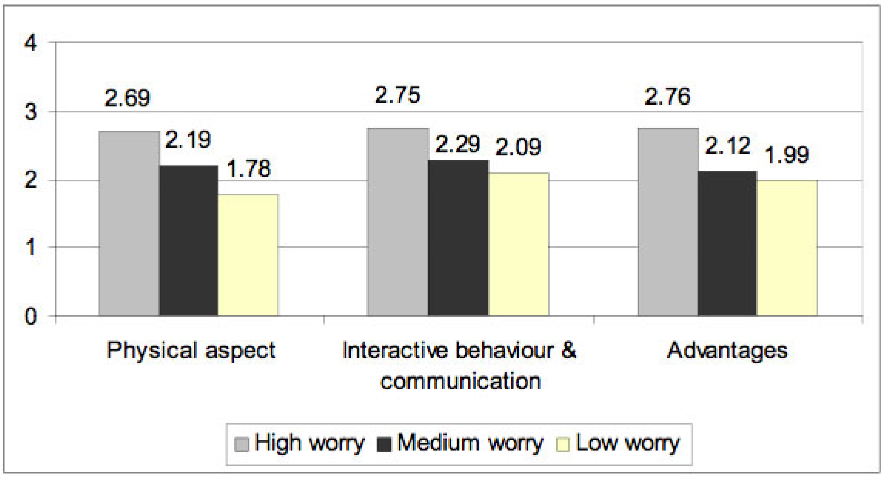

Figure 5. Influence of worry about cognitive impairments.
Users were asked to evaluate on a scale from 0 to 4.

In particular, elderly people worrying the most about a personal cognitive weakening showed a stronger confidence that the robot would make people feel tranquil at home ($F_{(2,37)}$ = 3.63, p < .05), a greater satisfaction for the possibility of a face-to-face ($F_{(2,37)}$ = 4.74, p < .05) and a direct speech ($F_{(2,37)}$ = 5.58, p < .01) interaction, a stronger agreement on positive cognitive support ($F_{(2,37)}$ = 3.36, p < .05) and help in everyday life management ($F_{(2,37)}$ = 4.46, p < .05) provided by the robot, and a lower apprehension for its maintenance ($F_{(2,37)}$ = 5.90, p < .01) than people with a lower level of anxiety about the loss of cognitive competence. Interestingly, they would also like more to train their cognitive competence by actively interacting with the robot ($F_{(2,37)}$ =

12,46, $p < .01$) than people with lower apprehension. On the other hand, users seemed to be aware of a potential dependence on the robot in certain cognitive tasks (M = 2.48, sd = 1.45).

Furthermore, the elderly who showed a higher apprehension for the weakening of cognitive competence expressed a more positive emotional reaction to the robot, being the agent perceived as more pleasant ($F_{(2,37)} = 9.09$, $p < .01$), useful ($F_{(2,37)} = 6.98$, $p < .01$) and dynamic ($F_{(2,37)} = 3.57$, $p < .05$), and less overwhelming ($F_{(2,37)} = 4.06$, $p < .05$), dangerous ($F_{(2,37)} = 4.37$, $p < .05$), scary ($F_{(2,37)} = 3.68$, $p < .05$), worrying ($F_{(2,37)} = 4.60$, $p < .05$), and out of control ($F_{(2,37)} = 3.60$, $p < .05$).

Elderly people showing a stronger anxiety about the loss of cognitive competence were also more confident to have the robot available in the market in the near future ($F_{(2,37)} = 4.35$, $p < .05$).

5. Discussion and Conclusions

The study allowed us to get some light on elderly people-assistive robotic technology interaction. First of all, we had some insights on how useful and accepted state-of-the-art assistive technology can be in real situations. Moreover, we got significant indications as to whether we are employing this technology to solve real needs felt by final users.

Overall, even if Cesta, Cortellessa, Pecora, & Rasconi (2007) showed the central role of safety in elderly people's experience, being the perceived utility of and the expressed preference towards a proactive robot intervening in case of an emergency higher, a positive reaction to different interactive situations was undoubtedly found. This picture is in line with the model of successful aging put forward by Baltes and Baltes (1990), in which the importance of selection and optimization of activities with increasing age was recognized. In addition, it showed the key role of compensation strategies to manage the loss of personal resources. Even though elderly people do not think that a robotic agent living in the domestic environment can be so useful for uncompelling activities as for safety, nonetheless they do not perceive it as completely out of place when supporting the former. This result shows an openness of elderly people towards a variety of functionalities, at least to some extent: they may be rather unfamiliar with some kind of supportive capabilities of the RDE, but not against them a priori. This can get an optimistic light on developments in the range of activities potentially performed by robotic agents, even though a more accurate understanding of psychological implication of user-RDE interaction in situations that do not involve safety is still needed.

In this respect, a clear difference emerged when comparing our results with other studies concerning evaluations of a domestic robot (Scopelliti, Giuliani, D'Amico, & Fornara, 2004), thus supporting the need for analyses in real environments: elderly people are not afraid of the robot's autonomy anyway, and the idea of the robot as a possible source of intrusion/disturbance in personal life, as depicted in previous research (see Scopelliti, Giuliani, & Fornara, 2005) did not emerge. Conversely, the elderly show more positive reactions and evaluations when it is possible to see clearly what a robot can actually do in the domestic environment. Beyond scenarios analysis, this picture is outlined also in the general assessment of the robot, which showed to be rather positive throughout the different areas of investigation. In other words, a representation grounded on unrealistic ideas (as the ones proposed by science fiction) may negatively bias attitudes and expectations.

The physical aspect of the robot emerged to be an important feature which can help support acceptability, and resemblance to human beings plays a key role to this issue. In particular, the No-face version of the robot was definitely preferred, and, interestingly, this physical feature emerged to influence also the evaluation of other characteristics that one might consider as apparently unrelated. In fact, the No-face robot was perceived as better integrated in the home setting and more valued as a source of advantages in the management of everyday life. Beyond evaluations, the No-face robot also showed to promote a deeper emotional involvement in elderly users, expressed in terms of psychological attachment to the assistive agent. Briefly, the better the aspect, the stronger the perception of positive qualities attributed to the robot and the affective bonds. This suggests the occurrence of a halo effect, consistently emerging in social sciences with reference to personality judgements (e.g., Asch, 1946). The possibility to develop a psychological attachment toward this kind of assistive technology is also confirmed by Turkle, Taggart, Kidd and Daste (2006), who showed how, even with simple relational artefacts, the possibility for significant attachment is very high and increases when considering relational artefacts with more complex capabilities. This issue, in turn, raises ethical concerns that are no longer avoidable when designing assistive robots. While the ethical issue has not been addressed within our study it is important to highlight how it is increasingly becoming a matter for both public policy debate (Barry, 2005) and research studies (Calverley, 2006).

The study also highlighted the relevance of some psychological variables in moderating the assessment of the robotic agent. In particular, the perception of one's health conditions being better or worst definitely plays a key role. Elderly people perceiving worst health conditions, hence presumably being more in need for some kind of support at home, are those who showed more negative evaluations of the robot, which is considered as less integrated in the domestic environment and a potential source of intrusion/disturbance in everyday life; likewise, it is worth noting that they do recognize the practical advantages of having such a device at home. This result probably shows a peculiar representation of the robotic agent by this group of users, according to which the perception of personal frailty leaves them weaker in case of difficulties. What if the robot should crash objects while moving? What if the robot is unable to do what people need? What if it autonomously takes decisions? In this light, practical advantages potentially granted by the robot are not denied, but simply undervalued when compared to personal demands for its management. Accordingly, they are more scared by the robot and find it somewhat cumbersome.

Beyond how elderly people feel at the moment, also the way they perceive their conditions with further ageing emerged to influence the evaluation of the robot. In this respect, the apprehension for cognitive impairments definitely showed to play a key role. Briefly, the more the worry for cognitive weakening, the more positive the assessment of the robot's capability and the general reaction towards it. For those people who have a stronger concern for cognitive weakening, the perceived utility and acceptability of the robot dramatically increase in evaluations of domestic situations/activities specifically referring to the use of memory and cognitive resources. Moreover, they appreciate much more the variety of practical supports in everyday life management, which can make them live more relaxed, but also other features of the robot, which have mainly to do with its interactive behaviour and communication modalities. This clearly identifies cognitive competence as one of the most important resources to maintain well-being from the elderly point of view. With increasing age and the natural weakening of this resource, the use of environmental coping strategies implying assimilation (Brandtstadter & Renner, 1990; Slangen-de Kort, Midden & van Wagenberg, 1998; Giuliani, Scopelliti, & Fornara, 2005) is likely to be the most suitable way of adaptation when related activities are of central importance. From a psychological point of view, what seems to be of greatest importance is that elderly people seem to forecast a potential loss in personal autonomy depending on the robot, which may lead them to reduce perceived competence and self-efficacy (Bandura, 1977), key factors for a successful ageing of people (Lawton, 1982; McAvay, Seeman, & Rodin, 1996; Willis, 1996). In this respect, they showed to appreciate the possibility to interact with the robot not only passively relying on its capabilities, but also through an active training to enhance their cognitive functioning. Beyond the cognitive component of their attitude, the positive evaluation of the robot and its capabilities is also associated to a more positive emotional reaction and, interestingly, a stronger confidence (or desire) to have such a device soon available.

Finally, some shortcomings of the study should be mentioned. First of all, given the exploratory purpose of this study, we performed a large number of analyses and it is possible that some results are significant only by chance (namely, an inflation of error rate). In this respect, internal validity could be increased by a larger sample of elderly people. This would also give the opportunity to perform different and more complete statistical analyses. For example, through a factor analysis it would be possible to identify a smaller number of macro-dimensions of elderly people-robot interaction which are relevant in the users' experience, and to perform comparisons with reference to them. This would dramatically reduce the possibility for an inflation of error rate to occur. Second, our study presumably lacks external validity, in that our respondents were rather well-educated and generally in good health conditions: when people are in a condition of actual need, the evaluation of a robotic agent supporting the elderly with age-related impairments may presumably be different.

Nonetheless, our findings can be considered an intriguing starting point to address the issue of acceptability of robotic agents in everyday life of elderly people, and to guide future research on this topic. On the one hand, the role of a domestic robot in the everyday experience of elderly people clearly emerged. In their eyes, the robot is perceived as a practical device, with one physical key feature: it should not resemble a human being. On the other hand, a face-to-face interaction is definitely preferred presumably in order to reduce the emotional distance from the agent. In this respect, it would be interesting to evaluate in further research the potential response of users to a domestic assistive device which cannot move about in the environment. An environmental system equipped with software, sensory and speaking services would probably be able to perform the same activities provided by the robotic agent shown in this study, but acceptability might be significantly influenced by such a difference.

Overall, our study wants to suggest the importance of employing experimental procedures involving real users and referring to real-life situations in order to get helpful guiding principles for further developments of robotic assistive technology for the elderly in the home environment.

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7. References

Asch, S. E. (1946). Forming impressions of personality. *Journal of Abnormal and Social Psychology*, *41*, 258-290.

Baltes, P. B., & Baltes, M. M. (1990). Psychological Perspectives on Successful Aging: The Model of Selective Optimization with Compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1-34). New York: Cambridge University Press.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, *84*, 191-215.

Barry, B. (2005). Better than people: why the Japanese want their robots to act more like humans. *The Economist,* 24. Retrieved December 19, 2007, from http://www.economist.com/world/asia/displaystory.cfm?story_id=E1_VPNPQNS.

Brandtstadter, J., & Renner, G. (1990). Tenacious goal pursuit and flexible goal adjustment: Explications and age-related analysis of assimilation and accommodation strategies of coping. *Psychology and Aging*, *5*, 58-67.

Calverley, D. J. (2006). Android science and animal rights, does an analogy exist? *Connection Science*, *18*(4), 403-417.

Cesta, A., Cortellessa, G., Giuliani, M., Pecora, F., Rasconi, R., Scopelliti, M., & Tiberio, T. (2007). Proactive assistive technology: An empirical study. In M. C. Calani Baranauskas, P. A. Palanque, J. Abascal, S. Diniz Junqueira Barbosa

(Eds.), Human-Computer Interaction - INTERACT 2007. *Lecture Notes in Computer Science* (*LNCS)4662*, (pp. 255-268). Berlin, Heidelberg: Springer.

Cesta, A., Cortellessa, G., Pecora, F., & Rasconi R. (2007). Supporting Interaction in the RoboCare Intelligent Assistive Environment. In *Proceedings of AAAI Spring Symposium on Interaction Challenges for Intelligent Assistants* (pp. 18-25) Stanford: AAAI.

Cesta, A., & Pecora, F. (2006). Integrating Intelligent Systems for Elder Care in RoboCare. In W. C. Mann & A. Helal (Eds.), *Promoting Independence for Older Persons with Disabilities* (pp. 65-73). Amsterdam: IOS Press.

Cortellessa, G., & Cesta, A. (2006). Evaluating Mixed-Initiative Systems: An Experimental Approach. In *Proceedings of the 16th International Conference on Automated Planning & Scheduling, ICAPS-06* (pp. 172-181). The English Lake District, UK: AAAI.

Delbaere, K., Crombez, G., Vanderstraeten, G., & Willems T. Cambier, D. (2004). Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. *Age and Ageing*, *33*(4), 368-373.

Feil-Seifer, D., & Mataric', M. J. (2005). Defining socially assistive robotics. In *Proceedings of the 9th International Conference on Rehabilitation Robotics* (ICORR-05) (pp. 465-468). Chicago, IL: IEEE.

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and Autonomous Systems*, *42*(3-4), 143-166.

Giuliani, M. V. (1991). Toward an analysis of mental representations of attachment to the home. *The Journal of Architectural and Planning Research*, *8*, 133-146.

Giuliani, M. V., Scopelliti, M., & Fornara, F. (2005). Elderly people at home: technological help in everyday activities. In *IEEE International Workshop on Robot and Human Interactive Communication* (ROMAN 2005) (pp. 365-370). Nashville: IEEE.

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press,.

Lawton, M. P. (1982). Time budgets of older people: A window on four lifestyles. *Journal of Gerontology*, *37*, 115-123.

Li, F., Fisher, K. J., Harmer, P., McAuley, E., & Wilson, N. L. (2003). Fear of falling in elderly persons: Association with falls, functional ability, and quality of life. *Journal of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(5), 283-290.

McAvay, G. J., Seeman, T. E., & Rodin, J. (1996). A longitudinal study of change in domain-specific self-efficacy among older adults. *Journal of Gerontology*, *51*, 243-253.

Myers, K. (2006). CALO: Building an intelligent personal assistant. Invited talk at the *Twenty-First National Conference on Artificial Intelligence* (AAAI-06), July 16-20, 2006, Boston, Massachusetts. Slides retrieved on December 6, 2007 from http://caloproject.sri.com/publications/.

Pecora, F., Rasconi, R., Cortellessa, G., & Cesta, A. (2006). User-Oriented Problem Abstractions in Scheduling, Customization and Reuse in Scheduling Software Architectures. *Innovations in Systems and Software Engineering*, *2*(1), 1-16.

Pineau, J., Montemerlo, M., Pollack, M., Roy, N., & Thrun, S. (2003). Towards Robotic Assistants in Nursing Homes: Challenges and Results. *Robotics and Autonomous Systems*, *42*(3-4), 271-281.

Pollack, M. E. (2005). Intelligent Technology for an Aging Population: The Use of AI to Assist Elders with Cognitive Impairment. *AI Magazine*, *26*(2), 9-24.

Rockwood, K. (2005). Frailty and its definition: A worthy challenge. *Journal of the American Geriatrics Society*, *53*(6), 1069-1070.

Rockwood, K., Howlett, S. E., MacKnight, C., Beattie, B. L., Bergman, H., Hébert, R., Hogan, D. B., Wolfson C., & McDowell, I. (2004). Prevalence, Attributes, and Outcomes of Fitness and Frailty in Community-Dwelling Older Adults: Report From the Canadian Study of Health and Aging. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *59*, 1310-1317.

Rowles, G. D., & Chaudhury, H. (2005). *Home and Identity in Later Life. International Perspectives* . New York: Spring Publishing Company.

Sabanovic, S., Michalowski, M. P., & Simmons, R. (2006). Robots in the wild: Observing human-robot social interaction outside the lab. In 9th *IEEE International Workshop on Advanced Motion Control* (pp. 596 - 601). Istanbul: IEEE.

Scopelliti, M., Giuliani, M. V., D'Amico, A. M., & Fornara, F. (2004). If I had a robot ... Peoples' representation of domestic robots. In S. Keates, P. J. Clarkson, P.M. Langdon, & P. Robinson (Eds.), *Design for a more inclusive world* (pp. 257-266). London: Springer-Verlag.

Scopelliti, M., Giuliani, M. V., & Fornara F. (2005). Robots in a domestic setting: A psychological approach. *Universal Access in the Information Society*, *4*(2), 146-155.

Slangen-de Kort, Y. A. W., Midden, C. J. H., & van Wagenberg, A. F. (1998). Predictors of the adaptive problem-solving of older persons in their homes. *Journal of Environmental Psychology*, *18(2)*, 187-197.

Strandberg, T. E., & Pitkälä, K. H. (2007). Frailty in elderly people. *The Lancet*, *369*, 1328-1329.

Tapus, A., Mataric', M. J., & Scassellati, B. (2007). The grand challenges in socially assistive robotics. *IEEE Robotics and Automation Magazine*, *14*(1), 35-42.

Turkle, S., Taggart, W., Kidd, C. D., & Daste, O. (2006). Relational artifacts with children and elders: The complexities of cybercompanionship. *Connection Science*, *18*(4), 347-361.

Willis, S. L. (1996). Everyday cognitive competence in elderly persons: Conceptual issues and empirical findings. *The Gerontologist*, *36*, 595-601.

Zijlstra, G. A. R., van Haastregt, J. C. M., van Eijk, J. T. M., van Rossum, E., Stalenhoef, P. A., & Kempen, G. I. J. M. (2007). Prevalence and correlates of fear of falling, and associated avoidance of activity in the general population of community-living older people. *Age and Ageing*, *36*(3), 304-309.