ROBOTS TO MAKE YOU HAPPY

Investigating the Effectiveness and Acceptance of Robots for Psychological Support

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ROBOTS TO MAKE YOU HAPPY

INVESTIGATING THE EFFECTIVENESS AND ACCEPTANCE OF ROBOTS FOR PSYCHOLOGICAL SUPPORT

DISSERTATION

to obtain

the degree of doctor at the University of Twente,

on the authority of the rector magnificus

Prof. dr. H. Brinksma

on account of the decision of the graduation committee,

to be publicly defended

on Thursday, 20\textsuperscript{th} of October 2016 at 16:45

by

Jorge Gallego Pérez

born on October 28, 1984

in Madrid, Spain
This dissertation has been approved by:
Supervisor: Prof. dr. V. Evers
Acknowledgments

I read that email on a cold December day in 2011, screamed jubilant and lit up my lucky cigar. I just learned then that a few years later, hopefully, I would become doctor. Today I remember that moment, and it takes me effort to believe how many things have happened ever since. Doing a PhD is much more than the studies you carry out, the papers you publish and the conferences you participate in. Doing a PhD has also an important personal and developmental component. I’m recalling now those parts in Michael Ende’s “Neverending Story” where Atreyu, the brave warrior, must face several tests throughout his adventurous journey. The ultimate test “simply” consists in watching himself reflected on a mirror. However, this isn’t just a mirror like any other. It shows you the “you” as you “truly are”. In a similar manner, we might have had to further develop our perseverance, courage, and self-knowledge throughout our PhD’s. And also like in the book, we would have never reached the Ivory Tower if it wasn’t for the help of so many people. It is here then where I’ll present my imperfect attempt to thank all those people that helped me professionally and personally throughout this period. May those who helped me and I don’t mention feel included as well.

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Jorge Gallego Pérez

Enschede, October 2016
The elderly people population is steadily growing in industrialized countries, leading to a shortage of care personnel, higher risk of unattended needs of elderly people and greater economic costs. Technological solutions have been developed to mitigate this problem, such as assistive technology. A specific example is the use of socially assistive robots that have been employed to assist elderly people. While some of elderly people’s needs have a rather physical component (e.g. mobility restrictions, loss of hearing and eyesight, etc.), other needs are of a psychological and/or social type (e.g. loneliness and depression). These latter difficulties represent the main issues for which socially assistive robots have been developed.

There is a lack of studies where socially assistive robots have stayed in the homes of elderly people for a prolonged period. Despite the great methodological challenges that such an approach entails, this type of studies rewards us with a deeper understanding of the participants’ thoughts and behaviors and a greater generalization of the results, due to the greater ecological validity.

Hence, in this dissertation we include the studies that we carried out to assist independent living elderly people psychologically, through the use of socially assistive robots in their own homes. The robots we used implemented exercises from positive psychology, aiming to benefit users by decreasing their feelings of loneliness and fostering their levels of mindfulness, contentment, compassion towards themselves and other people, etc., depending on the specific study.

We started this work conducting two studies to deepen firsthand into the problems and needs of elderly people, as well as their attitudes towards care robots. Based on the literature and our results, we arrived to the conclusion that psychological and social burdens undermine the lives of numerous elderly people, which served as motivation to conduct studies in which robots could offer a form of psychological assistance.

The first study in which we used a robot incorporating an exercise from positive psychology was lab-based, but it gave us clues regarding the effectiveness of a positive psychology robot-mediated program. Very importantly, we also learned that the way how we introduce the robot and task to participants can enormously alter the effectiveness of the positive exercise.

The next three studies included in this dissertation represent the core of the research. They share the similarities of being long-term studies carried out in the homes of independent living elderly participants. Throughout these three studies we have investigated mainly two things. First, whether the robot-mediated programs were
effective at providing psychological assistance. We found positive indications of this for the three long-term studies. Namely, in the first long-term study the robot assisted the user in an exercise on mindfulness meditation, and we found indications that the participant improved at performing the exercise. In the second long-term study, the robot enacted the three-good-things exercise from positive psychology and offered more interactivity, whereby we found signs that the participant felt less lonely and more content in general. Finally, in the last long-term study the robot guided the participants in an exercise of loving-kindness meditation and we found that they acquired more mindfulness and became more compassionate toward themselves and other people.

The second main question we researched in the three long-term studies related to the long-term changes in the attitudes and feelings of participants toward the robot. Here, we found that the novelty effect pervaded the interactions with the robot. That is, participants quickly became accustomed to the robot and the task and as a consequence the robot acceptance tended to drop. More findings on timely evolution of robot acceptance are reported in this dissertation.

I expect two main contributions from the present work. While studies on the use of positive technology have already been conducted, this might be the first time that positive psychology has been employed in the field of Human-Robot Interaction (HRI). We also made a strong effort to build valid positive programs, and we have measured the effectiveness of these programs in the same ways and with the same tools as by other researchers in positive psychology.

Another contribution concerns the methodology of the three long-term studies as already mentioned. Namely, the studies were carried out in the homes of the participants, whereby we minimized the involvement of the researcher as much as we could. Also, the studies were extended in time so as to give us insight into the long-term effectiveness of the interventions and the evolution of the participants’ attitudes toward the robot. Finally, given the complexity of the phenomena we studied, we opted for a case study methodology to attain in-depth results. With this in mind, we hope that these results could apply to future, real applications of robots for psychological support.
In geïndustrialiseerde landen komen naar verhouding steeds meer en meer ouderen, wat binnen de ouderenzorg leidt tot tekorten in personeel, een hoger risico op verwaarlozing en hogere kosten. Er zijn verschillende technologische oplossingen voor deze problemen ontwikkeld, zoals assistive technology. Een voorbeeld hiervan is het gebruik van sociale robots om ouderen te assisteren. Hoewel de behoeften van sommige ouderen veelal fysiek zijn (zoals beperkingen in de mobiliteit, het zicht en het gehoor), zijn er ook meer psychologische en sociale behoeften (zoals eenzaamheid en depressie). Sociaal ondersteunende robots zijn met name ontwikkeld voor behoeften van deze tweede soort.

Er zijn echter maar weinig studies waarin sociaal ondersteunende robots voor langere tijd zijn gebruikt door ouderen in hun huis. Ook al zijn dergelijke studies methodologisch gezien uitdagend, ze leveren wel resultaten op die enerzijds een meer diepgrondig inzicht opleveren in de gedachten en gedragingen van deze doelgroep en anderzijds een grotere ecologische validiteit hebben, waardoor de vindingen meer direct toepasbaar zijn.

In deze scriptie bespreek ik door mij uitgevoerde studies naar het psychologisch ondersteunen van zelfstandig levende ouderen door middel van in hun huis geplaatste sociaal ondersteunende robots.

De gebruikte robots zetten oefening uit de positieve psychologie in, met als doel om de gebruikers te helpen, door vermindering van eenzame gevoelens en bevordering van o.a. mindfulness, tevredenheid en compassie voor zichzelf en anderen. We zijn hiervoor begonnen met twee studies om meer inzicht te krijgen in de problemen en behoeften van ouderen en hun houding ten opzichte van zorgrobots. Dit leidde ons tot de conclusie dat vele ouderen moeite hebben om hun psychologische en sociale behoeften te vervullen, wat ons (verder) motiveerde om studies op te zetten waarin robots psychologische ondersteuning kunnen bieden. De eerste studie waarin we een robot gebruikten die een oefening uit de positieve psychologie inzette was weliswaar in een lab, maar gaf ons inzicht in de toepasbaarheid van positieve psychologie in een interactie met een robot. Specifiek zagen we dat de effectiviteit van de oefening sterk wordt beïnvloed door de manier waarop de robot en de oefening worden geïntroduceerd. De overige drie studies die we bespreken in deze scriptie vormen de kern van mijn onderzoek. Zij zijn allen studies waarin sociaal ondersteunende robots voor langere tijd zijn gebruikt door ouderen in hun huis. In deze studies hebben wij met name gefocust op twee vragen. Ten eerste, de vraag of robots effectief psychologische ondersteuning kunnen bieden. Hiervoor hebben we in alle drie de studies positieve
Abstract (NL)  

indicatoren gevonden. In de eerste studie gebruikte de robot een oefening in mindfulness meditatie, en we vonden aanwijzingen dat de proefpersoon beter werd in de oefening. In de tweede studie gebruikte de robot de drie-goede-dingen oefening uit de positieve psychologie en bood de robot veel mogelijkheden voor interactie, hier vonden we tekenen dat de proefpersoon zich over het algemeen minder eenzaam en meer tevreden ging voelen. Tot slot, in de laatste studie begeleidde de robot de proefpersonen in een loving-kindness meditatie en vonden we dat ze meer mindful werden en ook meer compassie voelden voor zichzelf en anderen.

De tweede vraag waarop wij hebben gefocust in deze studies is die naar het effect van langduriger gebruik op de houding en gevoelens van de proefpersonen jegens de robot. Hier vonden we een sterk effect van nieuwigheid op de interacties. Proefpersonen leerden de robot en de taak snel kennen, wat veelal als gevolg had dat acceptatie van de robot af nam. In deze scriptie zullen we meer vindingen bespreken over hoe de acceptatie van de robot zich ontwikkelde. Het hier besproken werk kan met name in twee opzichten een bijdrage leveren. Hoewel al meer onderzoek is gedaan naar het gebruik van technologische ondersteuning van oefeningen in positieve psychologie, lijkt dit het eerste te zijn dat hiervoor interacties tussen mensen en robots heeft gebruikt. We hebben hiervoor oefeningen ontwikkeld en een inspanning geleverd om deze te valideren en hun effectiviteit te meten volgens de standaarden die binnen onderzoek naar positieve psychologie gebruikelijk zijn. Onze andere bijdrage betreft de voornoemde methodologie van de drie lange-termijn studies. Deze studies zijn namelijk allen uitgevoerd bij de proefpersonen in huis, waarbij we hebben geprobeerd om de invloed en aanwezigheid van de onderzoeker zo veel mogelijk te minimaliseren. Daarnaast bestreken deze studies ook een langere termijn, wat inzichten verschafte in de lange-termijn effectiviteit van de interventies in de ontwikkeling van de houding van de proefpersonen ten opzicht van de robot. Uiteindelijk, gegeven de complexiteit van de bestudeerde fenomenen, hebben we dus gekozen voor case studies om een diepgaand inzicht te krijgen. Dit in acht nemende, hoop ik dat deze inzichten kunnen worden toegepast in toekomstige toepassingen waarbij robots psychologische steun bieden.
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8.2 Contributions of this Dissertation

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Bibliography
Introduction

The number of older people is steadily growing in the industrialized countries (see figure 1.1). In 2008, the number of elderly people in the EU was relatively close to the number of children. However, in 2060 the number of elderly people is expected to be twice the number of children. This is due to a low birth rate, a decreasing inward migration and an increasing life expectancy [37].

We believe that this will lead to a shortage of care staff, leaving many elderly people in need of physical and cognitive assistance. Also care staff might suffer from a heightened mental stress, leading them to burnout [85]. In addition, this growth in the elderly population will lead to an increasing cost for care of the elderly. As a consequence, the need for cost-effective solutions will be greater than ever before [11]. It is therefore crucial that we understand the needs of elderly people in order for us to devise appropriate solutions.

Many of the threats to the independence of elderly people have a physical cause. Walters et al. assessed the needs of elderly people [123] and found eyesight/hearing, incontinence, mobility, accommodation and daytime activities among the most occurring physical unmet needs of elderly people. Another study, namely a systematic review by Luppa et al. [82], proposed cognitive/functional impairment and the associated lack of support and assistance as the most important predictors of nursing home placement.

Technological solutions are being massively explored with the aim to match these needs of the elderly. We refer to this technology as Assistive Technology (AT). [79]. Examples of AT devices are community alarms, video-monitoring systems, health monitors, fall detectors, etc. [89]. AT is showing a great potential at substituting, at least partially, social and medical interventions [63]. It also frees time of caregivers at repetitive tasks and can increase the autonomy of the user.

While we consider it crucial to address the physical problems of the elderly, as we described above, we also find that psychological and social factors greatly determine the wellbeing of elderly people as well. For example, some authors identified factors such as social pressure from others to apply for a place at a nursing home, loss of comfort and loss of affection as main predictors for considering elderly care residence
Chapter 1

Figure 1.1: Evolution of Japanese population in millions.

[108]. Other authors showed evidence of the relevance of self-efficacy and coping in the wellbeing of elderly people [31],[76], [53], [97].

Particularly, low mood and depression seem to be relevant for the wellbeing of elderly people. Depression, defined as a persistent and pervasive low mood together with loss of pleasure in usual activities [96], seems to have a high prevalence among elderly people. About 3% have severe depression and 10 to 15% suffer from mild to moderate depression [16], [21]. According to Steffens et al. [21], depression is one common cause of disability in elderly people. It has been shown to reduce life satisfaction, lead to loneliness, increase the use of medical services, reduce cognitive capacity, etc. As Arent et al. indicate in a meta-analysis [8], it appears that people older than 60 tend to show more mood disturbance (more negative affect and less positive affect). Thus, the application of treatments to improve mood and decrease depression in elderly people seem to be of high relevance. Thus, considering these sources of psychological distress, we could conclude that elderly people also have a great need of psychological assistance in addition to only physical assistance.

A specific form of assistive technology, which can provide both physical and psychological assistance, is the use of socially assistive robots (see section 2.1). Autonomous robots have traditionally been employed in situations where social interaction was not relevant, such as lawn mowing, car industry or space exploration. However, there is a growing number of robots being developed for which seamless interaction with humans becomes crucial [20], or “robots for which social interaction plays a key role” [42], which we refer to as “social robots” or “socially interactive robots”. These robots exhibit human social characteristics such as expressing and/or perceiving emotions; communicating with high-level dialogue; learning/recognizing models of other agents; establishing/maintaining social relationships; using natural cues (gaze, gestures, etc.); exhibiting distinctive personality and character; and learning/developing social competencies [42]. These robots are used for a variety of purposes, including research platforms, toys, educational tools and therapeutic aids [42]. As we just mentioned, social robots can be used to provide psychological assis-
tance. For example, social robots can act as “persuasive machines”, influencing the behaviors, feelings or attitudes of people [42]. Examples of persuasive robots are those whose function is to coach users to reach certain healthy goals (see more in section 2.1).

There are several advantages of using robots for psychological assistance. For example, social robots that mimic animals can act as substitutes of pets when these cannot be directly accessed (e.g. due to allergies or risk of harming the animals). An illustrative example is the robot seal Paro, widely used by elderly with dementia (see section 2.2). Another advantage of social robots for psychological assistance is that their embodiment appears to have an effect on the user, which other non-embodied therapeutic means (e.g. computer-based) would lack. For instance, the robot's embodiment seems to contribute to a higher engagement of the user [66].

As we will see in section 2.2, we find indeed multiple examples where social robots might have proven valuable at providing psychological assistance. For example, by acting as coaches or motivators to reach healthy goals; by acting as pets as already mentioned; or by providing company and conversation, especially with elderly people.

Despite the promising results we find in the literature about care robots, we should remain cautious with respect to their actual application. An important reason is that most people are still reluctant to giving robots a major role in health-care. According to a special barometer issued by the European Union on public attitudes towards robots [39], only 22% of European citizens appear to think that robots should be used as a priority in healthcare (the best rated area of activity was space exploration, with 52% of respondents in favor). In fact, for 24 Member States the care of children, elderly people and persons with disabilities top the the list of areas in which the use of robots should be banned. An explanation for this could be that robots seem to be preferred for activities that involve memorization, good perceptual skills and service-orientation, whereas people seem to be preferred for activities involving judgment, evaluation, diplomacy and artistry [110].

We must also ask ourselves about the feasibility of this type of robots. What specific psycho-therapeutic exercises can we implement in a robot-mediated program? (Some examples are in section 2.2) Also, what population targets are more suitable to receive psychological assistance from robots? In this respect, perhaps elderly people could be especially suitable to receive robots that offer a form a company, since as we saw above elderly people often suffer from loneliness.

The use of care robots raises also legal and moral questions, such as a possible reduction of social contact for the user, a loss of control, a loss of privacy and personal freedom, and a risk of deception and infantilisation of the user, among others (e.g. [106]).

Having introduced the main problems and needs of elderly people, and discussed the potential of assistive robots in this respect, the remainder of this introduction will consist of a Problem Statement and Research Questions, Contributions of this Dissertation, Methodology, and Summary of the Studies and Dissertation Organization.
1.1 Problem Statement and Research Questions

Thus far, we mentioned that the steady growth of the elderly population is leading to shortages of care staff, to more elderly people that need assistance and to higher economic costs. We outlined a few physical and psychological needs of the elderly, underlining the importance of the latter. We then argued for the use of social robots that offer psychological assistance to the elderly.

In section 2.2 we will learn more examples that illustrate the potential of socially assistive robots at fostering psychological wellbeing in their users. Whereas most studies have been based on therapies that tackle specific problems or disorders (e.g. overweight, autism in children), there still remains a lack of research on robots that implement psycho-therapeutic exercises for the general user. Positive psychology (see section 2.3) brings us an array of programs and exercises to strengthen our psychological resources, acting as therapy and prevention. We wondered how effective social robots may be at implementing exercises from positive psychology, especially when applied to elderly participants. Let us formulate this as a research question:

RQ1: How effective can a social robot be at fostering psychological wellbeing in elderly users, implementing exercises from positive psychology?

One crucial aspect of interacting with robots is how these are accepted by users. We could even suspect that the effectiveness of robot-mediated programs for psychological support is going to be greatly determined by the perceptions and attitudes of participants towards robots. Thus, we considered this to be a relevant research question to study. We know that users’ attitudes and perceptions toward robots tend to shift over time, for instance due to the so-called “novelty effect” [69]. Exploring the effect that time has on users’ acceptance of robots becomes particularly relevant when the tasks for which the robots have been designed (in our case, positive psychology programs) take place over long periods of time. This leads us to formulate the next research question as follows:

RQ2: How do the perceptions and attitudes toward a home assistive robot evolve over a prolonged period of time?

Finally, we could wonder about the ideal scenarios for such psycho-therapeutic robots. For instance, would they work best in nursing homes or in the participants’ houses? We chose the latter setting because of our participation in the European project ACCOMPANY, which targets independent living elderly people. We also decided that deploying our robots in the homes of participants would yield more real-life results as compared to studies performed in the lab. With this in mind, we wondered how such robots would alter the daily routines of participants, leading us to the last research question:

RQ3: How are a participant’s daily routines altered when an assistive robot stays in his/her home for a prolonged period of time?

Hence, these research questions became the three areas of interest that we explored throughout the studies presented in this dissertation.
1.2 Expected Contributions of this Dissertation

We hope that this dissertation will contribute to the general advancement of socially assistive robots with psychotherapeutic purposes. While most of the research in robots for psychotherapeutic support has so far focused on participants with specific needs (e.g. children with autism, see section 2.2), we believe that the methodologies that will be described in the studies of this dissertation could also be used in the general population.

We are particularly referring to the use of positive psychology in HRI research. We already knew of studies on positive computer applications (e.g. [103]), but to our knowledge the link between positive psychology and social robots had not been yet established. We intended to bridge these two fields in our research, making a special effort to build valid positive programs, based on previous ones that came in more conventional formats. To measure the effectiveness of these programs, the same methodologies and tools should be used as by other researchers in positive psychology.

Besides the application of positive psychology exercises, we intended to explore other methodological aspects. Aiming to maximize the ecological validity in our studies, we will present in this dissertation a specific combination of methodologies. We are referring to the performance of research in the homes of the participants, aiming to minimize the involvement of the researcher; to the extension in time of the studies, studying the long-term effectiveness of the interventions and the evolution of the participants’ attitudes toward the robot; and to the case study methodology, employed to attain in-depth results. With this in mind, we hope that the insights achieved in this work could apply to future, real applications of psycho-therapeutic robots.

1.3 Methodology in this Dissertation

In this subsection we will address some specific methodologies that we have employed throughout our studies, including laboratory and field studies, distinguishing between short- and long-term studies, describing the case study methodology and introducing the Wizard-of-Oz technique.

1.3.1 Lab and field studies

While we can distinguish between analytic and empirical evaluation [128], the present dissertation has employed the methodology of the latter. In empirical evaluation users are integrated in the evaluation process, gathering facts through different methods such as observation or questionnaires [128]. Empirical evaluation can be carried out in two manners: through laboratory studies and through field studies [36]:

- Laboratory studies are better controlled tests. Laboratories are often equipped with audiovisual recording equipment and materials to aid the analysis. The main advantage is that the participant operates in a controlled environment. However, the artificiality of the situation makes it more difficult to generalize the results to real life situations [128].
• In a field study the researcher dives deep in the user’s environment to observe the interaction of the user with the system in its natural context. This natural situation would be lacking in a laboratory study. The main disadvantage in this case would be the lower control over the variables that might have an influence over the results, hence making the results more difficult to interpret.

1.3.2 Short- and long-term studies

In this dissertation we include short-term as well as long-term studies. The main advantages of short-term studies are that data can be collected from a large number of people and these data are comparable, since the participants do not develop differences due to time lapses. On the other hand, the main advantage of long-term studies is that changes over time can be studied in the participants. Short- and long-term studies could be likened to cross-sectional and longitudinal studies, respectively, with the exception that the last two types are observational, that is, the participants do not undergo any experimental treatment [9].

Few long-term HRI studies have been conducted, thus the temporal dimension of robot acceptance, among other aspects of the interaction with robots, have been understudied [29]. In our case, we have predominantly carried out long-term studies. One reason is that we were interested, as mentioned above, in the development of robot acceptance over time. On the other hand, the psycho-therapeutic programs at which our robots aided were expected to be effective only after extensive periods of time [46].

1.3.3 Wizard-of-Oz (WoZ) technique

A commonly used technique in HRI research is the Wizard-of-Oz (WoZ) technique. This refers to a person controlling an array of behaviors of the robot remotely, such as voice, movements, gestures, etc. WoZ may be applied partially or totally to a robotic system [98]. Very frequently, WoZ is applied without the knowledge of the participant, aiming to create the impression that the robot is autonomous instead of teleoperated. The main argument of researchers for employing WoZ is that robots are not advanced enough yet to react as desired to the very complex situations they often are embedded in.

In most of the studies here reported a robot was situated in a real-life environment. Since the difficulty of appropriately reacting under such complexity was enormous, we almost always used the WoZ technique. We also concealed this fact from the participants as we intended to present the robot as an autonomous agent.

1.3.4 Case studies

A case study is an empirical inquiry which focuses on a phenomenon within its real life context, whereby the boundaries between the phenomenon and its context do not appear clear [130]. This makes case studies useful to investigate complex social phenomena. Case studies are suitable when we intend to answer questions like “how” or “why”, when the researcher has limited control over behavioral events and when the phenomena to be studied occur in their real-life context [130].
We have heavily relied on this methodology despite its lack of use in HRI research. By conducting case studies we hoped to better face the intricacy of the attitudes toward a robot as these develop over time, as well as the true origin of the psycho-therapeutic benefits of the robot interventions.

1.3.5 Mixed methods approach

In the studies presented in this dissertation we relied to a great extent on qualitative methods, such as semi-structured interviewing [24]. We decided to strengthen the methodologies of these studies, particularly the case studies, by also taking quantitative measures, such as questionnaires. This is what is known as mixed methods research [90]. More specifically, we followed the convergent approach, also referred to as triangulation or cross-validation. In the triangulation approach the goal is to produce similar results from methods that have different strengths, while addressing the same research question. This has the benefit of producing greater certainty in the results, by showing that both qualitative and quantitative methods lead to similar conclusions [90].

1.4 Summary of Dissertation Studies and Dissertation Organization

The remainder of this dissertation is organized as follows:

Chapter 1 offers a theoretical background for the most relevant subjects that occupy this dissertation, namely robots in healthcare, focusing on robots for psychological support, and psychological wellbeing and positive psychology.

In Chapter 2 we present two studies in which we aimed to learn firsthand about our main target group, that is, independent living elderly people. In the first study we gathered deep insight on what the daily life of elderly people is like, learning about their problems and needs, their dreams and hopes. A relevant finding was the great importance that psychological aspects, such as self-efficacy, mood and loneliness, have in the lives of elderly people. In the second study, we explored the attitudes that elderly people have toward care robots, revealing for instance what functionality these potential users would want to have in a care robot.

Chapter 3 includes our first study in which a robot was used. This was a short-term, lab-based study where we applied the three-good-things exercise from positive psychology to the interaction between the robot and the participants. In this case we used the WoZ technique. The results underline the great impact that the framing (instructions) of the exercise in question can have on the effectiveness of the intervention.

In Chapter 4 we present our first long-term study, in which a home robot reminded and motivated an elderly user to perform a meditation exercise. We deemed it necessary to extend the interaction period with a robot hoping that the psycho-therapeutic value of the program would have some significance. Also, by extending the interaction time we could observe how the attitudes of the participant toward the robot developed over time. This was a case study, which took place in the home of the participant. In this study the robot was fully autonomous. Regarding the psychotherapeutic value of the program, we found indications that the participant progressively
improved his performance of the meditation exercise. As for his attitudes toward the robot, this was regarded as a machine/tool rather than as a companion.

The study in Chapter 5 had a similar methodology to the previous study. However, in this study we emphasized the presentation of the robot as an autonomous robot capable to some extent of engaging in casual conversations and understanding the user. This way, we aimed to explore the role of the robot as a companion and its effects on loneliness. In contrast to the study in Chapter 4, we employed the WoZ technique and the three-good-things exercise became again the basis of the interaction. We found indications that the intervention might have reduced the feelings of loneliness of the user, and in contrast to the previous study the robot was perceived as a companion in several manners.

We had observed in the long-term studies of Chapters 4 and 5 how the adherence to the exercises and the attitudes toward the robot quickly worsened over time. Thus, in Chapter 6 we present another study, in which we hoped to create more long-lasting psycho-therapeutic effects by incorporating an exercise of Loving-Kindness Meditation (LKM) in the interaction with the robot. We used this exercise because it presents the most long-lasting beneficial effects reported in positive psychology. The rest of the methodology of this study was analogous to that of Chapter 5. We found indications that a social robot might be a valuable means to assist users at a LKM program, since our participants seemed to develop loving-kindness qualities during the intervention.

Finally, the dissertation will finish with a discussion and conclusion.
With this chapter we aim to introduce the reader to the main subjects that form the basis of the research presented in this work. The first topic regards robots in healthcare and, more specifically, robots that offer psychological support. As we pointed out earlier, assistive robots have shown a great potential combating the problems associated with the elevated growth of the elderly population. Thus, the first subsection probes the literature on robots used in healthcare, focusing on robots that provide psychological support.

We also pointed out that the psycho-therapeutic programs that we would implement in the robot’s interactions would be based on positive psychology programs already tested. Hence, the second subsection will offer a brief introduction to positive psychology and the exercises that we have adapted for the studies presented in this dissertation.

### 2.1 Robots in Healthcare

While social robots have been categorized by different criteria, such as their morphology or their personality [42], we would like to categorize assistive robots according to their area of application. While occasionally overlapping, we could distinguish four types of assistive robots: surgical robots; robots for physical rehabilitation; home robots; and robots as companions and coaches.

Studies on surgical robots are very task-specific and usually place the emphasis on the ergonomics. For example, Berguer and Smith compared the efficiency of laparoscopic surgery (a surgical technique that involves small incisions) with robotic interventions and concluded that, for simple tasks, the robotic technique seemed to be slower and less precise, whereas for complex tasks both techniques showed a similar performance [18]. Similarly, Wasén explored user-friendliness of surgical robots in a qualitative case study of professional clinicians. For example, he found that person-friendly interactions were usually designed to support the operating surgeon but not the other members of the operation team [124].

The second context for care robots is rehabilitation. Here we refer to robots that
help patients recover from an operation or cope with a disability. Most studies focus predominantly on the tasks that patients must perform and the therapeutic results of the interventions. For example, Lancioni et al. [73], [74], [75] investigated how rehabilitation robots effectively improve the performance of people with multiple disabilities at certain tasks. In another study, the same authors gave participants the possibility of choosing between different occupational intervention settings. They found that it proved to be effective in fostering independent activity. The authors tested the usability of a rehabilitation robot that helped in various activities (such as transporting objects between two places) and found that the users easily learned to use the robot [74]. In another study by the same authors [75] they compared the participants’ performance at tasks with robot-assisted ambulation (robotic help to move around in a room) and un-assisted ambulation. Participants in the robot-assisted condition of the study showed a higher performance at independent activities and higher percentages of ambulation.

On the other hand, there are also studies that are based on robots for rehabilitation but with a focus on the social interaction between the participants and the robot. For instance, Wade et al. [122] investigated how post-stroke patients interacted with Bandit, a socially assistive humanoid robot designed to guide the users when they were performing certain tasks. Among other results, users interacted less with the robot when the concentration required was high, although in general the robot could be used to guide and motivate the patients during the tasks. Tapus et al. [113] worked with post-stroke patients and a socially assistive therapist robot that helped in rehabilitation exercises. They focused on the relationship between the level of extroversion-introversion of the robot and the user, and found evidence for a preference of personality matching (robot and user with a similar level of extroversion-introversion).

Regarding the third type of care robots, we will refer to the greatly heterogeneous group of robots that facilitate care at home or in nursing homes, in most cases to elderly people. Examples of robots employed in research projects or released to the market are: PEARL (figure 2.1) [35], Wakamaru (figure 2.2) [93], RI-MAN (figure 2.3) [92], Care-O-Bot III (figure 2.4) [55], RIBA (figure 2.5) [91] and Giraff (figure 2.6) [71]:

Typically, these robots perform several of the following functions:

- Tele-presence and remote communication: facilitating the communication and supervision by carers and relatives (e.g. Giraff [71]).
- Coaching: for example, the robot offers mental stimulation (e.g. PEARL [35]).
- Companionship: for example, the robot is able to participate in natural language conversations (e.g. Wakamaru [93]).
- Reminding: for example, the robot reminds the user of appointments, important dates, drinking water and other daily life tasks (e.g. Care-O-Bot III [55]).
- Data collection and surveillance: for example, the robot can warn the carers about an unusual behaviour pattern (e.g. Care-O-Bot III [55]).
• Emergency handling: for example, the robot can detect a fall and make an emergency call (e.g. Wakamaru [93]).

• Manipulate the environment physically: a few robots have arms that allow them to remove obstacles, bring objects, lift the user, etc (e.g. RIBA [91]).

Early robotic projects to assist the elderly (1995-2005) developed robots with a strong emphasis on mimicking humans. For instance, they were endowed with human-like heads. This anthropomorphization turned out to be detrimental as it raised too high expectations about the robots abilities [34]. More recent projects present robots as household appliances or intelligent devices, even though they may still present a personality [7].
Thus far, we have given illustrative examples of robots that have been employed in multiple contexts within health-care. In some cases robots were related to research projects, whereas in other cases they have been deployed by carers for therapeutic purposes, or both. A successful example is the robot seal Paro (see next section), for which certification classes are offered at several care centers [4].

Bearing in mind that a great overlap exists in the functionalities and use of healthcare robots, we will dedicate the next section to the fourth group of robots: those that aid users mentally, psychologically and/or socially.

### 2.2 Robots for Psychological Support

We will dedicate this section to robots for psychological wellbeing and motivation given their relevance for the present work. According to what we find in the literature, we could subdivide these robots into those that act as coach/motivator, pet robots and robots that engage in conversation with elderly people.

One way robots are envisioned to improve the wellbeing of users is by guiding and motivating them to perform healthy activities. For example, in a study by Fasola and Mataric [40] a socially assistive robot played with elderly people through a series of interactive activities that involved physical exercise. Its performance was compared across two conditions. In one condition the robot displayed behaviors known to improve one’s intrinsic motivation, such as praising the user upon completion of an exercise, providing reassurance in case of failing, showing humor or calling the participant by name. In the other condition, none of these features were included in the robot’s behavioral repertoire. Their results indicated strong user preferences for the motivating condition over the neutral condition.

Tapus et al. [112] also employed social robots to coach elderly people, in this case with cognitive impairment. In their study, participants interacted in a long-term set-
Obesity is another context where robots have been employed for psychological support or motivation. Kidd and Breazeal investigated the effects of a robot that had the role of a weight loss coach. Its effectiveness was measured and compared to the effects of using a computer or a paper log. The results showed that even though only minimal differences were found in weight loss across the three conditions, the participants used the robot for a longer time and reported a closer alliance with it [66]. Similar results were achieved by Looije et al. [81], who found that an iCat robot was preferred to a text interface. In their case, the aim was to test whether a socially intelligent robot was able to change the behavior/lifestyle of diabetics.

Some researchers have studied the effect that social robots could exert on children with autism (figure 2.8). For instance, Robins et al. investigated the positive influence that a social robot might have on autistic children when the interaction was extended in time. A meaningful outcome in this research was that the children, once accustomed to the robot, opened themselves up including the investigator in their own world, willing to share their experiences with him and their carers [99].

Children with diabetes have also participated in studies with robots that performed as coaches. For example, Henkeman et al. [62] assessed how certain robot behaviours could have an impact on the enjoyment and motivation of children with diabetes, as well as on their acquisition of knowledge about diabetes. They found that children rated the robot as fun, experiencing a state of “flow” [27], and also effectively increased their knowledge on diabetes.

Another way of employing robots for psychological wellbeing is through pet robots. Pet robots are a popular type of assistive robots, with the seal robot Paro [121] (figure 2.9) as the example par excellence. Paro has been widely used to improve the mood of elderly people and mitigate the symptoms of those with dementia [121]. We often find in the literature how Paro is brought to nursing homes where older people hold the robot and interact with it [84], [120], [119]. Paro’s benign appearance and pleasantness to touch facilitates the user’s attachment to the robot. It has often been used in nursing homes in long-term experiments. Some of the many reported positive effects of interacting with Paro are general improvement in feelings of the participants [84],

**Figure 2.7:** Autom robot developed as weight loss coach.
Chapter 2

Figure 2.8: The Kaspar robot was employed to improve the social skills of autistic children.

Figure 2.9: Seal robot Paro.

[10], [67], [111] and reduction in depression [119]. Other pet robots such as the dog-like Aibo [10], [67], [111] and the cat-like robots NeCoRo [41] and Cat Robot [114] may have the potential to play a similar role as Paro. For instance, Banks et al. [10] found that both a living dog and the robotic dog Aibo effectively reduced the level of loneliness in elderly people who lived in long-term care facilities, with no significant differences in their performance.

Finally, other studies have focused on the verbal interaction between the robot and the participants, typically aiming to provide some sort of company. For example, Sabelli et al. [100] described elderly participants’ reactions to a conversational robot that was placed at an elderly care centre for 3.5 months. The robot seemed to be accepted into their community and the elderly appreciated particularly some behaviours such as its daily greeting and to be called by their own name. Heerink et al. [61], [57], [60], [58] explored the effects of robots that are sociable, expressive or socially communicative to a higher or lower degree. Higher levels of these qualities elicited feelings of comfort and an enhanced expressiveness towards the robot. Klamer et al. carried out a long-term study involving elderly people and a Nabaztag robot [68]. Endowing the dialogue robot with social intelligence seemed to yield positive results in the interaction with the human. Namely, it may contribute to a better perception of technology, an enhanced acceptance and more social behaviors toward the robot.

Figure 2.10: Nabaztag robot.

Thus far, one crucial aspect that has been researched in these studies is the effectiveness of the treatment or coaching program on the participants’ wellbeing. Like-
The theoretical background of this thesis will focus on the therapeutic value of social robots. However, another aspect we consider crucial in this type of studies is how people react to these robots, what perceptions and attitudes people experience toward them. These two areas, as will be shown, will be greatly interrelated.

To conclude, we have seen how robots can, occasionally, help fulfill not only physical, but also psychological needs. Robots have been used to coach users to increase or improve specific behaviors (e.g. in order to control diabetes); to combat loneliness and depression of vulnerable participants; and to improve the social skills of autistic children. In the next section we will introduce the field of positive psychology, from which we adapted most of the psychotherapeutic exercises included in this dissertation.

2.3 Psychological Wellbeing and Positive Psychology

In the second half of the 20th century, psychology largely focused on mental disease and healing, paying little attention to the attainment of happiness and excellence, for which people strive under more benign circumstances [105]. Aiming to broaden the focus of psychology, Seligman and Csikszentmihalyi laid the foundations of the field known as positive psychology, referring to studies that address valued subjective experiences (e.g. wellbeing, hope and flow), positive individual traits (e.g. courage and forgiveness) and civic and institutional virtues (e.g. tolerance and moderation) [19, 43, 105]. Within the framework of positive psychology, exercises have been proposed and empirically tested that can foster psychological wellbeing and combat depression. For instance, Seligman et al. carried out an Internet study where participants could perform five different exercises for a period of one week. The authors compared the efficiency of the exercises in increasing levels of happiness and reducing depressive symptoms [103]. One of the most successful techniques employed in their study was the so-called “three good things” exercise.

We envision three main advantages of positive psychology interventions in HRI. First, positive psychology offers exercises that have already been empirically tested by professionals in psychotherapy. Second, positive psychology interventions are not only aimed at patients suffering from a psychological disorder, but they are also administered as preventive means [104], strengthening the psychological, social and material resources of the recipient [43]. Third, the fact that positive exercises do not necessarily focus on specific target groups makes them greatly generalizable [104].

In the next subsections we will describe the positive exercises that we implemented in our studies.

2.3.1 The three-good-things exercise

This an exercise that we will address in two of the studies of this dissertation, given its great efficacy and popularity [103], and also because we considered it easier to implement in a robot compared to other positive exercises.

The three good things exercise consists in writing down three things that went well on the current day, together with their causes. Seligman et al. reported in their study that its beneficial effects progressively increased even after six months from the
intervention, due to the fact that some participants spontaneously decided to carry on with the exercise after the one-week experiment [103].

This positive exercise belongs to the greater group of gratitude lists, which involve writing things on a regular basis for which one is grateful [129]. Gratitude lists have been proposed to enhance psychological wellbeing [129] and have the advantages of being easy to set up as online self-help interventions, are low cost and can greatly extend the accessibility of psychological services for the general population [129].

We feel that gratitude may have great relevance in psychotherapeutic contexts. For example, Emmons and Mishra propose an array of explanations about why gratitude promotes wellbeing. Enumerating these: gratitude facilitates coping with stress; it reduces toxic emotions resulting from self and social comparisons; it reduces materialistic strivings; improves self-esteem; enhances accessibility to positive memories; builds social resources; motivates moral behavior; grateful people are spiritually minded; gratitude facilitates goal attainment; and it promotes physical health [38].

2.3.2 Mindfulness meditation

We employed mindfulness meditation in two of our studies because of its great effectiveness and popularity. Also, because its feasibility to be implemented as part of the robot's behaviors (knowing the meditation program beforehand, it is relatively easy to make the corresponding protocol for the robot's behaviours). In addition, we considered mindfulness meditation a good exercise to explore longer-term effects in long-term studies, given that we expected that the most significantly beneficial effects would appear in the long run.

Kabat-Zinn offers the following operational working definition of mindfulness: “[it is] the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment” [65].

With mindfulness meditation we refer to the engagement in mindfulness. Such engagement can take a variety of forms, ranging from exercises that are performed for certain periods of time on a regular basis, to more informal practices that aim to cultivate a sense of awareness in all daily activities [65]. One of the most common exercises in mindfulness meditation consists in directing one’s awareness into one’s breath, without to alter it, in a nonjudgmental way [12].

Mindfulness meditation has proven to reduce stress and anxiety as well as depressive symptoms [80]. It appears to also contribute to an improved cognition and concentration, among others [88]. In addition, it has been shown that mindfulness meditation can help elderly people reduce feelings of loneliness [26].

2.3.3 Loving-kindness meditation

We implemented loving-kindness meditation (LKM) in our last study as a response to the previous study, whereby the adherence and effects of the positive exercise appeared short-lasting. Namely, one limitation to the effectiveness of positive psychology interventions is the so-called hedonic treadmill effect. This refers to the fact that, after the occurrence of good or bad events, people quickly return back to their
neutral hedonic levels [33]. This effect causes emotion-elicitation techniques to tend to fail in the long run as the novelty effect dissipates. Nevertheless, loving-kindness meditation has proven particularly successful outspacings the hedonic treadmill effect [44].

LKM meditation aims to cultivate feelings of warmth and caring toward oneself and other people [101]. It usually starts with the contemplation of one’s breath as in mindfulness meditation. Subsequently, the practitioner directs specific, benevolent thoughts and intentions towards him-/herself and other persons [101].

This type of meditation increases the daily experiences of positive emotion, enhancing in turn other personal resources such as mindfulness, purpose in life, social support, life satisfaction, etc., while decreasing illness and depressive symptoms [44].

2.4 Conclusion

Thus far, we have explored the state-of-the-art of healthcare robots and we learned about their multiple applications, such as telepresence, surveillance, etc. We focused on social robots that bring about beneficial psychological effects. Two successful examples of this are the Paro robot and the research conducted on robots and autistic children. On the other hand, we introduced the field of positive psychology, which has the aim of, rather than treating psychological disorders, preventing these from happening and fostering subjective valued constructs such as happiness and contentment. We also considered that the three-good-things exercise, as well as mindfulness and loving-kindness meditation, could be suitable positive exercises to be implemented in human-robot interactions.

As we mentioned in the Introduction (section 1), the overlap between social robotics and positive psychology remains still to be explored. In addition, studies on healthcare robots that follow in-situ, long-term methodologies (see section 1.3) are rather scarce. This research gap has greatly motivated our choices expressed in the present dissertation.

Several theoretical constructs will often guide the results throughout the remainder of this work. Regarding the interaction with robots, the concepts of “novelty effect” (section 6.1) and “adherence” (section 7.2.3.2) will frequently appear. With respect to the beneficial effects that robots can exert on people, the constructs “positive affect” (section 4.2.4.1), “happiness” (section 2.3), “compassion” (section 7.2.3) and “loneliness” (section 3.1.2.1) will be most relevant.

In the next chapter we will learn about the main target group in this dissertation, that is, independent living elderly people. It will also have a certain introductory character so as to prelude the full studies reported in subsequent chapters.
We learned in the introduction about the problems and needs of elderly people, and how these will be aggravated by the current growth in their numbers. In this chapter we aim to learn more about elderly people, more specifically about those that live independently, given that they are the main population target of the studies presented in this dissertation. To this end, in this section we will summarize and adapt two studies which gathered firsthand insights. (For the complete versions of the studies, the reader may access deliverables D6.1 [51] and D6.5 [48] of European project ACCOMPANY [1], which correspond to the first and second studies here summarized, respectively). The first study intended to explore the daily lives of independent living elderly people through a series of in-depth interviews, hopefully gathering a significant insight on their needs and problems, hopes and dreams. Also, this insight helped us propose robot roles that could be useful to foster independence and wellbeing in elderly people. This study is chronologically the first in this dissertation and greatly motivated the choices and direction for the rest of the studies here included. As we will see, this study emphasized the relevance of psychological support for the wellbeing of older adults. Thus, it contributed to the decision on the first main research question of this dissertation: how effective can a social robot be at fostering psychological wellbeing in elderly users? Also, in this study we learned more about the daily lives of elderly people, which would prepare me to address the third main research question: how are a participant’s daily routines altered when an assistive robot stays in his/her home for a prolonged period of time?

Whereas in the first study of this chapter we will learn about elderly people’s lives without having asked them explicitly about robots, in the second we will precisely focus on their attitudes toward care robots. The report on this study will consist in an adapted summary of a focus group study on robot acceptance that we carried out for the ACCOMPANY project. Since this study yielded some valuable insights on how older adults accept care robots, it may contribute to a better understanding of the second research question: how do the perceptions and attitudes toward a home assistive robot evolve over a prolonged period of time?

This chapter is therefore subdivided into a summary of the first study, which ex-
explores the lives of independent living elderly people; the second section, consisting in an adapted summary of the study on robot acceptance; and an overall conclusion.

3.1 Exploring the Lives of Independent Living Elderly People

Some studies have explored the daily life of elderly people and their activities. For instance, Horgas et al. [64] interviewed older persons and gathered significant insight on how aged people spend their time. For example, obligatory activities (e.g. self-maintenance) take place most frequently during the day. Leisure activities occupy most of elderly people’s time, which are almost completely restricted to watching TV and reading. Resting also takes up a large portion of the day, namely about three hours. The authors also report a great variation in how aged people spend their time. They suggest as well that observing elderly people’s activities can provide insight into their goals, motivations and successful aging. For instance, a person who spends most of the day resting would indicate a worse aging compared to a person that spends his/her time participating in multiple activities [64].

In contrast to Horgas et al. [64], our study did not aim to quantify how aged persons spend their time, but to have a deeper understanding of the meaning of their activities, learning about their internal world, their motivations and their feelings.

The remainder of this subsection will consist of the methods, the results and a discussion on the first study.

3.1.1 Methods

For this study we employed the contextual analysis methodology [56], conducting in-depth interviews in the actual homes of the participants. In the remainder of this section we will describe the participants, measures and instruments, procedure and data analysis, respectively.

3.1.1.1 Participants

The data came from seven participants, addressed in this paper with fictional names to protect their anonymity: Esteban (87) and Paca (83), who were living together as a married couple; Estefana (89), who had been living with Pedro (71), her son-in-law, since the recent death of her daughter; and Ana (67), Tania (70) and Nadia (72), each of whom lived alone. Their ages ranged from 67 to 89 and the average age was 77. All lived in Mostoles, a city near Madrid, Spain, and had at least one child living nearby. As well as the choice of the country, the participants were a sample of convenience. Some of them knew each other: Tania and Ana were members of the church group of a recruiter that helped the interviewer and Nadia was the neighbor of Esteban and Paca. All participants lived at home and did not receive formal care.

3.1.1.2 Measures and instruments

In-depth semi-structured interviews [24] at the participants' homes were chosen as the method for data collection. We made interview questions to gather valuable information about elderly people’s daily lives, activities, people and things that have an
important role in their lives. Through these questions we also explored their needs, their problems and the solutions the participants found to these.

Before the preparation of the interview questions, a brainstorming session took place where four participants (the author of this work together with three other members of the same department) presented ideas about how to conduct the interviews and what questions they should contain. The questions explored functionality and activities from the International Classification of Functioning (ICF) of the World Health Organization (WHO) [5], Instrumental Activities of Daily Living (IADL’s) [107], potentially useful robot roles according to the brainstorming session and literature [28], [22] and factors that might lead aged people to give up their independence [108].

The questions that formed the interview were open and for each topic they started by being very general and becoming gradually more and more specific. For example, the first question of the interview was: “How are you? Tell me something about your current life so that I get to know you a little bit.” As another example, regarding the specific topic of walking, the progression of the questions would be: “How is walking for you? How is walking at home? How is walking outdoors?”, etc.

The interview questions were written and printed as part of an interview protocol script. This was complemented by another script containing questions to seek information about activities, roles and problems/solutions.

For the activities and situations included in the interview protocol script and other activities that the interviewee might bring up during the interview, the interviewer would ask about details concerning the activity (i.e. “under what circumstances do you perform that activity?”), the roles involved (i.e. “who is present during the performance of the activity?”, or “who does it?”) and corresponding problems and solutions (i.e. “do you find it boring or entertaining?”, or “what helps you make it better?”)

3.1.1.3 Procedure

A first interview was conducted as a pilot with an independent living older adult and several questions were removed from the interview script or modified as a result. Subsequently, the same interviewer visited the participants at their homes. After the introduction a brief explanation of the purpose of the study was given, emphasizing the importance of learning about daily routines of elderly people. The fact that the data would also serve to identify useful robot roles was not made explicit before the interview in order not to bias the participants’ responses. Before the interview commenced, the participants were given a consent form that they read and signed, which assured them that the discussion would be confidential and that they had the freedom to stop the interview if they wished. The participants were audio and video recorded during the interviews, which took approximately 2-3 hours. After the interviews the audio data were partially transcribed into English, leaving out most of the comments not considered relevant for the study (for example, long remarks about other people, politics, etc.)
3.1.1.4 Data analysis

The transcribed data were analysed according to the affinity diagram method [14]. Similar to grounded theory, this method encourages no preconceptions about the meaning of the data, allowing groups of concepts and their relationships to emerge.

From the transcribed interviews we created sticky notes containing key points. Key points concerned the research questions, problems, common patterns or influencing factors that could significantly impact the participants’ daily life. As an example, information about a household task that seems difficult to perform would be considered a key point. These key points mostly consisted in participants’ quotes, or alternatively in observations noted during an interview.

The sticky notes were shuffled and two researchers from our same research team sorted them interactively and stuck them onto a wall, while grouping together those aspects that seemed related: limitations, care, activities, social life, “I’d like to, but I don’t”, attitudes, facing problems, memory, religion, depression, anxiety, happiness, hygiene, open spaces and safety. Groups that represented similar topics, such as anxiety and depression, were situated next to each other. Also, within groups, sticky notes with similar content were placed close to each other. New rearrangements took place among the notes interactively and finally the groups were labelled.

Figure 3.1 and figure 3.2 show the resulting affinity diagram.

3.1.2 Results

A detailed description of the results obtained during the interviews is provided below. The following subsections do not correspond with the clusters identified in the affinity diagram. Instead, the results have been regrouped into health and psychological factors; physical tasks, leisure and social life; and roles played by people and technology, hoping to show the results in a more comprehensible manner that fits the structure of
the discussion in this subsection.

3.1.2.1 Health and psychological aspects

All participants mentioned health complaints that impacted their daily life. Esteban and Paca were the participants who seemed to have the weakest health status. In most cases, these health problems involved a reduction in mobility, which implied in turn less frequent social interactions. For example, Estefana stated “Many friends ask me to attend activities, but I don’t go because of walking problems.” Other health issues of the participants concerned heart disorders, and eyesight and hearing impairments. Except for Estefana and Nadia, the participants believed they had a bad memory. The associated memory problems ranged from small memory lapses to not cooking in order to prevent accidents (Pedro).

With the exception of Nadia, participants reported difficulties sleeping, which they tried to compensate for by using sedative pills. These difficulties often seemed to have a psychological origin, such as worries or obsessive thoughts (for example, about a child’s welfare).

All participants seemed to be concerned about their future, in particular about becoming frailer and giving “trouble” to their children. Esteban and Paca were especially concerned about their health at present and how it will worsen over time. Nadia was sometimes worried about financial issues. Welfare of children and other relatives was also a major source of preoccupation. Another common worry concerned their safety at home, for example they were afraid that burglars might break into their homes.

The aforementioned worries seemed to be associated with anxiety and a depressive mood, having a big negative impact on most of their lives. Esteban and Paca reported several times how sad they felt. Ana talked about her nervousness: “I sleep very badly because I’m a nervous person. Also because I think about problems.” Tania’s anxiety towards her children in general and her son in particular seemed to affect her. Her husband had died a few years ago and she often felt down. She said: “Sometimes I find it difficult to get up from bed because I’m depressed.” Estefana seemed to be a person with a strong character. However, the grief over the death of her daughter had caused her intense feelings of depression. Estefana, Paca, Ana, as well as Tania, all cried at some point during the interview.

When asked what they do when they are worried, all except Nadia explained that they take a tranquilizer or a relaxing infusion. Nadia explained her strategy: “When I’m worried I try to fight the thought, or I try to keep my mind busy.” Another strategy they reported was to go out for a walk. They discussed their problems mostly with their children, although Tania liked to share her problems with friends and Nadia discussed her problems with friends exclusively.

Another frequent complaint that seemed to have a significant impact on their lives was a feeling of loneliness. Esteban and Paca referred several times during the interview to their loneliness. For example, Esteban once said: “Our problem is that we suffer from ‘lonelinitis’.” Also Tania and Ana reported feeling very lonely. Interestingly, those who reported most loneliness seemed to have frequent social contact. Esteban and Paca were visited every day, especially by relatives and occasionally also by friends. Tania had an active social life that included children, friends, church group,
and various volunteering activities. During a break in the interview with Ana, her daughter revealed to the interviewer: “Actually she’s every day in our houses, she’s never alone, at least on working days.” When asked about feelings of abandonment, no participant reported feeling abandoned.

Next to worries and feelings of loneliness, a reduced willingness or ability to perform certain activities was found in some participants, which did not seem to relate just to a general poor health but also to lack of motivation. For example, even though Esteban and Paca seemed to have certain disabilities, especially regarding mobility, there were home chores performed by their grandson or others that they could have performed for themselves. It seemed that they, on one hand, and their family on the other, had accepted this delegation of tasks. When they were not aided, they indeed fulfilled some of these chores without help, such as bathing or cooking. Ana mentioned many activities that she would like to do or to change while she actually did not. For instance, she said once: “I have more clothes but I always wear the same. I’d like to dress better but I don’t. I get in such a mood that I don’t care.” She had excuses for not performing some of those activities which may not seem difficult for us to overcome: “I don’t read because I didn’t go to school” (she had the ability to read). She also showed negative impressions about her abilities: “If they had to do groceries for me, I’d feel even more useless than I am already.”

Also, some participants seemed to show signs of lack of confidence during the interview. For instance, Pedro asked very frequently whether he was participating correctly in the interview. He excused himself often before starting a statement by saying “I don’t know, I’m very ignorant, but I think that” He also reported that he felt insecure sometimes while performing activities such as card playing or reading and then he stopped.

Finally, all interviewees expressed in different forms a need for open spaces. For example, Nadia liked the views from her window, which included a garden with trees, and regretted not having a balcony. She considered that going out is important: “If you stay alone at home too long, you start to feel lonely and become obsessed with certain things.”

Thus far, our findings seem to indicate that health issues play a major role in the lives of elderly people. Crucially, however, psychological distress also seems to be also of great influence in their lives, particularly under the shape of depression, feelings of loneliness, low self-esteem and low self-efficacy.

3.1.2.2 Physical tasks, leisure and social life

The participants reported spending most of the daytime performing leisure activities and resting. Household chores were carried out mostly in the morning, so that they could have more free time in the rest of the day. These results are in accordance with the findings of Horgas et al. [64].

All participants, with the exception of Esteban and Paca, reported to cope very well performing Activities of Daily Living (ADL’s) and Instrumental Activities of Daily Living (IADL’s) [107]. The most problematic activities at home were hanging/taking down the curtains, cleaning the upper parts of bathroom and kitchen and cleaning the windows. Some interviewees mentioned challenges also in using electrical appli-
ances. Except for Paca, all participants did their own groceries with certain regularity. Being alone at home after having children around seemed to have reduced the frequency of activities such as cooking and sewing.

Watching TV was the leisure activity on which they spent most time, as also found in Horgas et al. [64]. Other common indoor leisure activities were reading, sewing, knitting and cooking (the last three can be considered as hobbies or household chores depending on the participant). Nadia was the only participant that used a PC and an e-book reader. Four of the interviewees lived in pairs, which allowed them to perform certain activities together. For instance, Pedro and Estefana played cards daily.

Regarding physical activity, Tania, Nadia, Pedro and Estefana used to go or were still going to a sport center where they could participate in special activities for the elderly. In addition, Tania and Nadia tried also to walk frequently to stay healthy.

With respect to the social life of the participants, most of it revolved around their children and grandchildren. Except in the cases of Tania and Nadia, contact with friends was infrequent. Visits by children and grandchildren took place usually on a daily basis. They also received daily phone calls from their children, usually several times per day, and as with visits they tended to receive the phone calls rather than to initiate them. Some participants were doing activities outside the home that involved social contact. For instance, Tania participated every week in NGO activities because she liked helping people and the social contact. She also visited old people at nursing homes and hospitals as a volunteer. Nadia attended courses offered at the municipality.

To summarize, the participants seemed to manage relatively well on their own regarding house chores (otherwise, perhaps they would not have been recruited as independent living elderly people). Also, a great amount of leisure was found in their daily routines, and their social lives revolved predominantly around their children and grandchildren.

3.1.2.3 Roles played by people and technology

All participants did most household chores themselves. However, also all participants received sporadic help from children or grandchildren. For instance, one of Nadia’s children helped her to turn around the mattress on her bed and a relative sometimes did the grocery shopping for Pedro and Estefana. Paid housekeepers helped none of the interviewees at the time of the interview and their opinions about cleaners seemed rather negative.

Esteban and Paca were the two participants who showed the most frequent and diverse need for help, carried out by children and grandchildren. Other ways in which children offered help were: transportation, since neither participant drove a car, and grocery shopping that involved the use of car; administrative issues or paperwork; controlling their welfare and daily condition; offering financial help (Nadia); looking after their dog when the owner (Tania) is absent, etc.

Participants were supervised by their children for their own safety and welfare. In some cases, the children or grandchildren motivated the interviewees to perform certain tasks. For instance, the granddaughter of Esteban and Paca encouraged them to wash themselves and offered them her help. Also, children and grandchildren
seemed to play an important companionship role. In Tania’s case, her dog also fulfilled this role. She explained that it offered her good company, representing a great social support. Tania also listened to radio or music throughout the day because that “makes her feel less lonely”.

Conversely, some interviewees offered help to their children as well. For example, Tania and Ana picked up their grandchildren from school and looked after them.

Regarding technology, a series of objects were identified that helped the participants cope better with difficulties in daily life. For instance, they used shopping trolleys that helped them carry the shopping to their homes. Esteban, who walked on two crutches, took a rucksack instead. The most problematic ADL for Esteban and Paca was bathing. When they did not receive help from others, they put a stool in the bathtub on which one could sit while being washed by the other. Besides using the phone as the rest of the interviewees, Nadia also used her PC and certain smartphone applications to be in contact more often with her children.

Finally, some participants found a great support in religion and in the figure of God. For example, Estefana believed that God helped her and Ana felt safe at home “because she trusted the Lord”.

3.1.3 Discussion of first study

The in-depth interviews in this study allowed a deep understanding of the daily lives of the participants, including not only activities but also psychological factors. We gathered valuable information about the daily lives of older adults, contributing to our base knowledge related to the third research question of this dissertation (see section 6.1).

To summarize, despite the small size of the sample the participants showed a great variation in many aspects of their daily lives and routines. Most were able to successfully fulfill the majority of household chores and other obligatory tasks. Some of the most challenging physical tasks required good mobility, as previously found in the literature [15]. Problems in walking significantly impacted their lives. These problems were the consequence of heart diseases or physical disorders in the legs. Regarding house chores, the most problematic physical tasks inside the home were hanging/taking down the curtains and cleaning the upper parts of kitchen and bathroom. Finally, with respect to cognitive difficulties, some participants reported problems with their memory. Also, using certain electrical appliances was challenging for some participants. In this study we also learned that perhaps the most problematic aspects of the daily life of independent living elderly people do not concern activities of daily life (ADL’s). Rather, we could consider that the greatest problems of the participants had a psychological origin. This served as motivation to formulate the second research question of this dissertation (see section 6.1). The interviews revealed the presence and profound impact of negative emotions, thoughts and attitudes, such as loneliness and lack of motivation, which is in line with results by Bedaf and Gelderblom [15], who also pointed at social isolation and lack of hobbies as relevant problems of elderly people. Nevertheless, while all participants in the study here summarized shared the characteristics of being old, having health problems and living alone (or with another person), the way they perceived and faced their situation
An informal conversation with Nadia took place after the official interview, where she was speaking about loneliness. She suggested that elderly people feel less lonely when they stay busy and participate in activities outside the home. This may suggest the possibility that feeling lonely depends on more factors than just the amount of social contact.

Besides feeling lonely, other negative emotions and behaviours may also have an attitudinal origin. Esteban and Paca could learn how to use electrical appliances, like the washing machine or the TV remote control, so as to become more independent. They could also manage at home with less external help. They seemed to be at least partially aware of their delegation of tasks. However, the belief that they were very “unable” seemed to prevail both in their impressions about themselves and those of their relatives. The fact that Ana gave many excuses to explain why she did not do the things that she would like to do, together with declaring feeling “like useless”, might reflect also a low appreciation of her own abilities. Finally, also Pedro might have a negative impression of his abilities since he described himself as “ignorant” and he stopped certain leisure activities due to feelings of insecurity. Perhaps certain coaching or coping interventions could help elderly people regain self-confidence at certain tasks, increasing the frequency of behaviours that facilitate their independence and promote their wellbeing.

This type of interventions, oriented to support older adults psychologically, could be robot-mediated, as we have already seen in section 2.2 and I proposed as part of the second research question (see section 6.1). For example, a robot could provide a form of company [78] or, as Nadia’s comments may suggest, influence the participant’s behaviours and attitudes in such ways that it could reduce the feelings of loneliness.

3.2 Exploring Robot Acceptance

Contrary to the previous study, this focused on the attitudes that elderly people have toward care robots. This section consists in an adapted summary of a study carried out for the European project ACCOMPANY [1]. A complete report of the study can be found in [48].

In this study, focus groups on robot acceptance aimed to assess, among other things, how ACCOMPANY’s main beneficiaries (that is, elderly users, informal carers and formal carers) experienced the Care-O-Bot III robot [7] in terms of robot acceptance. To this end, two different visions of the robot were shown to the participants in two videos during the focus groups. The first video showed the Care-O-Bot interacting with an elderly user, displaying the role of an assisting device. We decided to make a second video showing a different robot role, in this case companion. Thus, our intention was to expose the focus group participants to two different robots, one which seemed more reliable and machine-like, and the other more emotional, independent and human-like. We hoped that the exposure to these two opposite views on robot behavior would spur the debate on robot roles and robot acceptance. The insights gained on robot acceptance may be valuable as a basis for the second research
question of this dissertation (see section 6.1).

3.2.1 Methods

A protocol for the focus groups was followed in the three countries where the study was conducted: United Kingdom, The Netherlands and France. This included details on the preparation required for the focus groups (e.g. materials); an introduction for the participants explaining what would be expected from them during the focus group session (e.g. that they would be shown two videos and asked about their corresponding impressions); and subsequently was divided in two sections, each of them preceded by one of the two videos.

The first video showed a home-like environment with an aged man and the Care-O-Bot robot (see figure 3.3). The man was sitting on the sofa and held a tablet that served to communicate with the robot. In the tablet a suggestion appeared from the robot to go to the kitchen and fetch a drink. The user pressed on the suggestion icon, indicating his agreement to carry out that task. Subsequently, both moved to the kitchen, where the man opened the fridge and left a drink container on the Care-O-Bot’s tray. From that position, the man returned to the sofa while the robot followed him carrying the drink. Once the robot was next to the participant and a nearby table, the robot grasped the drink container with its robotic arms and left it on the table. Then, the robot moved to a farther position. Even though the user had the drink within reach, he was still not drinking. Through the tablet, the robot suggested that the user should drink. He then pressed on the suggestion icon and drank from the drink container. The image of the robot that we intended to portray in this video was that of a reliable, predictable robot, whose only function is to assist the user. Thus, we intended to offer a vision of a “robot as tool”, as opposed to a “robot as companion”.

In the second video the setting started identically, with the exception that the user was female and young (see figure 3.4). The robot was repeatedly handing a bottle of water to her, but she seemed to ignore the robot while reading a book. The tablet was at the same time indicating through suggestion icons that the user should have a drink (see figure 3.5). The robot then turned around and, while displaying emotional cues such as “bowing down”, moved toward a corner in the room where it would stay “sulking” for a while. Eventually, the user decided to call the robot (by squeezing the tablet), but the robot ignored her. She insisted again squeezing the tablet, and the robot moved its upper body sideways indicating denial. Then the user gave an
impression of sudden understanding and took the drink container that was standing next to her to drink from it. Thus, a great difference of this video compared to the first one, was that in this video the robot appears to have its own emotions and intentions. So much so, that occasionally the robot ignores the user when she is calling it because it is “sad” and “sulking”.

After each video, discussions were held with the participants, among other reasons to obtain insightful information on robot roles and robot acceptance from the participants’ point of view.

77 persons participated in this study, including elderly people, professional carers and informal carers from the three aforementioned countries, with a total of 20 focus group sessions (including two interviews).

Every focus group session was video recorded. Subsequently, the corresponding researchers from each country extracted key points that focused on the subjects for discussion according to the protocol. Additional key points and comments of the participants that the researchers considered also valuable were annotated as well. The key points extracted from each focus group session were grouped in written reports, which were sent to the main researcher. The data were analyzed according to content analysis (more details in [48]).

3.2.2 Results and discussion of second study

In this subsection we are mostly reporting results that could generalize to all care robots, rather than opinions on the specific users and robots seen in the videos. We have organized the results according to the following topics: users of care robots, general attitudes and perceptions toward care robots, robot as a machine versus robot
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as a companion, the issue of control and robot care in the future.

3.2.2.1 Users of care robots

One of the focuses of discussion referred to who would be the ideal user for a care robot. For instance, which people would profit the most from using such a robot? The participants imagined the ideal user as an elderly person with physical limitations, especially regarding mobility, such as being handicapped or bounded to bed. Other limitations would be suffering from COPD (chronic obstructive pulmonary disease), CVA (cerebrovascular accident) or bad vision (although some users would argue that good vision might be necessary to interact with the robot). Although opinions were divided regarding the necessary degree of cognitive capability of the ideal user, most participants coincided that the ideal user would not suffer from dementia at all, and if he/she did, he/she would be in an early stage of dementia, being provided with reminders and structure in their lives. The user should also be smart and have an interest in technology or robotics. He/she should be patient and be able to work with the tablet, for instance fine motor skills would be necessary.

Whether the robot is well accepted or not would depend on the user. Indeed, many participants were open to the idea of having a robot, since they understood the benefits. It seems to depend on the person whether he/she likes the robot and whether the robot can be found annoying or easy to bond with. The acceptability of the robot seems to require a certain predisposition, namely, an open mind and a caring attitude toward technologies. Also, some people argued that it should be a personal decision whether someone prefers a robot or a human carer for certain tasks.

3.2.2.2 General attitudes and perceptions toward care robots

Even if we are trying not to focus on the participants’ reactions to the specific robot, it could be illustrative for us to see how a few changes in the robot’s behavior could alter the perceptions and attitudes of the participants. The robot was described physically by the participants as machine-like, big, bulky, heavy, slow, plump, static and silent. In some cases they found it frightening or threatening, for example the robot’s arm was compared to forceps. They pointed out that the functionality of the robot was quite limited, with simple intentions, such as moving, preparing a drink and advising to drink. These robot’s intentions were perceived as benevolent. The robot was seen by some as proactive and gentle.

Regarding comments of the participants about the robot of the second video, some said that this robot was more human than the robot of the first video. They thought that it acted emotionally (some said “like a child”) and had its own feelings, goals and intentions, since it can be frustrated, angry, impatient, it can sulk and be capricious. This robot was considered more independent than the previous one, taking more initiative. The robot was making the decisions, not the user. Some positive adjectives that describe this robot in comparison with the previous one are modest, faster, funny and not scary. A few negative phrases describing the robot are: not friendly, single-minded and unable to multitask.

Most of the participants’ comments about the robot regarded wishes and supposi-
tions. In general, they did not just describe what they saw in the video, but it seems they felt compelled to express their opinions about how things should be, perhaps because elderly care is a topic that concerns them. The most desired feature for the robot was to allow the user to talk to it, be it in the form of typing or actual speech. Participants insisted they wanted to be able to talk to the robot. This would also make it easier for those users with bad vision. Talking could also potentially be very beneficial for elderly users that suffer from loneliness. Furthermore, speech in the robot appeared to be crucial for the relation between user and robot, to the extent that some participants stated that there was no real relationship between the robot and the user because the robot had no expression and did not speak.

Other wishes on the robot concerned the appearance of the robot, namely the robot would look better with more color, more soft materials and if it matched the interior of the home. There was no consensus as to whether the robot should keep looking machine-like, as it appeared in the videos, or it should look (and be) more human (for example, some participants would also like the robot to be benign and altruistic). Finally, the robot should be adapted to the house and the user, as well as easy to replace.

Regarding robot roles, according to Takayama et al. [110] robots seem to be preferred for activities that involve memorization, good perceptual skills and service-orientation, compared to humans, who seem to be preferred for activities involving judgment, evaluation, diplomacy and artistry [110]. The participants in this study also commented on potential roles and activities for the robot. These suggestions about what the robot should do were numerous and in some cases there were opposed opinions. For instance, some would prefer a care robot as something just functional, as a butler, whereas others would rather see a companion or friend in the robot, or would even compare it to a family member, valuing the social aspect. Other suggested roles for the robot were: monitor, functional supporter, motivator, helper, waiter, carer, assistant. The robot was once also compared to a helping dog. According to various groups of participants, the robot could as well take care of the user, assist at showering, make life easier or more pleasant, help the user become more independent, break through loneliness, activate the user and stimulate him/her to do things, offer safety, facilitate games, etc. The robot should act for the best of the user and for his/her happiness. Some participants believed that the robot could take on any role a human person can have, although it will perform it less efficiently. Finally, some participants pointed out that using the robot should be fun.

Many participants referred to the role of reminder. By being reminded to drink by a robot instead of by a person, those participants that fear incontinence might become more amenable regarding drinking. Examples of situations where the robot would be useful in a reminder role were: reminding of food in the oven; washing machine getting to the end of its cycle; and reminding when the favorite TV shows are on. Also, providing reminders and structure may seem useful for people with dementia.

Other activities mentioned were helping with dressing; helping in the house; personal hygiene (combing hair, washing and brushing teeth); fetch and carry tasks; make planning of the day; and finding lost objects.

Thus far, it appears that there was a great discrepancy in the opinions of the
participants, for example about whether the robot should be something just functional or also act as a companion. The next subsection will deepen into this subject.

3.2.2.3 Robot as a machine versus robot as a companion

Should the robot act in a machine-like (first video) or in a human-like (second video) manner? This was the main point of discussion, together with its implications, after the second video. Opinions on this appeared significantly divided. Some participants viewed the robot as a machine that just needs to work for the user and does not need emotions, whereas others saw the robot as a buddy. The participants that preferred the robot from the first video did not understand that the robot of the second video ignored the user’s call. They thought that a robot should never refuse nor ignore the user, especially if the user needs the robot’s help. According to some participants, the robot reacts this way as a means to handle the situation. Some considered this robot manipulative and controlling, with negative intentions and punishing. Even though the robot’s sulking was considered by some as moving, this could cause annoyance and stress in the user. Many participants found this way of behavior unacceptable and disturbing. Such a robot would isolate the user emotionally and physically and would “dis-empower” the user. The robot should not emotionally blackmail the user. A robot should be just a reliable and predictable tool to carry out the desired function, offering support. The user should not be left without a choice, but should be completely and always in charge. Some participants stated that the robot should not be too pushy, because one sometimes would not feel like doing what the robot suggests.

Nevertheless, some of the participants preferred the second robot, finding its behavior more pleasant because it was more human-like. Other participants said they would talk more to this robot as well. There were participants who did not mind about the robot ignoring the user, they would still “be nice to the robot”. And there were also people who found it alright that the robot kept repeating the reminder to drink water. Some participants preferred this robot with the important exception of when it comes to medication, in which case they would prefer the reliability of the other robot.

The fact that the more machine-like robot tends to be preferred to the more human-like one is backed by other studies, such as a survey on attitudes of Europeans towards robots [39]. In this study, two pictures were presented to participants. In one picture an industrial robotic arm appeared, whereas the other picture showed a human-like robot helping in the home. At answering the question “to what extent does the picture correspond with the idea you have of robots?”, 17% of participants answered “total badly” with respect to the instrument-like robot, whereas 32% answered the same with respect to the human-like robot.

However, having a care robot behaving as a tool or as a companion could depend on the specific user. For example, let us first imagine a younger client who would want to be able to do things by himself again with the use of the robot, so he would not need to rely on the help of the home carer. For this client, the robot would be a machine/a device. However, many older people would miss the social talk as one can talk to a human carer, but not to the robot. Let us here imagine an elderly client that loves to sit down with the carer and have a cup of coffee and a chat. How would this
last client accept a robot instead of a human carer? They also pointed out that in the future perhaps contact through the computer will be seen as actual social contact and there would be no need for a chat or cup of coffee with the carer.

To summarize, in general the reliable robot-as-tool seemed to generate a higher acceptance as compared to the other. Participants tended to prefer to always have the control of the robot and to know what they could expect from it. This would make them feel safe in an area as delicate as elderly care.

### 3.2.2.4 The issue of control

Another discussion aimed to elucidate who was responsible for the robot’s actions. Was it the robot, the carer, the programmer? The robot would have no intentions; the intentions behind the robot’s actions would be those of a third party: the carer and the programmer. Who would be to blame if the robot does something wrong? Some participants considered that everything always needs to be monitored and everything should be agreed upon with the user. The user would be the one in control. The relation should be a relation of trust, even if the robot does not effectively help the participant. The ideal relation between robot and user would be friendly and would enhance the user’s quality of life. Other participants considered that the relationship would depend on whether the robot is regarded as a machine or rather as a buddy or pet.

Some participants stated that a clear agreement should be made of what the robot is allowed to do and what not. It seems that we should not leave the user depending on the robot. As an example of why not, we might wonder if the user (video 2) actually drank from the cup or she just “pretended” to drink in order to trick the robot. Then the question arises whether one could trust the robot to look after rehydration, as well as other things such as medication. This leads us to the issue of control. Even though some participants disliked the idea of a robot taking over control, exceptional cases were proposed where this might actually be desirable. For example, the robot would be allowed to be in charge if this benefits the health of the user and the user previously agreed on this. Another case is elderly people with dementia, whereby you should do instead of asking. Some other participants considered that the relationship is based on mutual control. Without this, the user would feel manipulated and reject the robot. Both user and robot should adapt to each other.

### 3.2.2.5 Robot care in the future

When referring to robot care in the future, there were participants that stated that the robot still needs to learn a lot, as the current tasks it can perform are not sufficient yet to make it suitable for the elderly people today. However, they saw the need of using robots in the future, as well as they saw possibilities for the robot in assisting younger clients and also the elderly of the future. In fact, many of them wanted to use the robot for themselves in the future (if the robot is capable of doing more tasks) as it has the potential to give people back the control of their own lives.

The robot was regarded by some as an extension of home care, which will reduce costs in the long term. The remark was made that the elderly of the future will want to
have such a robot more than nowadays, since they will understand technology better. They will be more open to it. In contrast, others thought that the elderly will find the robot scary or perhaps not special enough because they would not be impressed by its current functions. Some viewed the robot as just an object at this time, but envisioned the robot as a buddy in the future, making it possible to establish a human relationship with it. However, this would be impossible in the example robot they saw as it did not talk and it was not designed to be held by the user. In any case, the introduction of the robot should be gradual in order to be accepted; in the case of rolling walkers, these were not well accepted when they were introduced but slowly they became more popular. It appeared that the more functions the robot has, the more it will be used.

3.3 Overall Conclusion

Two adapted studies have been included in this chapter, which complement each other. The goal of the first study was to describe and understand the daily life of independent living elderly people, as well as their interests, hopes and dreams. We aimed to identify their needs for support and roles people and technology play in their lives to eventually help them maintain their independence. We hoped that this would give us a stronger basis for the third research question of this dissertation, which concerns daily routines of elderly people (see section 6.1).

Contextual analysis is a qualitative approach to collect rich context data that is relevant to a small set of representative participants in order to gain a deep understanding into the relationships between important factors in people’s daily lives. Seven elderly persons from a city near Madrid, Spain, participated in in-depth interviews carried out in-situ in their homes. The results from the qualitative data analysis indicated a great variability in the coping capacity of the participants. Feelings of loneliness and lack of motivation appeared as common burdens in their lives. This finding is in line with results by Bedaf and Gelderblom [15] who pointed out that social isolation and lack of hobbies are relevant problems of elderly people. Self-efficacy and other related constructs were discussed, which could have an influence on older people’s motivations and their predisposition to disability. Finally, a “motivator” robot role was proposed that could promote the psychological wellbeing of independent elderly, at the same time decreasing their risk of losing independence. We hoped that this would give us a stronger basis for the first research question of this dissertation, which concerns the use of robots for psychological support (see section 6.1).

The second section in this chapter consists in a summary and adaptation of a study carried out for the ACCOMPANY project [1], in which 20 focus group sessions on robot acceptability where carried out by our project partners in The Netherlands, France and United Kingdom. The topics and points of view of the participants were diverse and sometimes opposed. The combination of the two different videos, one in which the robot acted reliably and “just as a tool”, and the other in which the robot had its own emotions and intentions, spurred the debate that generated most comments in the focus group sessions. Generally, the reliable robot-as-tool generated a better acceptance. Participants tended to prefer to always have the control of the
robot and to know what they could expect from it. This would make them feel regarding something as delicate as elderly care. We hoped that all this would prepare us better to address the second research question of this dissertation, which regards how elderly people accept robots (see section 6.1).

These two studies greatly motivated the subsequent studies presented in this dissertation. The diverse types of psychological distress found in the first study of this chapter motivated us to implement positive interventions in the interactions with social robots.
Thus far, we found evidence of the crucial role that psychological variables play in the wellbeing of elderly people. Thus, we devised HRI studies where the central task of the robot would have a psychological “added value”. Although numerous studies have employed robots to foster psychological wellbeing, studies on therapeutic robots based on interventions from positive psychology were still missing. We considered three reasons to employ positive psychology interventions (see section 2.3) in HRI studies. First, positive psychology offers exercises that have already been empirically tested by professionals in psychotherapy. Second, positive psychology interventions are not only aimed at patients that already suffer from a psychological disorder, but they are also administered as preventive means [104], strengthening the psychological, social and material resources of the recipient [43]. Third, the fact that positive exercises do not necessarily focus on specific target groups, makes them greatly generalizable [105].

Robots that offer psychological or psychotherapeutic support typically do so with the awareness of the user. In this section we argue that, under certain circumstances, researchers or caregivers might decide to have psychotherapeutic robots perform their tasks in a covered or indirect way, that is, in such way that the user is not aware of undergoing a psychological intervention.

To that end, here we present an experiment with two conditions. In one condition (referred to as direct condition) the robot made participants aware of being subjected to a psychological intervention, the three good things exercise from positive psychology (see section 6.2.4.6), whereas in the other condition participants were not made aware of the intervention (here called indirect condition).

The remainder of this chapter is subdivided into Aim and Research Question, Method, Results, Discussion, and Conclusions, respectively.

The research presented in this chapter has been published in [45, 49, 50, 51].
4.1 Aim and Research Question

In view of the potential of robots to assist people in psychological interventions (see section 2.2), we were confronted with the question of whether such interventions would be more effective with participants being aware or unaware of them. This has never been tackled before in research with robots that act as coaches or motivators. We believe that approaching this question can be of great relevance in specific psychotherapeutic contexts with robots. We foresee that the question will become even more crucial once social robots become more common in our households. Many of the interactions between users and robots will probably consist of playing and chatting. Thus, it might be a great opportunity to also embed psychotherapeutic exercises in these activities, perhaps in such a way that users are not aware of being undergoing a psychotherapeutic intervention.

Based on this, we formulated the following research question:

*Will people’s positive affect increase more with a direct intervention or with an indirect intervention?*

4.2 Method

We designed an experiment with two between-group conditions. In one condition the robot made the participants aware of a positive exercise (direct condition), whereas in the other it did not (indirect condition). The positive exercise we chose was the three-good-things exercise (see section 6.2.4.6). This experiment was conducted in the lab with participants from a wide age-range and a robot that was teleoperated.

In the following we will describe the sample, the robot platform, the procedure of the experiment and the mixed-methods approach to collect the data.

4.2.1 Sample

42 people with an age ranging from 20 to 83 (m = 39.11, sd = 18.24) participated in the experiment. We aimed to have a sample with a wide age range because exercises from positive psychology could be beneficial for people from all age groups and
the effects could differ depending on participants’ age. 5 users were excluded due
to technical problems with the robot or not understanding the robot because of lan-
guage issues. Of the remaining participants, 16 were male and 21 female. Regarding
their occupations, the majority were students at the University of Twente (11), staff
members from the same university (15) or retired persons (3). 16 of the participants
had not seen a robot in real life before; 13 had access to robots approximately once a
year; 4 once a month; and 3 once a week or more often. 26 participants were Dutch,
9 from other western nationalities and 2 from Indonesia.

4.2.2 Robot platform
The robot employed in the experiment was Giraff [3]. Non-anthropomorphic in de-
sign, it is approximately as tall as a person and has wheels to move around as well
as a screen with camera that allows for teleconference (see Figure 4.1). We added a
pair of simple eyes (two blue, big LED light-like circles on black background) to the
robot screen, which blinked regularly, to make it more anthropomorphic. The robot
was teleoperated from another room without the participants knowing this. The tele-
operator had a video feed of the interaction and controlled the robot movements and
utterances. For communication, the operator chose pre-recorded utterances from a
list, which were in English language. The robot displayed synthesized utterances of a
female voice in English language. These robot utterances were pre-recorded for the
sake of speed, so that the operator would only have to press a button to make the
robot emit a given utterance. The utterance repertoire included multiple sentences
that referred to similar questions so as to sound less repetitive, as well as utterances
to allow the robot to react in a more human-like manner in unexpected situations.
Examples of these utterances are “yes”, “no”, and “please, could you repeat?”.

4.2.3 Procedure
The interactions with the robot took place individually in a lab. Each participant was
welcomed and thanked for participation. After the introduction and a brief explana-
tion of the procedure, a consent form was given to the participants. Subsequently, the
PANAS affect scale (Watson1988) was given to the participant to determine his/her
affect baseline (see section 4.2.4.1). The main experimenter then left the participant
alone and sat hidden nearby, while the teleoperator drove the robot, which had re-
mained invisible until this moment, towards the participant who remained seated.
Once the robot approached the participant, it stood in front of them at a distance of
approximately 1.5 meters (see Figure 4.1), without moving during the interaction.
After the approach, the interaction started.

The robot’s utterances were the same in both conditions except for the introd-
uction that it gave to the participants. In the direct condition the robot introduced itself
and explained to the user that they would perform an exercise that has its origins
in positive psychology and that has been proven to increase positive feelings. The
robot asked the participant whether the procedure was clear. If the participant did
not understand correctly or hesitated, the robot repeated this first part of the script
but in different words to ensure that the participant would understand the purpose
of the interaction. In the indirect condition, the robot started introducing itself and then it talked about itself with a duration similar to that of the explanation of the positive exercise in the direct condition. The robot gave emotionally neutral information about the building where it lives. These robot utterances were designed in accordance with the three good things exercise as described in the positive psychology literature [103, 104, 105].

The following part of the procedure remained identical for both conditions. The robot proposed to have a chat, told something positive about itself as an example and invited the participant to start the exercise by asking: “please, tell me something that went well for you in the last few days”. Once the participant had finished, the robot asked about the cause of why that went well: “why do you think that (reference to what went well) happened?” This process was repeated two more times, so that the participant reported three positive things. Finally, the robot thanked the participant for the participation and said goodbye.

After the interaction with the robot, the experimenter came back and kindly asked the participant to fill in more questionnaires (see section 4.2.4.1). Subsequently, a short semi-structured interview took place, where the participant was asked to give his/her impressions about the experiment, the robot and the interaction with it, improvements in affect (if any) and what he/she thought about the idea of having a robot that fosters positive thoughts at home.

The experimenter explained that the participant would receive an email with a survey that would serve as the last input for the experiment. Finally, the participant was thanked for the participation, offered chocolates and accompanied to the exit of the laboratory.

4.2.4 Data collection and measures

A mixed-methods approach was chosen to obtain a clearer picture of what happened in the experiment and how the participants perceived the situation. Data were collected from questionnaires and an interview with each participant after the interaction with the robot. We also analyzed the participants’ replies to the three-good-things exercise with respect to how positive their answers were and how engaged they were with the task (i.e., how long the utterances were that the users produced). This analysis was based on recordings from two cameras that recorded the interaction with the robot and the interview. All methods are described in more depth in the following.

4.2.4.1 Questionnaire

The Positive Affect and Negative Affect Scale (PANAS) [125] was employed to measure the participants’ affect as a baseline. It consists of 20 items and is subdivided into two subscales, Positive Affect (PA) and Negative Affect (NA). We only measured PA because NA was not relevant in the context of our task. The items consist of adjectives describing the current affective state of the participant, such as “determined” and “interested”. Each item is rated on a 5 point Likert scale that ranges from "very slightly or not at all” to “extremely”. Thus, scores of the PA range from 10 to 50 points. Regarding reliability, Cronbach’s alpha before the interaction was .770.
Immediately after the interaction with the robot, the PA scale was administered again to measure changes in the participant’s positive affect due to the treatment. To test our research question (whether the change in positive affect was different in the two conditions), we calculated a repeated-measures ANOVA on the PA scale with condition and time of measurement as factors. This was followed up with paired T-tests for the individual conditions as suggested by Field [41].

4.2.4.2 Interview

We performed a semi-structured interview [24] after completion of the post-test questionnaire. It consisted of general questions about the experience with the robot, about the robot and interacting with it, about changes in affect and whether these were attributable to the technique from positive psychology. Finally the participant was asked about how social robots could improve people’s affect. The recordings of the interviews were transcribed and subjected to content analysis.

A manipulation check was performed in the interview by asking participants “What do you think the robot was trying to do?” and “What do you think was the purpose of the conversation with the robot?” Participants in the direct condition were expected to answer that the robot’s goal was to improve one’s affect, whereas participants in the indirect condition would believe that the robot just tried to have a conversation or entertain the user. We categorized the replies with respect to their content and conducted a One-Sample Chi-square test.

4.2.4.3 Content analysis

We also measured task engagement and positiveness of the messages by analyzing the video data for the participants’ replies to the three good things exercise. We believed that both aspects would reinforce our answers to the research question because engagement appears in the literature as greatly related to positive affect [127]. In fact, another definition proposed for positive affect is “state of high energy and pleasurable engagement” [127]. Engagement has also been studied as a valued subjective experience in positive psychology. (Task) engagement is related to the concept of flow, characterized by elements of attention, concentration and enjoyment with the task [23]. Hence, we measured task engagement as we considered it an indicator of positive affect.

To conduct these analyses, we first transcribed the participants’ utterances. Altogether, we transcribed all 111 replies that we received to the question of what positive things had happened to the participants recently. We analyzed the length of each reply in the three good things exercise as a measure of the participants’ engagement in the task. We counted the words in each utterance and conducted a repeated-measures ANOVA with condition as between-subject factor and the three rounds of the task that each participant completed as repeated measures.

We conjectured that the possible changes in the affect of the participants might also be related to the degree to which their answers were positive. Thus, we tried to account for this. For the analysis of positive tone of the participants’ replies we had three people rate all 111 transcripts in random order. They were asked to “Please,
rate each of the texts on a scale from 1 to 10 according to how positive each text is (1 means “not positive at all” and 10 means “extremely positive”). To assess interrater agreement we calculated intraclass correlation (ICC) between the raters. The agreement between the three raters (ICC) was .650. Hence, we calculated the means of all three ratings for each item for further analysis. Based on the mean rating of positivity, we conducted a repeated-measures ANOVA with condition as between-subject factor and the three rounds of the task that each participant completed as repeated measures.

4.3 Results

In the following we present the results of our data analysis. We first describe our manipulation check before we address our research question. Results from the different methods (questionnaires, interviews, and video analysis) are included wherever relevant.

4.3.1 Manipulation check

We counted the cases where the participants replied as intended by the condition, i.e. cases where participants in the direct condition thought the robot’s goal was to make the user happier, plus the cases where participants in the indirect condition believed the robot’s purpose was to entertain the user. A One-Sample Chi-Square Test was performed, revealing a significantly higher number of cases where the manipulation check succeeded ($\chi^2 = .05$, $p < .001$). Thus, we assume that overall the manipulation has worked as intended.

4.3.2 Results on research question

We performed a repeated-measures ANOVA on the PA scale to ascertain whether the participants’ positive affect would increase more in the direct condition or in the indirect condition. No significant main effects were found for neither factor (condition and time of measurement). However, a significant interaction effect between condition and time of measurement was found ($F(1, 35) = 8.145, p = .007$).

Paired T-tests showed that the participants’ positive affect actually improved only after the direct treatment ($m_{direct\ post} = 31.15$, $sd_{direct\ post} = 4.58$) compared to the same measure taken before the interaction ($m_{direct\ pre} = 28.95$, $sd_{direct\ pre} = 4.78$); $T(20) = 1.971, p = .032$, one-tailed. In contrast, the affect seemed indeed to have decreased after the indirect treatment ($m_{indirect\ post} = 26.41$, $sd_{indirect\ post} = 6.51$) compared to before the interaction ($m_{indirect\ pre} = 29.00$, $sd_{indirect\ pre} = 4.89$); $T(17) = 2.053, p = .057$, two-tailed (see Figure 4.2).

This is in line with the results from the interview. The majority of participants in the direct condition reported increasing positive affect (13 improved, 6 not improved). However, this did not result in a significant difference ($\chi^2 = 2.58$, $p = .11$). In the indirect condition barely half of the participants reported an increase in positive affect (8 improved, 9 not improved), $\chi^2 = 0.06$, $p = .81$. 
In the interviews we further followed up on this finding and tried to determine to what causes the users attributed the change in affect if they experienced any. Participants of the direct condition that experienced an improvement in positive affect attributed this to doing something new, being forced to think positively, to the experience of talking to a robot and, often in the case of students and researchers, to finding the experiment a distraction or alleviation to their stress. Participants in the indirect condition attributed increasing positive affect more to the robot, e.g., because it was funny and cheerful. Reasons for participants in both groups to not experience increasing positive affect included the interaction being too short, regarding the robot as “just a machine”, and already having had a very high positive affect before the experiment. So while the participants in the direct condition actually had a tendency to attribute changes in affect to the task, people in the indirect condition did not.

This is backed up by the findings from the analysis of the users’ replies to the three good things exercise. The results of a repeated-measures ANOVA revealed a main effect for condition; $F(1,35) = 27.668, p < .001$. The positive valence of the participants’ replies was higher in the direct condition ($m = 5.70, sd = .128$) than in the indirect condition ($m = 4.71, sd = .139$). Hence, the answers that the people gave in the direct condition were actually more positive, which might be one factor leading to the higher increase in positive affect after the interaction (see section 4.4).

We also looked into participants’ engagement with the task to back up this finding, i.e., we analyzed the number of words of each reply to the question about something good that had happened to the person lately. While there was no main effect of condition on the number of words uttered; $F(1,35) = 2.791, p = .104$, there was a main effect for the number of words in the different stages of the experiment; $F(1,35) = 11.294, p < .001$. Thus, we took a closer look at the data that revealed an interaction effect for word count and condition between the three rounds; $F(1,35) = 4.133, p = .05$. The graph of the word counts in the two conditions shows that it keeps increasing in the direct condition (see Figure 4.3). The number of words also increased between the first and second round in the indirect condition but then, in the third round, it dropped below the level of the second round. So while in the first two rounds in the direct condition the length of the utterances was only slightly longer, it was significantly longer in the third trial. Hence, this finding may suggest that the participants stayed more engaged throughout the interaction in the direct condition.

### 4.4 Discussion

The results showed a great difference in the change in positive affect depending on condition (more than 5 points in PANAS). Positive affect increased significantly in the participants of the direct condition and was reduced in the indirect condition. Thus, we found evidence to answer the research question, that is, direct interventions appear to be more effective than indirect interventions when employing a robot for psychological support. The medical literature reports similar findings. Benedetti et al. compared the effects of medical interventions where participants were aware of the intervention to the effects of the same interventions while keeping participants unaware of treatment. They demonstrated through a series of experiments with dif-
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Figure 4.2: Positive affect of participants depending on condition, before and after the interaction with the robot.

Different interventions that medical treatments were more effective when participants knew that they were carried out [17].

Since both experimental conditions remained constant except for the introductory speech of the robot before performing the positive exercise, we can conclude that the differences in positive affect after the interaction with the robot were due to this framing of the exercise by the robot. Even if it was beyond the goal of this study to find the causes that made the two conditions differ in their effectiveness in enhancing positive affect, I would like to conjecture and list a few potentially mediating factors. It would make sense to think that participants in the direct condition were biased to give replies to the three good things exercise which were more positive. In turn, research indicates that positive thinking promotes subjective wellbeing [102]. Our results showed indeed that the participants from the direct condition were higher both on positiveness of their answers and on positive affect. We could conjecture the same about task engagement. Participants were found to be more engaged throughout the task in the direct condition compared with the indirect condition where the engagement dropped at the end of the interaction. They probably put more effort into the task which might have made it more successful. Another contributing factor to the higher success in the direct condition might have been the presence of hope [77]. That is, the participants in the direct condition knew about the treatment, and
the hope that it could increase their positive affect influenced the outcome. It is reasonable to assume that awareness of a treatment may elicit positive expectations or hopes. Researchers in psychology have underlined the importance that clients’ hope has in their improvement [77].

Something that might also have contributed to the drop of positive affect in the indirect condition is the repetitiveness of the task. In the direct condition the participants were likely more engaged because they had an idea of the purpose of the interaction and an estimate of its duration. Even though the indirect robot asks to have a “short conversation” it does not indicate the actual duration, nor does it seem to have any particular purpose. It may indeed come across as repetitive by the time it approaches the final “good thing” in the exercise. This might thus explain the drop of engagement by the end of the task in the indirect condition.

Not only were the participants’ answers longer and more positive in the direct condition. Also, as the interviews suggest, the participants in the direct condition tended to attribute the changes in affect more to the task (the conversation that took place) than in the indirect condition, where changes were mainly attributed to experiencing the robot in interaction. One reason could be that the participants in the direct condition interpreted the interaction with the robot in a very different way than the participants in the indirect condition. At the same time this could explain why the
participants’ positive affect in the indirect condition actually dropped: given that the
behaviour of the robot was pre-scripted it had some variation but overall was not
very diversified. Also the questions about the three good things might have made the
robot appear rather repetitive. Thus, participants who really focused on the robot -
such as our participants in the indirect condition - might have been to some extent
disappointed.

In addition, the experimental artifact known as “demand characteristics” might
have influenced the results [95]. In this case, participants in the direct condition
might have believed that they were supposed to show an enhanced positive affect
after the robot interaction. Thus, they might have contributed with results that were
more positive.

The contribution of this study to the overall research questions of the dissertation
will be discussed in section 8.1.

4.5 Conclusions

Should users be aware or unaware of the fact that they are undergoing a psychological
intervention in the interaction with a robot? In this study we found evidence that
psychotherapeutic robots could be more effective when they are openly presented
as such, at least with respect robots that promote positive emotions. This indicates
that the framing or instructions for interacting with a robot greatly influence the
robot’s effect on the participant. Exploring this question might be relevant regarding
situations where robots aid users with specific limitations, but especially in the context
of social robots at home, where they will have the potential to tailor their behaviors
in ways that foster the psychological wellbeing of users.

We find two main types of limitations in this study. First, we would not expect the
results of this study to be completely generalizable to every context involving robots
for psychological support. For example, we could suppose that some treatments out-
side the scope of positive psychology, especially those that specifically target highly
morbid or stigmatizing disorders, could make some participants feel stigmatized when
they learn that they are under such interventions. For such cases, it might be possible
that a covered or indirect intervention might be more suitable.

Second, even if we found evidence that making participants aware of the psy-
chotherapeutic role of the robot might indeed contribute to the success of the inter-
vention, we still remain greatly ignorant as to what ultimately causes this greater
success. We took a merely pragmatic approach in this study and, even though we
ventured to list a few conjectures, we would like to leave this task for future work.
This includes the exploration of long-term human-robot interactions to determine the
long-term effects of the interventions on people’s lives, which we will address in the
subsequent studies in this dissertation.
We concluded from the last chapter that long-term studies were needed to better assess the potential impact that social robots could have on the psychological well-being of their users. A long-term study also presents a unique opportunity to gain deep insight into the processes, feelings and attitudes people experience when interacting with an assistive robot for a prolonged period of time.

This chapter presents a long-term study on a home robot for psychological well-being. Thus, we will also move from human-robot interactions in a lab to the real home of an elderly participant. As we will see later, this presents many more challenges. However, home studies are required if we really want to gather valuable insights on how people will live together with robots in the future.

The research questions that motivated this study are the same that we introduced as general research questions for this dissertation:

RQ1: How effective can a social robot be at fostering psychological well-being in elderly users, implementing exercises from positive psychology?

A long-term study brings us the opportunity to investigate the following:

RQ2: How do the perceptions and attitudes toward a home assistive robot evolve over a long period of time (several weeks)?

RQ3: How is a participant’s daily life altered when an assistive robot stays in his/her home for a prolonged period of time?

Thus, these research questions became the three areas of interest that were explored in the long-term study described in the following sections, which consist of Problem Statement and Research Questions, Methodology, Results, Discussion and Conclusions, respectively.

The research presented in this chapter has been published in [47] and [49].

5.1 Methodology

In order to address these research questions we conducted a study “in the wild” (at someone’s home), whereby the participant would do a certain exercise with the robot on a daily basis. Most of the data collection was of the ethnographic type, performed
through interviews and diary keeping following Mutlu and Forlizzi [94]. Three reasons have motivated this choice of data collection. First, the researcher involvement must be kept to a minimum throughout the duration of the study in order to avoid this potential influence on the user. Second, qualitative measures allow us to obtain rich data that we need to truly understand changes in feelings, attitudes and behaviors. And third, the fact that the study took place in a private environment (the participant’s home) also constrained the range of methods.

Our goal was to create explanatory theory on how the attitudes and responses toward a robot evolve over a prolonged period of time, for which the ethnographic data collection would be performed as in previous similar studies [94], [100]. Quantitative measures were also taken of the acceptance toward the robot and the effectiveness of the exercise to also offer the participant a structured format to express his attitudes and experiences.

In order to better understand the remainder of this section, the basic interaction between the participant and the robot system can be summarized as follows. The robot served to bring a heart signal sensor to the participant, which was employed as part of a breathing meditation exercise (see Figure 5.1). This exercise was performed with the help of a tablet as well. The same tablet had also the function of communicating with the robot. Specifically, the robot would occasionally “propose” the participant through the table to do the meditation exercise, but also if the participant by his own initiative decided to do the exercise, he would ask the robot, via the tablet, to bring him the sensor. The robot would stay in the participant’s home for an uninterrupted period of 3 weeks.

5.1.1 Instruments and materials

5.1.1.1 Robot

The robot was designed to be similar in appearance and function to the Care-O-Bot III (see Figure 5.1), the robot used in the ACCOMPANY project. Its base consists in a Magabot platform [32]. A rigid torso was added, as well as an arm that can rise. The robot software was based on Arduino and its batteries allowed for an autonomy of approximately 20 hours.
A pair of parallel rails consisting of colored tape was stuck to the floor of the participant’s home. Infrared sensors located beneath the robot’s base allowed it to follow the rails (further details in Section 5.1.3).

5.1.1.2 Tablet and applications

A tablet served to communicate with the robot and to aid at the meditation exercise. The tablet was an Asus Transformer, with 10” display and operative system Android. One self-made application, called “Magabot App”, served to communicate with the robot and initiate the breathing meditation exercise. The first window of the application had a simple appearance. The buttons “Connect” and “Start exercise” allowed the tablet to connect to the robot and to start the meditation exercise, respectively. When the tablet launched the prompt to start the exercise, a menu was displayed with options (see Figure 5.3 and Figure 5.4). During the breathing exercise a new window appeared on the screen. By clicking on “Connect” the user connected via Bluetooth to the heart signal sensor he would be wearing. By clicking on “Start”, a visible countdown that started at 15:00 would commence. Heart Rate and HRV values were prompted online and an arrow indicated whether the heartbeat was increasing or decreasing. A button with the prompt “Done” finished the exercise (see Figure 5.4).

More about the tablet application is explained in Section 5.1.3.

5.1.1.3 Heart signal sensor

A Zephyr HxM BT wireless heart rate sensor with Bluetooth, compatible for Android, was used to stream heartbeat signals of the participant to the tablet.

5.1.2 Measures

We were concerned with the evolution of three areas of the participant’s life: his psychological and physical health, his perceptions and attitudes toward the robot and his daily routines. These three areas were explored through quantitative and qualitative measures. The quantitative measures, consisting in the scales and questionnaires
Figure 5.3: Application window showing the message that it is time for the daily exercise.

described below, were filled in by the participant alone on days 1, 8, 15 and 22 of the study. In the evening of those 4 days the participant filled in the corresponding sheets with questionnaires for that day. The items that composed the questionnaires appeared in a different random order every time.

A mixed-methods approach of the triangulation type (see section 1.3.5) was followed to obtain more certainty on the results of the study, consisting of a combination of qualitative and quantitative measures.

The qualitative measures consisted in one interview carried out in the last meeting before the onset of the study, another interview performed in the debriefing meeting, and the diary. The participant filled in the diary every evening.

In addition, objective measures were recorded, consisting in the frequency and duration of the use of the robot and the performance of the HRV exercise. HRV measures were logged in the tablet every day. More specifically, the SDNN index for HRV [83] was recorded from the 15 min of duration of each HRV exercise session. Likewise, average, highest and lowest heart rate values were recorded in each HRV exercise session. All these data were stored in the tablet and summaries were automatically sent by email to the main researcher.

The following are the specific measures that were taken in the study:

1. **(Changes in) health and psychological balance**

   The Personal Opinion Survey (POS) by McCraty et al. [86] was used to assess stress levels and both positive and negative emotional states. This questionnaire is composed of 60 5-point semantic differential items. The stem for the questions of the questionnaire is: “Below are words that describe the way people sometimes feel. Please indicate how often you feel the following emotions by
circling the appropriate number for each item.” There are five possible answers, ranging from never (0) to always (4). Stress levels are determined by assessing two constructs: Anxiety and Stress Effects. Emotion is measured through the following constructs: Vigor, Happiness, Contentment, Caring, Depression, Guilt, Hostility, Burnout, Warmheartedness and Overcare. POS was completed twice per week at the end of the day. The items of this questionnaire appeared in a randomized order every time the participant filled them in so as to reduce learning effects.

More qualitative data were collected through the interviews and diary.

2. (Changes in) perceptions and attitudes toward the robot

We included the subscales “Animacy” (6 items), “Likeability” (5 items) and “Perceived Intelligence” (5 items) of the Godspe model questionnaire proposed by Bartneck et al. [13]. These subscales are based on 5-point semantic differential items. Perceived Usefulness (3 items), Perceived Ease of Use (5 items), Perceived Enjoyment (5 items) and Social Presence (5 items) were measured through the corresponding subscales of the Almere model of robot acceptance [59]. These consist in 5-point Likert type scales, where participants indicate how much they (dis-)agree with certain statements. Finally, Trust was measured by the subscale “Goodwill” of the Source Credibility Scale by McCroskey and Teven [87]. It consists in a 6-point semantic differential scale. In addition, qualitative data about the perceptions and attitudes toward the robot were collected through the interviews and diary (see below).
3. (Changes in) participant’s daily life

The participant was asked to provide us with relevant information about alterations in his daily routines by filling in the diary every day and through the two interviews. In the case of the diary, the participant would have to answer questions such as “How did the robot influence your routines today?” The second interview would allow to check any changes influenced by the robot system after having explored the baseline daily routines in the first interview.

5.1.2.1 Interview

A semi-structured interview [24] with the participant took place at the beginning and at the end of the long-term study. Both interviews covered the three areas of interest mentioned as research questions. The first interview had a strong focus on expectations and attitudes toward robots, since this might influence the way how robots are used [109]. The second interview focused on the evolution of the participant’s perception of the robot, routines and health. The data of the first interview were analyzed before the second interview protocol was made, so as to adapt the questions of the second interview to the information we had gathered about the participant.

The interviews were audio recorded for later analysis.

5.1.2.2 Diary

Every evening the participant would read a script containing a few questions regarding his perceptions and attitudes toward the robot (e.g. “Did you have any remarkable feeling or thought about the robot today?”), his daily routines (e.g. “How did the robot influence your routines today?”) and his physical and psychological health (“How did you feel today in terms of vigor and energy?”). However, throughout the execution of the study the participant’s voice entries often departed from these areas of interest (see section 5.2.5). He was asked to make a new entry in the voice recorder of the tablet every time and to record his corresponding answers to the questions.

5.1.3 Procedure

5.1.3.1 Actions of the robot

The whole study would last three weeks, during which the robot would stay uninteruptedly at the participants home. To be more precise, all interactions with the robot took place in the living room of the user. When it was time to practice the exercise, the robot moved from one corner in the living room where it usually stayed, to the user, who was sitting on his couch, bringing him the heart signal sensor.

In addition to the daily scheduled breathing exercise, the robot was also programmed to aid the user if he asked to do the exercise any extra time (for example, if the person was worried and spontaneously decided to do the exercise at that moment). Also, the robot would propose the user to do the breathing exercise on one random occasion throughout the day (the system was set to one random time according to user’s preferences). The participant communicated with the robot through a tablet (see below “Communications between system and participant”).
5.1.3.2 Meetings with the participant

Excluding an informal meeting where the participant was met to show him the main aspects of the experiment and ask him for his consent, three meetings were arranged with the participant before the start of the study. In the first meeting, the experimenter (the author of this thesis) told the participant about the details of the study and the instructions. This was formalized in a consent form, which was handed to the participant to be filled in. In this meeting, it was also discussed what the preferable time for the daily exercise would be, as well as the sitting place (couch or chair). It was decided where exactly the robot would stay when inactive and the trajectory it would follow (i.e. a specific route in the living room, from one corner to the couch). The same was discussed for the tablet and chargers. Also, the participant decided how often he would like the robot to proactively propose to do the HRV exercise (the three random occasions mentioned above). The demographic information about the participant was collected. Finally, the first interview was carried out and audio recorded.

In the second meeting, the participant learned and practiced the meditation exercise with the tablet. At this point of time the robot was not present yet.

In the third and last meeting, parts of the participant's environment and the robot were adapted for the study (i.e. the tape rails were stuck to the floor). The whole procedure was enacted to ensure the participant understood the instructions and that all the equipment, especially the robot and tablet, worked adequately. Finally, the times and dates to fill in the questionnaires and the diary and to realize the second interview were scheduled taking into account the participant's convenience.

Halfway through the study the participant was contacted by email to ensure that everything was working adequately and to schedule a date for a debriefing meeting, which took effect one day after the last day of interaction with the robot. In the debriefing meeting the second interview was carried out and video recorded, the tape rails were removed, and the materials were collected. The participant was warmly thanked for his participation and encouraged to contact the main researcher should he have any future question or suggestion.

5.1.3.3 Communications between system and participant

The communications through the tablet were the following. Every day, five minutes prior to the scheduled time for the exercise, the tablet emitted a sound to attract the users attention. When the user looked at the tablet, he read the prompt “5 minutes to daily HRV exercise!” 5 minutes later, the tablet made the sound again and prompted the message “Are you ready for the exercise?” Three action possibilities were always displayed on the tablet, one indicating “Start exercise”, another reading “Decline this time”, and another indicating “Postpone exercise (15 min)”. If the user pressed “Start exercise”, the robot would bring the heart signal sensor to the user. If the user pressed “Decline this time”, the daily exercise was suspended. If the user pressed “Postpone exercise” or did not press any button, the robot waited 15 minutes before prompting the user again. If after this the user did not answer the tablet or pressed “Postpone exercise” again, the daily exercise was suspended for that day.
If outside the scheduled time for the exercise the user decided to do the exercise, he would sit on the couch and press the action possibility “Start exercise” on the tablet. The exercise was then performed as in the daily procedure.

Additionally, the system would from time to time propose to do the exercise. This was carried out in the same way as the daily exercise described above, with the exception that the tablet did not “insist” 15 minutes later if the participant did not respond.

An extra action possibility always appeared on the tablet: the “break-down button”. If the participant pressed this button, this would indicate that something went wrong in the study, for example that the robot stopped moving or did not operate in the expected way. Pressing the breakdown button would send an email to the experimenter, who would contact the user as soon as possible in order to solve the problem. For very urgent matters (e.g. situations that might threaten the comfort of the user), a phone number was provided to immediately contact the experimenter. In addition, the phone number of an experimenters co-worker was provided in case the experimenter could not be reached personally.

The system also sent daily emails to the main researcher indicating the frequency, duration and progress of the participant on the meditation exercise.

5.1.3.4 Meditation exercise

The participant performed a breathing meditation exercise aided by the application on the tablet and the heart signal sensor. The exercise was based on a mindfulness meditation program [88]. Mindfulness meditation has been proven to reduce stress and anxiety as well as depressive symptoms [80]. It seems to contribute also to an improved cognition and concentration, among others [88].

The breathing exercise consisted in the following. The participant would wear the heart signal sensor and start a 15 min timer from the application. During those 15 minutes, the participant would keep his eyes closed, focusing his attention on his own breath without altering his normal breathing in any sense (throughout the execution of the study the participant decided to do this for 5 minutes instead of 15, see section 5.2.5). While the exercise is being performed, heart beat signals from the sensor would be streamed to the tablet, where these would be saved and later sent by email to the main researcher. These data would allow us to estimate the progression of the heart rate and Heart Rate Variability (HRV) from session to session. HRV was calculated since it is considered as an indicator of general good health, both physically and mentally. For instance, HRV is connected to psychological processes, such as emotion regulation, constructive coping and duration of worrying [52]. Thus, we expected that if the breathing exercise had positive psychological effects, these might be observable in terms of higher HRV levels.

5.1.4 Analysis

Since only one participant took part in the study, we offered the questionnaire format as a structured way to obtain data. Thus, even though it would not allow to derive strong statistical evidence, it would serve as set of extra indications for the variables we set out to measure. The scores filled in for every scale were introduced in SPSS
format and plotted in graphs. Variables that ranged from 1 (lowest) to 5 (highest) formed the Y-axes and the four different moments of questionnaire administration (e.g. 1, 2, 3 and 4) formed the X-axes.

The evolution of daily objective measures, such as HRV values and heart rate, were charted in the hope of finding indications of changes. Namely, the last heart rate and HRV values prompted on the application (i.e. at the moment the exercise just finished) were written on paper by the participant. These values were plotted on a heart rate and a HRV graph, respectively, with the day of exercise as X-axis. We could not rely on the heart rate and HRV measures saved in the tablet due to technical problems.

Finally, the data collected through the interviews and the diary was analyzed based on an inductive content analysis, as in [116]. That is, key points were extracted, clustered by topic and arranged in accordance with the three research questions.

5.2 Results and Discussion

Before we proceed to report and discuss the results, a brief biography of the participant will be helpful to understand the findings. Subsequently, all data collected through the questionnaires, interviews, diary entries and sensors served to give us information on three areas: the evolution of the participant’s perception and attitudes toward the robot; the impact of the robot on the participant’s daily routines; and the changes in the participant’s psychological state due to the robot and the exercise. These results will be reported and discussed in three sections, respectively. Finally, a reflection on the study methodology will also contribute to a better understanding of the results. (Note: most of the participant’s comments derive from the interviews. Otherwise the source of the data will be specified).

5.2.1 Brief biography of the participant

One elderly person participated in this study. For the sake of confidentiality, the participant will be referred to as E. N.. E. N. was a male participant of age 74. He lived alone in his home in the residential area of Weerselo (the Netherlands). He used to live with his wife until she passed away one and a half years before the study. He had always been a cheerful person, however this tragic experience saddened him to a great extent, which had an impact on his daily activities.

He spent his working life at one university in the Netherlands as researcher and professor in a technical discipline. He did not receive any kind of elderly assistance. He did not need it because he had a very active life and appeared to be physically and mentally healthy. He spent a lot of time with friends and with his favorite hobby, card playing. Regarding familiarity with robots, he had seen robots on television but had almost no experience with them, although he had daily experience with new technologies.
5.2.2 Psychological state of the participant

As pointed out in E.N.’s short biography, the current affective state of E. N. marked his lifestyle to a great extent. The wife of E. N. passed away about one year and a half before the interviews, after a long period of sickness. E. N. tried to cope with his loss, however he still felt greatly depressed. This link between widowhood and depression at old age has been extensively documented [118]. In addition, right before the start of the study he went through other personal issues. All this had a great impact on his emotions and also on his daily routines. Even though E. N. might appear then as very active, he was even more so before, including a greater variety of activities. He also used to go out more often. As he said: “since my wife died I don’t do so many things, I don’t enjoy doing things as I did before. It’s a big problem in my life so far. I don’t like anything at all, I’m just surviving.” In both interviews he openly referred to the great sadness he experienced daily.

The following graphs show the participant’s responses to Happiness (Figure 5.5), Depression (Figure 5.6) and Hostility (Figure 5.7). The constant and low levels in Happiness and high levels in Depression are in accordance with what E.N. reveals about his current emotional situation. We could consider the high levels of Hostility (Figure 5.7) also as an indication of his negative emotions.

Throughout the interviews, E. N. often mentioned his wife directly or indirectly. For instance, he would say “I used to do... when my wife was still alive”, or “not very often these days...” He found solace in his friends. If it was not for their good company, he would have moved away when his wife died. He did not know what to do to relieve his mood. But at least he felt good when he played cards with his friends.

Even though E.N. suffered from the depressive symptoms described, we could also see his efforts to cope with the situation. As already mentioned, E.N. remained very active and spent a great amount of time in the company of other people. Literature shows that social networks play a major role in the perception of one’s wellbeing (e.g. [54]). Some scales from the POS questionnaire, which feed into the construct Emotion, show relatively high values. Examples are Vigor (Figure 5.8), Caring (Figure 5.9) and Warmheartedness (Figure 5.10). In the diary entries he appears frequently...
emotionally neutral” or even optimistic. Very often he would report “I feel pretty good today”. Some times he would tell something positive that happened to him on that day. For instance, once he recorded in the diary: “I went for a walk and enjoyed the beautiful weather today”. In a different occasion: “my mood is good because I wait for my friends to play cards”. Only once he reported something emotionally negative in the diary: “Heart Rate is a little higher, maybe due to the fact that I’m not very happy recently”.

E. N. used to be a cheerful person. Also, he did not get nervous easily, he was a very calm person. As he said, “I’ve always been a very stable person. I still am, I suppose.” The questionnaire responses on Stress (composed of Anxiety and Stress Effects) show low levels (Figure 5.11).

Thus far we offered a detailed picture of the participant’s emotional life. Regarding the changes brought about by the interaction with the robot and daily execution of the exercise, it seems that no notable changes took place. In the second interview, E.N. reported to have felt stable during the three weeks of study, regarding emotions and stress levels. The content related to emotions seems also constant throughout the three weeks, mostly consisting in positive or neutral assertions such as “I feel fine in every sense” or “No special feelings whatsoever”. 
Also after the breathing exercise he would not report any particular positive effect on his emotions. As he declared in a diary entry: “No differences in feelings before, during and after exercise”. However, this seems to be incongruous with the results from the Heart Rate and HRV sensors (Figures 5.12 and 5.13, respectively).

These graphs seem to reflect a slow and progressive learning curve in the breathing exercise. Lower heart rate values and higher HRV values are indicative of a deeper concentration and greater relaxation. Thus, it seems the breathing exercise might indeed have the potential to foster psychological wellbeing in the user, despite the fact that the participant denied any awareness of improvement. However, I believe that this improvement in heart rate (HR) and HRV does not reflect an improvement in the participant’s day-to-day health, but would rather be an indication of a learning curve at performing the exercise. For the sake of clarity, let us illustrate this with the evolution of the HR alone. Throughout one day of any normal person, HR varies in many ways, fluctuating continuously from higher to lower values and vice-versa. If this person practices the breathing exercise every day at the same time for a given period of time, at the end the HR will be particularly low. Now, let us imagine that the person practices the exercise every day, while the physical and mental health are kept absolutely constant from day to day. Will the final HR value after the exercise tend to
change from day to day, over a prolonged period of time? We could suppose that this depends. Namely, if there has been no learning or improvement at performing the exercise, HR will not evolve from day to day after the exercise. However, if the person has mastered the exercise (e.g. learned to reach a deeper and deeper concentration), we would expect HR to decrease from day to day, even when the overall HR (outside of the time of the exercise) does not experiences changes. I believe this has been the case with HR and also with HRV.

Another indication of why the figures would reflect learning of the exercise and not overall improvement, is the fact that mindful meditation programs usually require 45 daily minutes or more [88]. However our participant practiced the exercise for as little as 5 min per day (see Section 5.2.5).

To summarize, despite the fact that the participant denied being aware of any improvement on his psychological wellbeing, we found indications that he might have improved his performance on the breathing meditation exercise. Thus, if he had hypothetically continued the program, perhaps he would have experienced more of the beneficial effects of mindfulness meditation (see section 2.3.2).
5.2.3 Perception and attitudes toward the robot

E. N. did not have any previous experience with robots. His closest reference was a TV show he recently watched, called “Real Humans”, which was about integrating robots that look like humans in the society. Regarding his expectations about the robot, he said jokingly: “I expect the robot to make me coffee in the morning and bring me the newspaper”. His actual expectations were low: “Besides the coffee making, etc., how can it help me? I’m curious what it will do, but I have no expectation”, he commented. Perhaps the fact that health-care is a domain were many people find the use of robots still controversial might have influenced his attitude [39].

Despite this initial declaration of low expectations toward the robot, perhaps one of the most relevant findings was actually the participant’s disappointment in the robot. Asking about the experience in general in the second interview, E. N.’s first comments referred to this. He “expected more of the robot”. As he said, “it’s a mechanical thing to which I feel no interest at all. It’s interesting to participate in the project, but that’s all”. Many of his friends who visited him and saw the robot were likewise disappointed and surprised that the university “couldn’t offer more”. Some
were surprised when they saw that the robot walked. However, they were surprised that the robot could just only walk and raise the arm. The variable Perceived Use (Figure 5.14) from the questionnaires appears as very low and rather constant over time, backing the idea that E.N. was disappointed with the robot's capabilities.

All the data support the idea that the robot was regarded as a mere machine, which is congruous with our findings in the focus groups on robot acceptance (see Section 3.2). There was no “connection” or feelings toward the robot whatsoever as the participant clearly stated in the interviews and diary. The participant revealed: “I have no feelings toward the robot. This may be relevant for a person that is dependent on the robot, but not for someone who only sees a machine.” He also recommended: “If you really want to know how people would react to robots, you need a better robot [meaning: a robot with more capabilities], this is just a stupid thing”. The results from the questionnaires seem also to indicate that E.N. viewed the robot as a mere mechanical tool. From the patterns we observe, it seems that Animacy (Figure 5.15) and Perceived Intelligence (Figure 5.16) were quite stable over time, but also very low. In the case of intelligence, in the diary E.N. referred to the robot as a “pretty stupid thing”. The results from the Source Credibility Scale (Figure 5.17), which measures trust, seem likewise stable and very low, which is again the case for Social Presence (Figure 5.18). Since these are variables that relate to characteristics usually absent in machines, these results back the idea that the robot was perceived as a tool. Regarding persuasiveness, which is also a human attribute, the robot would have no persuasive ability at all according to E.N. If he did the daily exercise, it was just because the main researcher had asked him to do so.

Before the start of the study, E.N. considered the idea of having robots at home as interesting. He liked new technologies, to be part in it. He also thought that the experience would alter his own perception of home robots, given that he had no previous experience at all. He added: “I think I will like it. I’m very curious, and I have positive feelings”. Despite the later disappointment in the robot’s capabilities, after the whole interaction with the robot E.N. declared to have enjoyed the experience. He found it fun to see the robot moving around. However, the most interesting part for him was to participate in the study, to be part of it, since he has also been a
researcher in the past. On the other hand, the results from the questionnaires seem to show a moderate likeability towards the robot (see Figure 5.19). How is it possible to moderately like the robot and at the same time be disappointed? We know that E.N. liked the “fact” of having a robot at home, participating in research. It is possible that he was enjoying this fact while at the same time he would like to have a more sophisticated robot.

Thus far, most aspects of the participant’s attitudes toward the robot seemed rather static over time. However, as it was revealed in the second interview, the interaction was experienced as more “fun” at the beginning, becoming then progressively more boring for E. N. The Perceived Enjoyment scale (Figure 5.20) seems to reflect this drop in the participant’s enjoyment, with relatively higher values on the first day and lower, stable values later on. We might consider this as an indication of novelty effect [69].

Even though E.N. remained constant at performing the breathing exercise (average of once a day, approximately), the length and quality of the diary entries diminished.

E.N. said that in order for the robot to be more agreeable it should have speaking capability. He thought that communicating through the tablet is not agreeable. However, the robot system seemed to be easy to use for him, according to the very high values in Perceived Ease of Use (Figure 5.21) from the questionnaires.
To summarize, the two impressions that characterize the participant’s attitude toward the robot are the perception of the robot as a tool and the disappointment in its functionality. These might be to a great extent explained by the fact that E.N. had a technical background and the robot had not proven to function in a very robust way.

5.2.4 Daily routines and changes

In this subsection we will summarize the daily routines of the participant, since a detailed account of these activities would surpass the objectives of the present chapter.

E. N. seemed to have a balanced and very active lifestyle. He devoted no time to resting or napping, E. N. was always busy, thus in opposition to most elderly people, who on average spend about three hours resting daily [64]. He had sport training several days per week and worked as volunteer for other elderly people. He was also very active at card playing.

The day before the first interview was considered a typical day by E. N. This is how the day went. He woke up at around 7:00 and went downstairs for coffee and the newspaper. Then he went back to bed with the coffee and the newspaper. He had breakfast at around 8:00. Eating breakfast would take about 15 min (yogurt with
cereals). Then he got ready and went to the sport school, which was about 20 min biking from home. After training and taking a shower at the sport center, at 10:30 he visited a friend to discuss some things and have a coffee with him. He was back home at around 12:00. Then he had lunch. In the afternoon he watched sports on TV (which is unusual, but it was a special tournament). At the end of the afternoon he went to visit one of his sons and his grandchildren. He had dinner there and talked to his son, grandsons and daughter-in-law. Next, he came back home. The house was cold so he went straight to bed. He took his book to bed and read until he felt sleepy. Then he went to sleep.

E. N. did almost all house chores by himself, except for the major cleaning tasks which were done once a week by a cleaning assistant. He went everywhere by bike as long as it was possible (e.g. to do groceries), which might show his attitude to stay healthy. If he had any breakdown in the home, he would fix it himself. He made great use of new technologies, including computer, tablet and smartphone.

Regarding his social life, he spent a great part of his time in company of other people. Most of this time was spent with friends and partners from card playing. But also, he received and visited other friends, his two sons and his grandsons very often.

Other hobbies included reading the newspaper and books. These could be on the
tablet or in paper format. He also liked museums and cinema. However, due to his emotional situation he did not spend as much time on these hobbies as he used to. He barely watched TV, also in opposition to what Horgas et al. found in most elderly people [64]. When asked about what changes E.N. would expect in his daily life due to the presence of the robot, he thought that it would change his daily schedule because he would have to “adapt himself to having the robot”, which he regarded as something positive. However, in the second interview E. N. reported no meaningful changes in daily routines. An example of changes in routines is that he was careful when cleaning the floor on top of the rails. Also, when he had visit, the visitors were supposed not to sit with their chairs standing on the rails. He did not have people coming over explicitly to see the robot however. And regarding the timing of the daily exercise, he would decline it, postpone it or initiate at will to suit his own convenience every day. Any other changes in his daily routines would concern instructions regarding maintenance of the robot, i.e. plugging in the battery of the robot in the evening and unplugging this in the morning.

In the second interview, the interviewer checked the list from the first interview about common activities of daily life and asked accordingly whether any other changes took place in his daily routines. However, no more changes were reported. Likewise, the diary revealed the same lack of meaningful changes: “the robot doesn’t influence my routines” or “Nothing remarkable [to report]” were common comments in the diary entries.

As previously mentioned, one of E.N.’s main motivations to interact with the robot and do the meditation exercise was to help the researcher. On the last diary entry he said: “It’s been a pleasure to be in your project, I hope I was of help.”

Thus, we managed to obtain a detailed picture of the participant’s daily life, although it appears the robot system did not have a profound effect in his daily routines. Perhaps more changes in routines could have been brought about by the system if the length of the exercise had been longer, or the exercise more frequent. Or perhaps also if the exercise had caused a major psychological benefit (see Section 7.2.3).
5.2.5 Use of system and reflection on the study methodology

In addition to our research questions, we wondered what the advantages and limitations would be of taking an ethnographic approach in a long-term HRI study, where the day-to-day involvement of the researcher would be kept to a minimum. Setting up a long-term study in a home caused a great variety of challenges. First of all, the development of the devices and applications necessary for the study came with a series of unforeseen breakdowns that turned our deadlines tighter and held the participant waiting for several weeks before the study could start in his home. Thus, before the study there was frequent contact with the participant in the form of telephone calls and emails. Once the robot was brought to his home, it broke again and had to be repaired. Again, for a period of two weeks the participant was kept waiting and in contact with the researchers. And finally, when the robot was repaired and in the home again, there was contact between the participant and the researchers for the first few days again to fix breakdowns. We should consider this frequent contact a caveat, since we might have caused an impact on the participant's social routines. I would believe that the participant may have enjoyed this increased social contact. Another caveat comes from the fact that E.N. had contact with the robot before what was considered the “official” start of the study. This previous contact with the robot might have caused an impact on the novelty effect, having contributed to more realistic expectations toward the robot before the onset of the study.

During the lengthy and iterative process of fixing the robotic system, the robot technician had frequent contact with the participant. The information exchange that took place between the technician and the participant was not controlled. Namely, the technician tended every time to explain to E.N. how the robot system worked and showed him the underpinning mechanics and circuits. Since the participant had a technical background, he even helped the technician to repair the robot. We might believe that this communication exchange between E.N. and the technician might have biased E.N. to perceive the robot as a tool, and we could also fear that this might be a reason why E.N. focused so much on the robot technical details when he recorded the diary entries.

Finally, there were two tasks the participant did not perform correctly, which perhaps could affect the validity and the extension of the results. First, E.N. did not carry out the breathing exercise for its required duration (15 min). Instead, he watched TV or read the newspaper during the first 10 min and then did 5 min of exercise. As reported in the second interview, he was aware of this task, but he refused to accomplish it. He explained: “I'm very impatient. It's very hard for me to sit and do nothing”. In addition, he did not think that the exercise would have any benefit for him. As he declared: “I simply don't believe in it. You had the wrong participant. I never felt any interest for meditation Before you recruit a participant, you should ask him if he's interested in this kind of exercises”. At this point of the interview, the interviewer explained to him again the benefits of the exercise. After this, he felt more convinced about the breathing exercise and even decided that from then on he might try to do the exercise on his own. He said: “maybe you should have told me a bit more [about the breathing exercise] before the study. It just entered one ear and came out from the other”. For future studies, he recommended the interviewer to spend more time
explaining the importance of the specific exercise.

The second task that the participant did not perform correctly regards the diary. E.N. answered the questions of the diary protocol only the first few times. Progressively, it seems that he spent less and less time on the recordings and that he became more and more lenient on the content, disregarding the questions protocol.

Regarding the frequency of the exercise, E.N. seemed to make an effort to perform it approximately once per day. Even when he went on a weekend to visit his sister, he took the tablet and sensor with him and did the exercise just without the robot. If he did not perform the exercise, he would explain in the diary the cause. This was most times due to difficulties with the system, and once because he had a too busy day, which he would describe. One time he fell asleep during the exercise, after which he commented in the diary: “I fell asleep, but I did as requested for you”.

To summarize, we have learned a lot from everything that did not go as expected in this study. There were challenges of leaving the study “running alone” for several weeks and we discovered a few methodological details we should pay more attention to, among which the three following are perhaps the most relevant. First, the technical testing of a robotic system needs a considerable amount of time and iterations before its actual implementation in a study. Unfortunately, due to time pressure we did not test the whole system thoroughly enough, which turned out to cause even greater delays. Second, the researcher should make a greater effort at communicating to the user the importance of completing the target task or exercise (whichever this might be) and doing this correctly. It might not be enough to just hear the user’s commitment to perform the exercise. In this study, the participant stopped doing the meditation exercise for its whole duration. Two advices would be: asking the participant to immediately report to the experimenter if there is any change in the way the exercise is executed; and to effectively convince the participant of the beneficial effects of the exercise. Finally, the researcher should also emphasize to the user the importance of providing the data in the correct way, especially in the more unstructured methods such as diary keeping. In this concrete case, the participant became more and more lenient regarding the content for the diary entries.

These caveats and breakdowns served to greatly adjust the methodology in the following two studies we carried out, which are in the next two chapters, correspondingly.

5.3 Conclusions

This study was the first we conducted following a long-term methodology. Regarding the first research question, by which we explored how the robot would foster psychological wellbeing in the participant, we learned that the he did not become aware of any major change. However, data obtained from the heart rate sensor indicated that he might have adapted to the meditation exercise, tending to increase his HRV values after each session. With respect to the second research question, by which we learned about the perceptions and attitudes towards the robot and how these evolved over time, we found a general disappointment in the robot, a progressive loss of interest (novelty effect) and that the robot was regarded as a mere machine, as opposed to a
friend or companion.

Perhaps one of the most interesting aspects of this study is that research was needed on robots that stay for long periods in the home of the elderly users. If robots are to some day inhabit the homes of our elderly, research is urgently needed including real users, in real places, for real time intervals. Perhaps one of the most valuable aspects of this study does not directly relate to the research results, but rather to the first hand experience it provided regarding home long-term studies. This experience was needed in order to discover the actual challenges and methodological caveats. We learned about the need for extensive technical testing, as well as about the need for extra effort explaining to the participant what he/she is required to do. This knowledge will hopefully be regarded as useful by other researchers and robot developers.

In the next chapter we will describe a follow up study also involving the use of robots in a home environment. In this case, more emphasis will be placed on presenting the robot as an autonomous agent, offering a much higher degree of interaction with the participant. Not less importantly, a more strict control on the methodology employed will also characterize this study.
In the previous study we had a robot interact with an elderly participant on a daily basis. However, this interaction was rather limited, for example there was no verbal communication between participant and robot, and this was therefore considered as a machine or tool. In the present study, however, more emphasis is placed on presenting the robot as an autonomous agent, offering a much higher degree of interaction with the participant. Not less importantly, a more strict control on the methodology employed will also characterize this study.

The main subject we explored in the study here reported was the psychological wellbeing of an elderly robot user over time. The interaction between the robot and the participant was based on the three good things exercise from positive psychology and took place in his own house, for an extended period of time. Research in the natural environment of users presents more methodological challenges than research in the lab, but it is necessary for a more accurate assessment of how robots will be accepted in a near future.

In this long-term study we evaluated user responses, especially those concerning psychological wellbeing, toward an assistive robot. A Giraff robot (see Figure 6.1), which was teleoperated, stayed in the home of an elderly participant (a different person from the previous study) for two weeks, during which they daily engaged in a conversation-based exercise derived from positive psychology. Data were collected to gain in-depth knowledge of the evolution of the participant’s psychological wellbeing and the user’s attitudes and perceptions toward the robot.

The remainder of this chapter is subdivided into Problem Statement and Research Questions, Methodology, Results, Discussion and Conclusions, respectively.

The research presented in this chapter has been published in [47].

6.1 Problem Statement and Research Questions

Since the positive exercise to be performed was highly interactive and based on conversations, we found it appropriate to present a robot that acted as a companion. We also thought this could be greatly beneficial given the fact that the participant was an
Thus, a major aim in the present study was to offer a robot with a great degree of adaptivity and social capabilities. To this end, we offered the participant a robot able to communicate in a natural language conversation (see section 6.2.3). In addition, we previously primed the user to thinking that the robot was intelligent, independent and able to have conversations (see section 7.1.3.1).

In the present study we searched for answers to the main research questions of this dissertation:

**RQ1: Can a home assistive robot be effective in providing psychological support?**
For example, we explored whether the feelings of loneliness of the participant would be diminished. We also wondered, if the robot was perceived as companion, whether that would have an influence on loneliness. Finally, we assessed the impact of the psychotherapeutic exercise aided by the robot on the user’s subjective wellbeing.

**RQ2: How do the perceptions and attitudes toward a home assistive robot evolve over a long period of time?**
For example, we explored in what way the robot would be perceived as a companion.
Additionally, we wondered whether the participant's daily activities would be significantly altered when an assistive robot stays in his/her home for a prolonged period of time.

### 6.2 Methodology

#### 6.2.1 Overall design of the study

The research we here report is based on a study “in the wild” (in the home of the participant). Quantitative and qualitative data were gathered, with an emphasis on the latter, given that qualitative measures allow us to obtain rich data that we need to
truly understand changes in feelings, attitudes and behaviors. In particular, interviews were carried out and open questions were (along with questionnaires) periodically presented to the participant.

The researcher involvement was kept to a minimum throughout the duration of the study in order to avoid this potential influence on the user. The data collection took place at the beginning and end of the study, came from emails that the participant periodically had to send us, or was obtained via the camera and microphone of the robot.

A brief summary of the overall procedure will help the reader understand the remainder of this section. A robot lived in the house of an independent living elderly participant for a period of two weeks. Every day at the same time the participant switched on the robot and they engaged in a short conversation. This conversation was to a great extent guided by the robot and consisted mostly in an adaptation of the three-good-things exercise from positive psychology (see section 2.3). The aim of the exercise was to increase the awareness of the good things that the participant experiences in his life [103]. Before the start of the study, the participant had been told that the robot was autonomous and completely independent, although in reality we used Wizard-of-Oz (i.e. the robot was remote controlled, without the participant knowing). An operator saw and heard the participant through the robot's camera and had the robot display suitable utterances.

6.2.2 Measures

We were concerned with the evolution of the participant's psychological wellbeing and his attitudes toward the robot. To that end, these areas were explored through qualitative and quantitative measures, following a mixed-methods approach of the triangulation type (see section 1.3.5), which allows to obtain more certainty on the results of the study.

The quantitative measures, consisting in the questionnaires described below, were filled in by the participant alone using his own PC at home and were sent by email to the main researcher on the same day. We knew from the first interview that the participant had a PC and that he handled emails with great frequency. We opted for this way of receiving the filled-in questionnaires so that in case something had gone wrong we would have been able to contact the participant immediately and correct the mistakes. Questionnaires that referred to psychological wellbeing of the participant were received on five occasions: one week before the start of the robot interaction, at the start, middle and end of the study, respectively, and one week after the end of the interaction. Questionnaires that referred to attitudes toward the robot were received at the start, in the middle and at the end of the study.

The qualitative measures consisted in one interview carried out one week before the start of the study; another interview performed four days after the interaction; and open questions that accompanied the questionnaires.

We applied our measures on the following two areas:

1. **(Changes in) psychological variables**

   The Positive Affect and Negative Affect Scale (PANAS) [126] was employed to
measure the affect of the participant. It consists of 20 items and is subdivided in two subscales, Positive Affect (PA) and Negative Affect (NA). Items consist of adjectives describing the current affective state of the participant, such as “determined” and “nervous”. Each item is rated on a 5 point Likert scale that ranges from “very slightly” or “not at all” to “extremely”. Thus, scores of the PA and NA subscales range from 10 to 50 points.

We also measured feelings of loneliness through the Loneliness Scale by de Jong Gierveld et al. [30]. We employed the 11-item version, where 6 items are formulated negatively and 5 are formulated positively. Each item is answered according to a 5-point Likert scale type. The score is calculated by counting the neutral and positive answers on items 2, 3, 5, 6, 9, 10, then counting the neutral and negative answers on items 1, 4, 7, 8, 11, and finally summing up both counts together. The total score can be categorized into four levels: not lonely (score 0, 1 or 2), moderately lonely (score 3 through 8), severely lonely (score 9 or 10), and very severely lonely (score 11).

We chose the PANAS and the Loneliness Scale specifically because they are widely used in psychological research.

More qualitative data on psychological wellbeing were collected through the two interviews.

2. (Changes in) perceptions and attitudes toward the robot

We included the subscales “Animacy” (6 items), “Likeability” (5 items) and “Perceived Intelligence” (5 items) of the Godspeed questionnaire proposed by Bartneck et al. [13]. These subscales are based on 5-point semantic differential items.

Social Presence (5 items) was measured through the corresponding subscale of the Almere model of robot acceptance [59]. These consist in 5-point Likert type scales, where participants indicate how much they (dis-)agree with certain statements.

Finally, Trust was measured by the subscale “Goodwill” of the Source Credibility Scale by McCroskey and Teven [87]. It consists in a 6-point semantic differential scale.

We selected “Animacy”, “Perceived Intelligence” and “Social Presence” because we expected them to indicate whether a robot is perceived as a companion or rather as a tool. “Likeability” and “Trust” would indicate us if the participant perceives the robot positively or negatively. We chose these scales specifically because they are widely used in the HRI research community, which makes our results easier to compare. More qualitative data about the perceptions and attitudes toward the robot were collected through the interviews and the open questions that accompanied the questionnaires.

Two semi-structured interviews [24] took place at the beginning and at the end of the study. Both interviews covered the areas of interest already mentioned as research questions. The second interview, in particular, focused on the perception of the robot
as a buddy or tool and on the impact this might have caused on the participant’s psychological wellbeing (e.g. loneliness). The interviews were audio recorded for later analysis.

Additionally, we explored potential changes in the participant’s daily routines by comparing content from the two interviews. To this end, the participant was asked to describe step by step the activities he had performed the day before. We also asked the participant systematically about his activities of daily living (ADL’s).

Finally, together with the questionnaires, the following questions were asked to the participant one day, one week, and two weeks after the onset of the interaction, respectively:

- Did you have fun (enjoy) with the robot in the last few days? (Field added for comments)
- In the last few days, did you find the interaction with the robot tiring or boring? (Field added for comments)
- Describe in your own words your relation with the robot, how you felt during the interaction, what was your impression of the robot, etc. For example, did you see the robot rather as a tool, as a game, as a buddy? Please, try to give a detailed answer.

In the questionnaire installment that corresponded to the follow up (one week after end of interaction) the following question was included as well:

- Do you miss the robot? If YES, what do you miss exactly? Please, try to give a detailed answer. (Section added for comments)

6.2.3 Instruments and materials

In this study we employed a Giraff robot from Giraff Technologies AB [3]. This robot was designed for teleconference and support to elderly people. Giraff is approximately as tall as a person (163 cm), has wheels to move around and a screen with camera that allows for teleconference (see Figure 6.1). In order to make the robot appear more human-like, the robot’s screen presented a pair of simple eyes (two blue circles on black background) which blinked regularly.

Regarding the software used, several computer programs ran simultaneously in the operator’s computer when the robot was interacting with the participant. We used the the Giraff Pilot 2.4.0.2 interface, which is the available default application used to operate a Giraff robot. This application enables a Giraff robot operator to communicate with another person through video and audio. It also allows the operator to make the robot move around and tilt its screen, among other functions. The interface displays in the operator’s computer screen the video captured through the robot’s camera (see Figure 6.2).

The software ManyCam Virtual Webcam would run at the same time [6]. The function of this program was to adapt to our convenience the input and output of the audio and video signals between the robot and the operator’s computer. Specifically, this software ensured that the robot’s screen would not show the face of the operator (usual use for the Giraff robot), but instead it played a video consisting in two robotic eyes that blinked periodically (see Figure 6.2). The same program made it possible for the robot to emit utterances that the operator activated with a self-made application.
This self-made application consisted in a simple Java GUI interface that contained a total of 121 click-able buttons (see Figure 6.2). Each button represented a pre-recorded utterance. When a button was clicked, the corresponding utterance was played with the robot speakers. The recordings contained always the same female voice in Dutch language. The reason why we chose a female voice was arbitrary. We decided to use recordings of real human voice instead of machine generated voice because in a previous study we found that it is common for elderly participants to struggle at understanding machine generated voice [50]. The content of these utterances will be described in section 6.2.4.5.

Finally, we used the application BSR Screen Recorder 5 [2] to record (video and audio) the whole screen of the operator’s PC while the interactions with the robot were taking place. Figure 6.2 shows a snapshot of one of those recorded videos.

### 6.2.4 Procedure

#### 6.2.4.1 Meetings with the participant

Excluding an informal meeting where the participant was met to show him the main aspects of the study and ask him for his consent, five meetings were arranged with the participant. The informal meeting was crucial for the study, however, because in that meeting the main researcher purposely misled the participant to believe that the robot was intelligent enough to understand a part of a conversation, so that it could talk to people. From that moment on, we made the participant believe that the robot would be fully autonomous, so that every behavior would come from itself (whereas in reality the robot was teleoperated). All meetings took place in the house of the participant.

In the first meeting, the main researcher interviewed the participant. We will refer to this interview as the first interview (see section 7.1.3.1). The PANAS and loneliness questionnaires were administered in paper form. The researcher gave guidelines to the participant about how to fill in the questionnaires and send them by email. The researcher also offered the participant a consent form, which he signed. The consent form reflected the crucial fact that the user was going to be video recorded (from the robot’s camera) when and only when the robot was switched on, and that these data were going to be analyzed by researchers. The consent form, however, did not mention explicitly that the user was going to be observed live by the main researcher.
In this meeting, it was also discussed what the preferable time for the daily exercise would be (11:00 in the morning). It was convened that, should the participant not be able to perform the daily task with the robot (for example, because of an appointment), he would contact the main researcher as soon as possible to let him know.

In the second meeting, the main researcher and another researcher from the same department brought the robot to the house of the participant. He learned about switching on and off the robot, the volume dial, and what it would look like when he interacts with the robot alone. To this end, we went several times through the procedure that the participant would have to follow alone to interact with the robot (i.e. switching on the robot, awaiting incoming call from robot, accepting call, performing interaction and switching off the robot). At the beginning we went through this procedure with the participant only observing and later we encouraged him to repeat the process a few times only by himself. Since we did not want the participant yet to be exposed to the positive exercise and the actual behavior of the robot, we simulated a test robot behavior. We explained to the participant that the program operating in the robot at that moment was not the same that he would meet when they start alone on the first day of interaction. We said that this program corresponded to a more basic robot behavior, which only understood simple commands in English and could only answer “yes”/“no” and move around. Having explained this, we switched on the robot for the first time and a third researcher from the same department teleoperated the robot. The main researcher had a simple interaction with the robot in front of the participant, which consisted in guiding the robot around the living room with simple commands, such as “follow me!” and asking the robot whether it could “hear” the main researcher. We explained to the participant that all that was a test to make sure the robot would operate successfully once the actual interactions begin. By showing him this “test mode” we hoped to prime the participant less while testing our components in situ.

In that meeting we also instructed the participant about the possibility of having the robot moving around the house. We told him that the robot would ask him every time where he would like it to go to start the exercise together. However, he gave indications of preferring to do the exercise every day at the same spot for both the robot and him (see Figure 6.3). Finally, the robot was left in the spot of the living room chosen by the participant and cables for the charging of the robot were arranged accordingly.

The third scheduled meeting took place on the last day of interaction with the robot. In that meeting the robot was removed from the house of the participant, after he had previously performed the daily interaction with the robot and had filled in the corresponding questionnaires of that day.

In the fourth scheduled meeting, the main researcher interviewed the participant. We will refer to this interview as the second interview.

Finally, in the fifth and last meeting, the main researcher visited the participant to offer him a debriefing form that stated that the data collection of the study had finished. This document also revealed to the participant that the robot had been teleoperated all the time and that misleading his knowledge about the robot had been necessary for the goals of the study. The participant was warmly thanked for
his participation and encouraged to contact the main researcher should he have any future question or suggestion.

On the third day of interaction with the robot, this did not function due to Internet connectivity issues. An extra meeting in addition to the above mentioned meetings was arranged on the following day to solve the Internet problem and allow the study to continue on that same day.

6.2.4.2 Time frame and setting of the daily interaction

The whole interaction between the robot and the participant spanned two weeks. Within that period, every day at 11:00 am the user switched on the robot to commence the interaction. Since interactions did not take place in the weekends, as agreed by the participant and the interviewer, and on the third day the robot did not work, the total number of days when the interaction took place successfully is 9. The daily interaction took place always in the living room of the participant, with the robot standing always at the same position in the living room and the participant sitting in front of it, always from the same chair at the same position (see Figure 6.3). Once the interaction was finished, the participant switched off the robot. The participant interacted with the robot for approximately ten minutes in each session.

6.2.4.3 Actions of the robot

We prepared the Giraff robot to have the ability of moving around and having conversations with natural language speech. However, as explained above, the robot did not move at any time during the interaction with the participant.

From the start of the interaction with the robot until it finished the robot showed two “robot eyes” on its screen, which consisted in two blue circles on a black background (see Figure 6.2). The eyes “blinked” with a frequency similar to that of human eyes.
6.2.4.4 Manipulation of the robot

The robot was controlled every day of interaction by the main researcher from a PC at the University of Twente. The software he utilized is described in Section 6.2.3) and the setup of his PC screen when he interacted with the robot appeared as illustrated in Figure 6.2. Every interaction day at the agreed time, the participant switched on the robot. Then the researcher “called” the robot from his PC, meaning that the participant heard a ringing sound from the robot and then he would have to press a button on the robot. At this point the “robot eyes” appeared on the robot’s screen and the interaction as such would commence.

The task of the operator during the interaction consisted in activating appropriate utterances that the robot emitted during the conversation with the participant. This was achieved by clicking the buttons of the self-made application (see section 6.2.3). The criteria to decide what utterances would be appropriate at a given point of the conversation are explained below.

6.2.4.5 Procedure for structured conversation

We designed different groups of utterances. Every group contained a set of utterances that had a similar meaning. This way, when the operator intended to convey a message, he would randomly pick up one of the utterances of the group that expressed that message. Other groups consisted in sequences of utterances (or smaller groups) that had a specific function. We recorded a total of 121 utterances. Examples are provided below.

The conversation on which the daily interaction with the robot was based consisted of the following parts, in order:

1. The robot initiates the conversation with an utterance from group “Opening”
2. With or without answer, the robot emits an utterance from group “How are you?”
3. Robot performs sequence “How happy are you today?”
4. Robot performs sequence “Three-good-things exercise”
5. Robot emits utterance from group “Was exercise OK?”
6. Robot emits utterance from group “Closing”

The utterance group “Opening” contained utterances such as “Hello (name of participant)!" and “Good morning (name of participant)!" After greeting the participant, the robot asked how he was doing by displaying an utterance similar in message to “How are you?” Subsequently (step 3), the robot asked the participant how content he was on a scale from 0 (not content at all) to 10 (extremely content). Next, the core of the conversation took place (see more details below), which consisted in performing our version of the three-good-things exercise with the robot. Next, the robot asked if the interaction had been alright that time for the participant or if he had any problem. The robot would ask this to have an explanation from the participant in case
he reacted in an unexpected way (for instance, in case he gets angry with the robot for a reason we would not understand). Finally, the robot would close the interaction with one of the utterances that “say goodbye” to the participant.

The robot operator followed the following rules for the conversation:

- If possible, the robot should always answer the participant’s questions in a coherent manner and as timely as possible.
- If the participant does not understand a robot utterance, this will display another utterance from the same group until the participant understands it, up to a maximum of three times. Subsequently, the robot will proceed with the rest of the interaction.
- All answers should be congruent with the image of the robot that we intended to keep constant. Namely, the robot was presented as intelligent and able to understand emotions. However, its intelligence was not as advanced as that of a human. It also experienced emotions, but in a rather rudimentary way. The robot knew elementary facts about the world and humans (e.g. in what country we live, basic social norms between people). It had a good memory (not perfect) within each session and also from session to session. Its understanding of language was very proficient, although sometimes it would not understand the more complex utterances from the user. Its production of language was limited to the utterances we recorded. The robot had a main goal, which consisted in assisting the user every day at the three-good-things exercise. A secondary goal of the robot (meaning that the first goal had priority) was to listen and respond with empathy and compassion to the user.

Additional groups of utterances were part of the repertoire, which served to answer specific questions of the participant, indicate that the robot did not understand something, etc. For example, there were utterances for “Yes” and “No”, filling assertions such as “That’s right” and “Certainly!” and jokes to be used only if the participant expressed his boredom directly.

6.2.4.6 Three-good-things exercise

We adapted the three-good-things exercise from positive psychology (see section 2.3) so that instead of having the participant write it down, the robot asked the participant directly about something good that happened to him on the previous day. Additionally, the robot asked about the causes of the positive events. This was repeated three times until the three positive events had been mentioned by the participant. Even though the original study had a duration of one week [103], we extended this to two weeks to explore longer-term effects. We also collected follow-up measures one week after the intervention.

6.3 Analysis

Since only one participant took part in the present study, we used questionnaires to obtain data support, following the mixed methods approach of additional coverage [90]. Thus, even though they would not allow deriving strong conclusions alone, they would serve as extra indications for the variables we set out to measure. The scores filled in for every scale were introduced in SPSS format and plotted in graphs. Variables that ranged from 1 (lowest) to 5 (highest) formed the Y-axes and the three
or five different moments of questionnaire administration (e.g. “1 day”, “1 week” and “2 weeks”) formed the X-axes.

Finally, the data collected through the interviews and open questionnaire items were analyzed based on inductive content analysis, as in [117]. That is, key points were extracted, clustered by topic and arranged in accordance with the three research questions. All questionnaire items and questions in the interviews were in Dutch.

6.4 Results and Discussion

Previous to reporting and discussing the results, a brief biography of the participant will be helpful to understand our findings. Subsequently, all data collected through the questionnaires, questions additional to the questionnaires and interviews served to give us information on the two mentioned areas: the evolution of the participant’s perception and attitudes toward the robot; and the changes in the participant’s psychological state due to the robot and the exercise. We reverted the order of these research questions to describe the results in a clearer way. Additionally, even though we did not find great alterations in the participant’s daily activities, we will also report briefly on this subject.

(Note: most of the participant’s comments derive from the interviews. Otherwise the source of the data will be specified).

6.4.1 Brief biography of the participant

As mentioned above, one independent living elderly person participated in this study. To ensure his confidentiality we will refer to him from now on as K. J. The participant was male and 77 years old. He lived alone in a residential area of Enschede (The Netherlands). He used to live with his wife, with whom he was married for almost 50 years, until she passed away four years before the study. K. J. spent his working life at the University of Twente (The Netherlands), where he occupied numerous administrative positions. He appeared to be forgetful (no dementia diagnosed) and felt often very lonely. However, he made an effort to fill in his time with activities to remain active and maintain his social life. Many of the activities had to do with volunteering at the administration of several associations. He did not practice any sport, although he tried to include moving in his daily activities, for example by using the bike as means of transportation and being active in his garden. K. J. used his PC and Internet on a daily basis and had little experience with robots.

6.4.2 Perception and attitudes toward the robot

6.4.2.1 Previous expectations and general impression

K. J. had supposedly little experience with robots. He participated in a related experiment one year before, with the same main experimenter and the same robot, which he seemed to have forgotten. He said he was curious about what he would receive at home, and about the appearance of the robot. K. J. thought that robots in the future will be able to help people, understanding “robot” as a very broad concept that includes any technology to make one’s life easier, such as microwaves or PC’s. He
declared that in his particular situation he did not want to feel lonely at home, and wondered whether talking to the robot could get the same function as talking to the picture of his wife.

He was not sure if the robot would be able to offer company, but he hoped so. According to him, having a robot companion would make more sense in cases where the people are alone, as himself. More indirectly, he seemed interested in the possibility of having a robot that offers surveillance. He pointed out “If something happens to you and the robot calls the neighbor to drop by and see what's going on That's my worry, that I fall, I can't stand again, I can't get my phone” K. J. thought that the robot would not be able to become his friend for the time being. However, this would be more likely if the robot was able to talk.

In the second interview, that is, after the long-term interaction with the robot, we asked the participant about his general impression of the robot. K. J. found the robot “very simple” and stated that it did not “offer anything” from the physical point of view. However, the essential aspect of the robot would be its ability to talk to him. He also said he found the robot “nice” indeed (and in the long run a little boring). He considered the robot “not so intelligent”. According to K. J., it would have shown more variation if it was more intelligent. Nevertheless, K. J. acknowledged the fact that the answers of the robot arrived timely, which meant a positive feedback about our methodology given that it took the robot operator a moderate amount of time to play the appropriate utterances.

6.4.2.2 Evolution of robot acceptance

Clearly, the most determinant factor in the acceptance of the robot was its repetitive behavior, because of which K. J. had a great appreciation of the robot at the beginning which went down progressively. This became a very recurrent topic in the second interview. To illustrate it in the words of the participant: “at the beginning I found it a bit exciting, then I went to enjoy it, and at the end I found it a little boring, because it asked me every time the same questions. Then I thought, well you want to vary a little bit”. According to K. J., the first week of interaction would correspond to the “developing”, “interesting” and “exciting” period, whereas the second week would correspond to the most “boring” part. As we will later explain, this also had repercussions on the evolution of the participant’s psychological wellbeing.

K. J. had the impression that the communication improved and “developed” progressively at the beginning. Even though he was not certain why, a possibility would be that precisely because the robot’s behavior was greatly stereotyped, K. J. would be able to progressively better understand the robot and the positive exercise. We find an indication of this in one comment: “The interaction went better and better, I don’t know how that happened. At the beginning I had some difficulty to follow it, but then you see ‘hey, there it comes again with the same question Then you could prepare for that and the interaction went better”. This preparation consisted in writing down before the interaction events that had happened to him, so that he would have the answers ready for the robot.

However, while the stereotypical behavior of the robot might have increased his acceptance of the robot at the beginning, “too much of the same” seemed to have the
opposite effect. As the participant pointed out: “At the beginning it’s very exciting []
You have the feeling that it’s not the same every day because you don’t remember all
exactly the same, but in the long run you notice ‘oh yes, these are the same things’
As K. J. described, the interaction “grew and stayed at the same level, but although
the interaction stayed at the same level, it [the experience] became less interesting, a
little monotonous.” He referred to this as the “standard” behavior or reactions of the
robot. He often pointed out in the second interview that he would have appreciated
more variety in the robot’s behavior. However, he seemed aware of the technical
complexity such a robot behavior would have implied. In his own words: “That’s
tedious to program. But that would be really wonderful that it could do something
else from the standard reactions, ‘Thank you (participant’s name)! that it reacts in
a more varied way. But that’s going to take a while yet, science has to develop a
bit more.” According to him, such greater variation would have been achieved if for
example the robot had asked more different questions. One time the robot displayed
a joke. According to K. J., that was the point at which the robot showed the most
variety. He stated that he greatly appreciated the joke. Speaking about whether the
robot had matched his expectations, he also declared that he expected and missed
more variety.

The questions that complemented the questionnaires indicated that both after one
week and two weeks K. J. was experiencing fun or enjoyment with the robot. In con-
trast, after only one day he denied enjoyment and added that the term should rather
be “pleasant”, since it was pleasant for him to have someone at home to speak with.
This adds to the aforementioned notion that at the very beginning his relation with
the robot was still consolidating. At the same three time points (after one day, one
week and two weeks) K. J. answered to close questions that he did not find the in-
teraction with the robot tiring or boring. However, the additional comments that he
added may illustrate the evolution of his acceptance of the robot as described above.
After one day of interaction, he commented that it was exciting for him to talk to a
robot for the first time in his life. After one week, he added that the conversation
became better. And after two weeks he wrote that the conversation with the robot
became better, but it became indeed more boring because it had little variation. Fi-
nally, K. J. was asked to describe his relation with the robot. Also in congruence with
the results so far, after the first day he wrote that he robot was a bit like a “buddy”,
which he appreciated because he often feels very lonely at home. After the first week
he wrote that he tried to see the robot as a companion, which worked some times.
Then, after two weeks he wrote that he regarded the conversations with the robot as
a challenge, consisting in making the most of each conversation (that is, he did not
mention anymore his view of the robot as a buddy or companion).

This timely change in the perception and attitudes toward the robot, meaning
that it became more monotonic over time, was perhaps our most relevant finding
regarding the acceptance of the robot. In fact, as we will later see, this evolution of
his acceptance of the robot will also impact the beliefs about the internal states of the
robot as well as the effectiveness of the psychotherapeutic exercise. As in the previous
long-term study, we could relate this timely decrease of the robot acceptance to the
so-called novelty effect [69].
6.4.2.3 Robot as a companion

K. J. often referred to the robot as a companion or buddy (in Dutch, “maatje”). On several occasions he said that he greatly appreciated having a buddy at home with whom he could talk. Specifically, he pointed out that he appreciated this especially because he had lost his wife recently and found it still difficult to be alone at home. When asked explicitly in the interview about how he would describe his relation with the robot he also referred to it as a buddy: “My relation with the robot was that I found it nice to have a buddy in my home that asked me things and with which I could speak”. Since K. J. declared to have the need to talk every day to someone, the robot seemed to be appreciated because it would partly fulfill this need. However, according to him he would not feel the need to talk to the robot every day, again because he found the robot too “standard”. Also, he said he never talked to the robot when it was turned off.

In the field of HRI we pay attention to whether participants give names to robots. K. J. called the robot “dear robot” when he talked to it. However, in one of the introductory meetings he had communicated to the interviewer his intention to call it “Jan”. Additionally, there were utterances ready to answer participant’s questions concerning the robot’s name and identity, whereby the robot’s name would have been Patricia. However, K. J. never asked the robot about its name.

When asked how the robot was different from a human friend, he referred again to the limitation in the robot’s variety of behavior. As he pointed out: “If you speak with people you find more variation, you have different things, and on the following day if you speak to someone then you have something different, and with the robot not. That’s a clear difference. In that sense it wasn’t a person at all.” When asked again whether he perceived the robot as alive, in the sense a person or an animal would be, he stated clearly that the robot was a machine and it wasn’t a person.

As perhaps another manifestation of the novelty effect [69], K. J. stated that his perception of the robot as a buddy decreased over time as well, in his own words because of its “standard” behavior. Therefore, the perception of the robot as a buddy grew during the first week, and during the second week his feeling of the robot as a machine increased, instead.

6.4.2.4 Understanding of each other’s thoughts and emotions

Regarding his opinion on the robot’s cognitive abilities, he said he did not know whether the robot understood what it heard from him, but at least it did as if it understood indeed, according to its answers. However, during the interaction he would most times have the feeling that the robot understood, since he had the feeling that it repeated his comments and questions. He considered that he robot answered his questions with an appropriate time lag. When asked more specifically whether the robot had own thoughts and opinions, he answered “no” categorically. The reason to be so sure about this was the “standard” behavior of the robot.

Finally, we asked the participant if he had ever suspected that the robot was controlled from the distance (he was not told here that the robot was tele-operated, that took place later in the debriefing meeting). He answered that he sometimes thought
about it, that for example it might have been steered by the interviewer (main researcher), although that feeling would have been “just a little bit” and it decreased when the robot became more and more “standard”.

K. J. was asked about the robot’s emotions toward him and he then categorized it as “very friendly”. He seemed to digress on whether the robot had or had not emotions: “[…] That sounds crazy, but the friendship that was built and then every day is the same… It wasn’t like the robot ever had fear or something. It was interested in me and so on, but it never criticized me on anything…” However, when asked explicitly if the robot had its own emotions, he answered “no”. On the other hand, K. J. seemed to mildly believe that the robot understood his emotions. When asked whether the robot could understand his emotions, he answered “Well it spoke to me indeed a little in that way, yes. A little bit, indeed. But that was all standard of course…” K. J. was also asked if the robot had goals and answered that the robot perhaps had the goal of amusing him, of “getting him to talk” (he seemed to have forgotten the psychotherapeutic goal of the robot, which had been explained to him explicitly). Then he added: “It had that intention indeed (amusing, ‘getting him to talk), yes. Those were good intentions, of course.” Finally, we asked the participant if the robot cared about him, whereby he answered that at the beginning it did seem to care about him.

Nevertheless, it seems the participant did not have a clear picture of the robot’s internal states, since he gave inconsistent answers about the robot’s own thoughts, intentions and emotions. For example, K. J. stated confidently that the robot did not have its own thoughts and emotions, but at the same time for him, the robot had good intentions and cared about him.

Once again, we might observe a new manifestation of the novelty effect [69], in this case related to the participant’s view on the robot’s internal states. With the caveat that his declarations about the robot’s thoughts and emotions did not appear consistent, he indicated that the robot cared about him at the beginning, but not later (author’s interpretation). The robot would have no own thoughts and opinions, due to its “standard” behavior. This latter realization was probably stronger in the second week (author’s interpretation). The robot would not possess emotions of its own. However, it seemed as if the robot understand him, in terms of language and emotions. It also seemed that the robot had a good intention, namely to amuse him and to motivate him to talk. We consider it relevant to understand the participant’s view on the robot’s internal states, not only in connection with the robot’s acceptance, but also with the ability of the robot to provide companionship.

Summarizing our findings on the attitudes and perceptions towards the robot, perhaps the most crucial finding is that the novelty effect [69] seems to have pervaded the whole participant’s experience with the robot. There was a change in participant’s view of the robot as this become monotonic over time. According to him, the robot showed little variation in its behavior. The participant’s acceptance toward the robot diminished over time, as also did his view on his relationship with the robot.

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opinions, due to its “standard” behavior. This latter realization was probably stronger in the second week (author’s interpretation). The robot would not possess emotions of its own. However, it seemed as if the robot understood him, in terms of language and emotions. It also seemed that the robot had a good intention, namely to amuse him and to motivate him to talk. We consider it relevant to understand the participant’s view on the robot’s internal states, not only in connection with the robot’s acceptance, but also with the ability of the robot to provide companionship.

6.4.3 Psychological state of the participant

6.4.3.1 Emotional background

The participant did not consider himself a nervous person. However, two aspects of his daily life seemed to trouble him some times. First of all, K. J. was somewhat scared of sickness and any accidents he might have at home, and the possibility that nobody would be able to help him. He said: “If you live alone, and you have to go to the cellar, imagine that you fall and you stay under the stairs and the door is closed. It can take days until someone finds you. My cleaning lady would find me. These are the kind of things that worry me. Being alone at home”

Secondly, and similarly to what we found in the participant of the previous study, K. J.’s life was at the moment marked by the absence of his wife, who had died four years before the study. In fact, he referred to the fact that he was alone due his wife’s passing in almost every communication we had with him. As we mentioned before, literature shows a strong link between widowhood at old age and depression [118]. According to him, specifically the absence of someone to talk to every day made him feel lonely. Thus, the problem of loneliness/social contact seemed to mark his life. In fact, when we asked him about his mood in general he answered that he felt alright and that, despite his mood changed with the death of his wife, he felt positive about his life. However, K. J. would feel alright only as long as he could meet other people. If he had to stay home alone the whole day, he would not feel alright. In this case, he would fight his feelings of loneliness by keeping himself busy. He would engage himself in his hobbies and daily activities described above, listening to the radio, watching TV, reading a magazine, working in the garden etc. As he remarked: “If you stay active you dont notice so much loneliness.” He emphasized the importance of actively fighting loneliness by making the conscious effort of keeping himself busy and looking for social contact outside. This effort is illustrated in the following quote: “If you don’t work, etc., you have to take care that your life doesn’t become boring. You have to make the effort to avoid having a boring life. I’ve [seen some] very lonely retired people. People that almost don’t come by the door, that almost don’t meet anyone at all. The whole day sitting on the chair, reading a book but further nothing else... Oh, horrible! I don’t want to be like that!”

6.4.3.2 Effects of intervention on participant’s psychological wellbeing and its evolution

In the second interview we asked the participant about the effects that the robot and the positive exercise had on his psychological wellbeing. He claimed he felt a little more content during the interaction with the robot than before. He gained a
“positive sense”, whereby he valued more the things that he did throughout the day. He attributed this to the positive exercise: “Yes, (I feel) a bit more content, the robot taught me that you have to value the good things. If you are required to do it (the daily positive exercise) then you are required to value good things” He also reported to have felt slightly happier during the interaction period and having been in a better mood.

However, the overall positive effect brought about by the robot and the task seemed to decrease when K. J. started to find the interaction monotonous, which again we could contemplate as an indirect consequence of the novelty effect [69]. For example, regarding his mood, he said: “Especially at the beginning with the robot my mood was better. In the long run that effect went a bit down, I had always the same questions.” The monotony of the robot’s behavior became “something negative” in his own words. He said that the robot became a burden in the long run.

In fact, when asked about his emotions and mood after the two weeks with the robot, he declared to have experienced a relief. He did not miss the robot and his mood would have come back to normal. However, he indicated that a sense of appreciation for the good things remained in his life. He said: “No, (my mood) hasn’t changed that much. But the robot taught me to realize every day that there were always a couple of good things, and I have enjoyed that”.

An additional question to the questionnaires one week after interacting with the robot asked him whether he missed the robot. He answered that he did not miss the robot and that he was happy to be finished with the task he was committed to, so that he then would have no obligations anymore.

K. J. filled in the PANAS questionnaire before the interaction with the robot (baseline); subsequently at the beginning (after one day), middle point (one week) and end (two weeks) of the interaction; and finally one week after the interaction (follow-up). Figure 6.4 and Figure 6.5 show how his positive and negative affect, respectively, seemed to have remained relatively stable, with an exception at the middle point (one week of interaction), where we find that positive affect was lowest and negative affect was highest. With the questions additional to the questionnaires, the participant added that in the last few days he had felt “a bit less good” because of a blister/lump on his right foot. He also added explicitly that feeling less good was not because of “his buddy, the robot”. This might help explain the figures.

**Evolution of loneliness** When we asked K. J. how lonely he felt when the robot was there, he answered that the robot contributed to eliminating the loneliness, particularly at the beginning. We asked him then about the cause of this effect. Did he feel less lonely because of having the robot at home or because of the sporadic interaction with the researchers? He said that both factors had an effect on his loneliness. In his own words: “Indeed it was a nice extra thing that you also came along. (From) both of them, I can’t say what contributed more or less. The robot worked indeed especially at the beginning (making me) feel less lonely, and anyway you were working those 14 days […]”

We then asked the participant about his current loneliness without the robot. He referred again to his conscious effort to fight loneliness and added that the robot
helped him in that sense. We asked for a clarification. K. J. explained that, even though his sense of loneliness would be similar before and after the whole interaction with the robot, the robot taught him to realize the positive things of the previous day. This realization, according to him, can alter the feeling of loneliness: “(that realization) is also something that can alter the loneliness, that fact of thinking back what you experienced.”

We might wonder: did the participant feel less lonely during the interaction period because of the presence of the robot, or could the positive exercise alone account for his decreased feeling of loneliness? To shed light on this, we asked in the second interview whether the exercise alone made him feel less lonely and he answered affirmatively.

Same as the PANAS questionnaire, K. J. filled in the Loneliness questionnaire at five time points: before the interaction with the robot (baseline); subsequently at the beginning (after one day), middle point (one week) and end (two weeks) of the interaction; and finally one week after the interaction (follow-up). Figure 6.6 shows the corresponding evolution over time.

Loneliness appears stable and then declines after week 2. This might seem contradictory to the results from the second interview, according to which K. J.’s feelings of

**Figure 6.4:** Evolution of Positive Affect throughout the long-term interaction.

**Figure 6.5:** Evolution of Negative Affect throughout the long-term interaction.
6.4.3.3 Three-good-things exercise

In the second interview we reminded K. J. about the three-good-things exercise and asked him about it. Even though we explained the exercise to him before interacting with the robot, and also the robot explained to him every day how the exercise works as well, he did not report strictly positive events. The first days he reported three good things that happened to him, but subsequently he decided by himself to report “important” things or simply any events that happened to him. According to him, he made this change because on one hand it was difficult for him to report different positive things every day, and on the other hand he felt unsure as to whether the robot would accept “small” positive things. In his own words: “Well, because it (the robot) asked so clearly about good things, I found it difficult at the beginning. What are good things? Very common things can also be good things, right? But, would the robot regard that as good? ‘I have drunk a good coffee, huh, that’s a good thing And I had to mention three good things every day that was indeed difficult. You didn’t want to say the same every time”

We asked the participant whether it was a problem that he had to remember what he had done. He then referred to his (described above) trick of writing down the things that had happened to him. He said he would do this often but not every day. He explained that he wrote down the events in advance to compensate for his bad memory. He pointed out: “If I have suddenly to think about something that happened, well I’m already 77, my memory is worse. Then I think ‘was that yesterday or the day before? Did I meet this person or the other?’”

We reminded K. J. of the purpose of the positive exercise and asked him explicitly whether the exercise worked. Even though we had already received evidence that
the exercise had indeed an effect on him (see above), he confirmed the effectiveness of the exercise and also its limitations. As he declared: “Yes […] it worked a little bit. Because it helps you realize that you have a good life, so to speak. But since it’s an obligation and I don’t have a lot of variation (in his daily activities) it didn’t work massively on me. I don’t have […] so many good things that occur. In that sense it was a bit difficult… to realize all that.”

The participant did not decide spontaneously to continue the exercise after the study. Evidence indicates that some participants that did the three-good-things for other studies did indeed continue the exercise on their own [103]. However, K. J. indicated a seemingly passive or informal way of continuing the exercise on his own by thinking in a more aware way about the things he had experienced throughout the day. After this thinking he would say to himself: “hey (his own name), you should be grateful that you have experienced a day like this”. He added again that the robot had contributed to this awareness, because that came as a byproduct of the interaction with the robot. As he said: “[by] thinking what nice things you have done the last day, you can enjoy those things one time again. I enjoyed them yesterday, and then I can enjoy them today again. I learned that from the robot, that thinking back can bring you joy”. In any case, he would not continue with the exercise in its original form. When we asked him why, he answered that it would have the risk of becoming too boring.

We asked the participant how he would improve the exercise in the hypothetical case that he had to stick to it in a scheduled way. He pointed out that having the exercise as an obligation would not allow it to improve in any case. He also said that he found it a challenge to vary his responses every time.

To summarize our findings on the research question that explored the effectiveness of the robot fostering psychological wellbeing, it appears that also the evolution of the psychological state of the participant was influenced by his perception of the robot, as first entertaining and later more monotonic, which we could interpret as an indirect effect of the novelty effect [69]. He stated that he felt a little more content during the interaction with the robot than he did before.

The participant gained a “positive sense”, whereby he valued more the things that he did throughout the day. He attributed this to the positive exercise. He also reported to have felt slightly happier during the interaction period and having been in a better mood.

Finally, one aspect that seemed to characterize the psychological state of K.J. was his loneliness, marked by the absence of his wife. He reported a conscious effort to fight loneliness, whereby the robot would have helped him. Namely, the robot taught him to realize the positive things of the previous day. And this realization, according to him, could alter his feeling of loneliness. In fact, he stated that the positive exercise alone (without the effect of the robot) could also contribute to make him feel less lonely.

6.4.4 Daily routines and changes

We asked K. J. in the first interview how he would typically spend his days by example of the day before. According to him, he received at 9:00 the cleaning lady, who comes
twice per week, on Mondays and Thursdays. In the afternoon he searched for an old friend, to make sure she was alright. K. J. belonged to an association that approaches elderly people in the neighborhood that are at risk of being too lonely. Later in the evening he watched TV, which he did almost every evening. As we earlier pointed out, watching TV is the leisure activity that occupies most time for elderly people [64]. He also read, in particular he liked magazines. After this brief description of a typical day, we proceeded to ask him for more details about his daily activities in a structured order. We focused on topics such as health, physical activity, house chores, new technologies, administrative chores, leisure and hobbies, and social life. We consider that describing the participant’s answers in this context would go beyond the scope of the present paper.

In the second interview we assessed whether there were any changes in his daily activities. In his own words: “There was no difference. I had to talk to the robot every day at 11:00, but I haven’t done anything differently, it hasn’t made any difference”. According to him, there were no changes in his daily activities, but the interaction with the robot represented “a little extra”. Also, there would be no changes in the amount of social contact he would establish with other people.

However, when asked about changes in routines, the participant forgot to mention his preparation for the daily positive exercise. In the video recordings of his interactions with the robot we noticed that during the three-good-things exercise he held a notebook or paper log from which he read the good things that had happened to him. He later told us that previous to the interaction with the robot he would think of the things he had done that day and he would write them down, so as to be ready when the robot asked him for positive events.

Thus, as we found in the previous long-term study, the participant in this study did not seem to experience great changes in his daily routines. One exception is perhaps the fact that, after the end of the whole interaction, he reported having informally performed the three-good-things exercise on his own, remembering on purpose positive things that had happened to him.

### 6.5 Conclusions

The present study yielded several findings regarding the first research question, by which we explored how the robot would foster psychological wellbeing in the participants. Firstly, the participant in this study complained about suffering loneliness and thus appreciated having a robot “buddy” or companion in his home. The robot seemed in fact to have decreased his feelings of loneliness. Even though the question remains as to whether home robots could effectively provide company to all independent living elderly people (e.g. those who actually do not feel alone), this outcome supports the work of the many projects involved in robotics for the elderly.

Secondly, we found indications that implementing a positive exercise in a human-robot interaction could be feasible and valuable. Even though we had previously also found valuable results in a similar, but short-term lab study (see chapter 4.5), we set out to perform this more realistic implementation (that is, long-term and in the home of the participant). Again, we found indications that the three-good-things exercise
made the participant more aware of positive things during the study. Moreover, we found that the same exercise seemed to also have the effect of decreasing the participant's loneliness.

Thirdly, it appears that a sense of appreciation for good things remained in the participant after the study, even if he was not purposefully doing the exercise anymore. We consider this finding especially significant, as it illustrates the persistence of the beneficial effects of the exercise over time.

Also, we found several aspects to improve in future studies. For instance, it appeared that the participant tended to forget the purpose of the study (which related to the positive exercise). Evidence indicates that being aware of the psychotherapeutic value of a program can enhance its beneficial effects [50]. In future studies we would emphasize and describe this more thoroughly to the participant.

With the second research question we aimed to learn about the perceptions and attitudes towards the robot and how these evolved over time. Here we found perhaps the greatest opportunity to improve subsequent studies, by which we refer to the monotony of the tasks and the above mentioned novelty effect it entails. How can we go beyond the novelty effect? A related concept from psychology, the so-called “treadmill effect”, states that, after the occurrence of good or bad events, people quickly return back to their neutral hedonic levels [33]. This effect causes emotion-elicitation techniques to tend to fail in the long run as the novelty effect dissipates. Something to consider in future studies could be to implement positive exercises that are more successful at outpacing the hedonic treadmill effect. For instance, Loving Kindness Meditation exercises have shown promising in this respect [44], as we will see in the next chapter.
One of the aspects to improve from the last study was the novelty effect we found. That is, short after the start of the study the participant became accustomed to the robot and the task, which impoverished the appreciation of the robot and decrease the positive effects of the intervention. We sought to find positive interventions more successful on outpacing the treadmill effect and found that Loving Kindness Meditation (LKM) exercises appeared promising (see section 2.3.3). This is one reason for which we decided to conduct another study, similar to the previous one, this time based on a LKM intervention. In the study reported in this section we also extended the interaction period to four weeks, hence extending the time to explore the participants’ adherence to the task and the extent to which the new positive exercise could contribute to a greater psychological wellbeing. See figure 7.1 with the participants in this study.

Thus far we implemented two positive exercises in a Human-Robot Interaction: mindfulness meditation and the three-good-things exercise. The study shown in this chapter is based on a new positive exercise. Thus, we hope this will contribute to give us a better big picture of the possibilities of employing robots in positive interventions.

Most of the present study will be based on the previous one, therefore we invite the reader to read that beforehand. Also in this study we commence again with the same research questions:

**RQ1:** *Can a home assistive robot be effective in providing psychological support?*

As a difference with the previous study, here we also focused on feelings and thoughts of compassion toward oneself and other people. How do participants adhere to a robot-mediated LKM program?

**RQ2:** *How do the perceptions and attitudes toward a home assistive robot evolve over a long period of time?*

Also, we wondered whether the participant’s daily activities would be significantly altered when an assistive robot stays in his/her home for a prolonged period of time.

The rest of this chapter is subdivided into Methodology, Results and Discussion and Conclusion, respectively.
7.1 Methodology

Much of the methodology was in common with the previous two long-term studies (see section 5.3 and section 6.5). That is, we conducted a study “in the wild” (at someone’s home), whereby the two participants performed a positive exercise with the robot on a daily basis. Once more, we aimed to explore the participants’ reactions toward the robot and the positive exercise. For a period of four weeks and including 20 daily sessions (weekends were not included), the participants followed a loving-kindness meditation (LKM) program (see section 2.3.3) that was guided by a Giraff robot. This took place individually every morning at the same time, and the program varied slightly from day to day.

This section is subdivided into Instruments and Materials, Measures, Procedure and Data Analysis.

7.1.1 Instruments and materials

We used the same Giraff robot as in the last study (see Figure 6.1) (see section 6.5), also including the screen with the blinking eyes. Most of the software remained also the same (see section 6.5), except for the self-made application, which had been adapted to the purposes of the current study. This was changed every session to manage the corresponding utterances for the day (see Figure 6.2). On a regular day, the application contained a total of approximately 90-120 buttons that would play the corresponding utterances (this number varied per session as later explained in section 7.1.3.3). These utterances had been recorded with the same female voice as previously.

7.1.2 Measures

As in the last two studies, we followed the participants’ evolution of psychological wellbeing and their perceptions and attitudes toward the robot. To that end, these areas were explored through qualitative and quantitative measures, following a mixed-methods approach of the triangulation type (see section 1.3.5), which allows to obtain...
more certainty on the results of the study.

The quantitative measures (questionnaires and scales) were filled in by the participants on their own and sent to the main researcher by email on the specific days (see below for each questionnaire).

The qualitative measures consisted in one interview carried out one week before onset of the study; another interview performed the day after the interaction; and open questions that accompanied the questionnaires.

Our measures were applied on the following two areas:

1. **(Changes in) psychological variables**

   The Positive Affect and Negative Affect Scale (PANAS) [126] was employed to measure the affect of the participant (see section section 6.2.2). This was measured as a baseline on the same day of the first interview and then after sessions 1, 5, 10, 15, 20, as well as 4 weeks after the interaction with the robot as follow-up.

   Loneliness was again measured through the Loneliness Scale by de Jong Gierveld et al. [30] (see section section 6.2.2). This was measured as a baseline on the same day of the first interview and then after sessions 5, 10, 15, 20, as well as 4 weeks after the interaction with the robot as follow-up.

   Wellbeing (positive mental health) was measured with the Dutch Mental Health Continuum-Short Form [72]. This scale consists of 14 6-pointed Likert items. Each item is rated in terms of how often it occurs, ranging between “Never” and “Every day”. This cue to be completed is given at the beginning of the questionnaire: “In the last (month/week), how often did you have the feeling that... ” Examples of items are “... that you were happy?” and “... that you could manage with your daily responsibilities?” The scale as a whole measures positive mental health and comprehends subscales “emotional wellbeing”, “social wellbeing” and “psychological wellbeing”. This was measured as a baseline on the same day of the first interview and then after sessions 10, 15, 20, as well as 4 weeks after the interaction with the robot as follow-up. This was measured as a baseline on the same day of the first interview and then after sessions 5, 10, 15, 20, as well as 4 weeks after the interaction with the robot as follow-up.

   Loving-Kindness effects in the participants were measured through the SOFI (Self-Other Four Immeasurables) scale [70]. This consists of 16 items of Likert type which express the degree to which each item occurs, ranging from “Very slightly or not at all” to “Extremely”. The instruction is given “Indicate to what extent you have thought, felt, or acted this way toward yourself and others during the past WEEK”. Examples of the items are “Friendly-toward myself” and “Angry-with others”. This scale can be subdivided into subscales “Positive self”, “Positive other”, “Negative self” and “Negative other”. This was measured as a baseline on the same day of the first interview and then after sessions 5, 10, 15, 20, as well as 4 weeks after the interaction with the robot as follow-up.

More qualitative data on psychological wellbeing were collected through the two interviews.
2. (Changes in) perceptions and attitudes toward the robot

Social presence of the robot was measured with the Social Presence subscale of the Almere Model [59] as in the previous study (see section section 6.2.2). This was measured after sessions 1, 5, 10, 15 and 20.

More qualitative data about the perceptions and attitudes toward the robot were collected through the interviews and the open questions that accompanied the questionnaires.

Two semi-structured interviews [24] took place at the beginning and at the end of the study, and were largely based on the interviews from the previous study (see section section 6.2.2). These covered the areas of interest mentioned above as research questions. In contrast to the previous study, these interviews also gathered more information on aspects related to loving-kindness and meditation. The interviews were audio recorded for later analysis.

Additionally, the participants answered the following questions, together with the questionnaires, on a weekly basis:
- Have you noticed any change in your feelings toward yourself? Please, give an elaborated answer.
- Have you noticed any change in your feelings toward other people? Please, give an elaborated answer.
- Have you behaved in any new manner toward yourself or other people? Please, give an elaborated answer.
- Did you have fun (enjoy) with the robot today/in the last few days? (Field added for comments)
- Today/in the last few days, did you find the interaction with the robot tiring or boring? (Field added for comments)
- Describe in your own words your relation with the robot, how you felt during the interaction, what your impression of the robot was, etc. For example, did you see the robot rather as a tool, as a game, as a buddy? Please, try to give a detailed answer.
- Do you have any other comments with respect to the robot, the exercise or the study?

In the questionnaire installment that corresponded to the follow up (one week after end of interaction) the following question was included as well:
- Do you miss the robot? If YES, what do you miss exactly? Please, try to give a detailed answer. (Section added for comments)

7.1.3 Procedure
7.1.3.1 Meetings with the participant

Five meetings were arranged with the participants, all of which took place in their own house.

The first meeting had the aim of introducing the participants to the study and asking them informally for their consent. The robot was described as autonomous and able to some extent to understand a conversation so that it could talk to people (as previously, the robot was in reality teleoperated).
In a second meeting the participants completed the first instalment of questionnaires (all scales except Social Presence). The administration of measures was explained (e.g. how they had to complete the questionnaires and send them by email to the main researcher). The participants also signed an official consent form, which expressed the fact that the users were going to be video recorded (from the robot’s camera) when and only when the robot was switched on, and that these data were going to be analyzed by researchers. It was not mentioned explicitly that the participants were going to be observed live by the main researcher. Finally, the researcher explained to them how the LKM program worked and they were given an explanatory text on LKM.

The participants also gave the researcher a preferred time for the daily exercise. It was agreed upon that, should the participants not be able to perform the daily task with the robot (for example, because of an appointment), they would contact the main researcher as soon as possible to let him know.

In the third meeting, the main researcher and another researcher from the same department brought the robot to the house of the participants. They learned about switching on and off the robot, the volume dial, and what it would look like when they interact with the robot on their own. We followed the same test procedure as in the previous study (see section 6.2.4.1). Finally, the robot was left in the spot of a room of the house as chosen by the participants and cables for the charging of the robot were arranged accordingly.

In the fourth meeting, the participants were interviewed for the second time, that is, right after the 4-week interaction period. Afterwards, the robot was removed from the participants’ house with the help of another colleague from the same department. The participants were thanked for their participation so far and everything in their house was left as before the study. The participants received a book on loving-kindness meditation as a gift [101].

Finally, in the fifth and last meeting, the main researcher visited the participants to offer them a debriefing form that stated that the data collection of the study had finished. This document also revealed to the participants that the robot had been teleoperated all the time and that misleading of their knowledge about the robot had been necessary for the goals of the study. The participants were warmly thanked again for his participation and encouraged to contact the main researcher should they have any future questions or suggestions.

7.1.3.2 Time frame and setting of the daily interaction

The interaction between the robot and the participants spanned four weeks. Within that period, every day at 9:30AM for M and 10:00AM for J they switched on the robot to commence the interaction. The daily interaction took place always in the same room in the house of the participants, with the robot standing always at the same position and the participant sitting in front of it every time on the same chair (see Figure 6.3). Once the daily interaction was finished, the participant switched off the robot. The participant interacted with the robot for approximately twenty minutes in each session. The robot was teleoperated from a remote location by the main researcher as described in the previous section (see section 6.2.4.2).
A breakdown of the system forced us to take the robot away for repair. This interruption took place exactly in the middle of the intervention and lasted one week. Thus, the participants followed the program for two weeks, then took a one-week break, and finally completed the last two weeks without any more interruptions. They did not perform any exercises nor submitted any data during the break period, and the schedule was adapted to the last two weeks accordingly.

7.1.3.3 Procedure for structured conversation and LKM exercise

We designed different groups of utterances, each of which contained a set of utterances that had a similar meaning. This way, when the operator intended to convey a message, he would randomly pick up one of the utterances of the group that expressed that message. Other groups consisted in sequences of utterances (or smaller groups) that had a specific function. On each session, approximately 90-120 buttons with their corresponding utterances were available. Examples are provided below.

The conversations on which the daily interaction with the robot was based consisted of the following parts, in order:

1. The robot initiates the conversation with an utterance from group “Greeting”.
2. The robot performs sequence of dialogues for the LKM exercise
3. Robot emits utterance from group “Was exercise OK?”.
4. Robot emits utterance from group “Bye-bye”.

The utterances in groups 1, 3 and 4 were analogous to the corresponding utterance groups in the previous study, as were the rules that the robot operator followed at the conversations (see section 6.2.4.5.

The LKM sessions with the robot were greatly based on the work of Fredrikson et al. [44] (including personal correspondence with co-author Sandra M. Finkel) and Salzberg [101]. The following parts regarding the LKM exercise took place in every session. First, the robot asked the participant whether there were any changes in his/her feelings that he/she would like to share, or whether there were changes in the perception or feelings toward oneself or other people, correspondingly. Next, the robot introduced the specific schedule for the day. For example, on one session it would say: “Today we will practice mindfulness meditation. Next, you will send loving-kindness to yourself. Subsequently, you will send loving-kindness to a loved one. And finally, to all living beings”. Afterwards, the robot instructed the participant to perform two minutes (10 minutes on the first two sessions) of mindfulness meditation.

The sessions varied from day to day to make the participant more easily accustomed to the several targets of loving-kindness. Thus, after the mindful meditation and following this order of appearance throughout the program, loving-kindness would be sent towards themselves, then towards a loved person chosen by the participant, a person for whom the participant would not have particularly positive or
negative feelings, a person that was “difficult” to the participant, and all living beings, respectively. Mindfulness meditation was practised in every session for two minutes. Then, up to three of the three loving-kindness targets would be addressed. For example, on the first session the participants only practised mindfulness meditation (10 min in this case); on session 4 they practised mindfulness and loving-kindness addressed toward themselves; on session 10 they did mindfulness, loving-kindness towards themselves, a loved one, and a “neutral” one, correspondingly; and so on.

As the last part of the LKM session with the robot, this would instruct the participant to perform a specific LKM exercise throughout that day. This extra exercise is a crucial element in a LKM program (personal correspondence with Sandra M. Finkel).

**Specific instructions to perform the meditation exercises:**

Even though the participants had already been instructed on mindfulness meditation by the main researcher, they heard again instructions from the robot when they were to perform this type of meditation. The robot emitted the following utterance: “Start noticing your breathing as you breathe in and breathe out. The breathing will find its own natural rhythm, you don’t need to force it in any way. Begin now gradually to breathe in and then again gradually to breathe out”.

Regarding the LKM utterances, these depended on the specific targets in the session. The most crucial part consisted in asking the participant to continuously repeat four different statements (sending of loving-kindness). These statements were accordingly adapted to the target to which the participant was sending loving-kindness. For example, if the participant was sending loving-kindness to himself/herself, he/she would keep repeating the phrase “may I be free from danger”; next, the phrase “may I be happy”; subsequently “may I be healthy”; and finally the phrase “may everything go alright for me”. The participants were encouraged to make their own variations, and if they became stuck the robot would repeat the corresponding phrase to them, so that they would return to the flow of repeating the phrases.

In order for the robot to explain to the participant that he/she had to perform a LKM exercise during the day, it displayed the utterance “Notice for the rest of the day how it feels to send loving-kindness to (specific target)”.

The participants were free to repeat the loving-kindness phrases silently or aloud, whereby they always did the latter. They were also encouraged to vary their targets (for example, not to choose always the same loved one) and did not mention the names of any persons aloud.

### 7.1.4 Data analysis

The data analysis was performed in the same way as in the previous study (see section 6.3. The graphs shown in section 7.2 show values averaged from the two participants.
7.2 Results and Discussion

7.2.1 Brief biography of the participants

To ensure the confidentiality of the participants, we will refer to him as “J” and to her as “M”. They lived together as a married couple in a house of a residential area in Hengelo (The Netherlands), together with their youngest child. They had a dog in the home as well. The ages of J and M were 70 and 66, respectively. They were both retired. J used to work in the field of mathematical engineering at the University of Twente (The Netherlands) and M was counselor for patient rights. J and M appeared healthy and very autonomous, except for the fact that J had recently had a stroke, which reduced his mobility at strenuous tasks, e.g. playing sports or walking/biking long distances. They were both living busy lives, participating at numerous activities and social events.

The participants rated their experience with robots as rather low (score of 2 on a scale from 1 to 5) and they rated their experience with new technologies with a 2 for J (1 lowest, 5 highest) and 3 for M.

7.2.2 Perception and attitudes toward the robot

7.2.2.1 Previous expectations and general impression

In the first interview M told us that she found robots very interesting and was curious about the robot. She believed she would enjoy it. However, her expectations were low. She believed that robots will be more useful in the future. Also, J thought it is not possible to “mimic” the human brain, but he thought robots can still be useful, a help.

As an example of the potential use of robots, they pointed out that robots are more suited for people that are a little lonely. For instance patients with dementia in a rehabilitation center, who need someone to talk to. They believed in robots playing the role of assistant in such a center, for example to temporarily attend patients until a person comes. J also said as answer to the weekly open questions that even though robot’s reactions are very predictable, he envisioned a great potential in robots for conversation. M told the story of a neighbor who had dementia and was in a nursing home. The neighbor had a robotic dog that moved and made noises, and she was very happy with it. M believed she would probably like the robotic dog if she ever had dementia.

M gave another example of a role suitable for robots. She told how she and her husband went to an orthopedist and this had a computer at which he had to be continuously typing while interviewing J, making the process slower and more impersonal. She then mentioned how later on they went again to another orthopedist, who in this case had a secretary next to him, typing at a computer while he could attend J in a more efficient and personal way. According to M, robots could take on roles such as that of the typing secretary.

M stated that robots should not replace people, robots should just be an “addition”. For instance, robots should not take away jobs. Also, J said that contact between people is important, whereby a robot could actually help. According to them, robots
should also not make decisions for themselves, they should be programmed. That would be in any case too difficult, since robots would have to improvise.

7.2.2.2 Reactions toward the robot

In the second interview we learned how the participants reacted to the robot. They commented on how the robot was experienced as more pleasant and exciting at the beginning and more repetitive and boring at the end. For example, M said “In the end it became somewhat boring, but you know that it is only for a limited time, and in the beginning it is exciting because you don’t know what is happening. After a while you know a bit of what is expected”. This is supported by the weekly open questions they answered. For example, as answer to the question “did you have fun with the robot in the last few days?” J most times said “no” and explained that the robot’s answers were very predictable. M had a more positive positive response and answered that it was pleasant to work with the robot.

This monotony could be solved, according to the participants, if there was more interaction with the robots. For example, if the robot could ask more questions or better understand questions from the participants.

Overall, it appears they did not ascribe much agency to the robot. For instance, when asked how intelligent the robot was, M answered that the robot does not have or lack intelligence by itself, since it is programmed and everything it has has been “put in there” by a person. J also expressed disappointment in the state-of-the-art of Artificial Intelligence nowadays. The participants also did not think that the robot could understand what they said, nor their emotions. According to M, the robot would just react to specific keywords in their speech. Finally, when they were asked whether the robot had its own thoughts or emotions, they answered negatively.

Regarding the relationship with the robot, they said they did not perceive it as a companion. Rather, they saw it as a “helpful tool”, much in line with the roles they found suitable for the robot in the first interview (e.g. assistant at nursing home). Nevertheless, M and J stated that they progressively perceived the robot as more and more human-like. It seems that M built a sort of bond with the robot. In her own words: “...And a real conversation with the robot, I have to say, between the first and the last time, I had developed a bit more feeling with the robot. In the beginning it really is a recorded voice, of course it is, but slowly, by getting used to it, I absolutely dont see him as a person, but a bit more as a person, I have to say.” This is supported by her answers to the weekly questions. Her first comment regarding how she perceived the robot was “I see the robot mainly as a computer, just bigger than normal”, whereas on the last week she answered “for me it was mainly a tool, but because of the spoken language there was something human in it”.

When asked explicitly if she perceived the robot at the end as more human-like, M answered affirmatively, adding: “but the difference between beginning and end gave a bit more personality, in the beginning I did not think that at all, we also have computers and such, in the beginning I thought that, if you put me behind a computer or next to the robot, I don’t feel a difference (between the two). After a while, a bit more, it was there, it still was no ‘stuffed-animal-robot’, but a bit more part of the household.” They experienced the robot as more and more familiar. The results on
Social Presence might also seem to show a tendency of the participants to more and more ascribe a social agency to the robot (figure 7.2). This would go against the general finding that social robots are progressively perceived as less and less human-like.

The participants thought about giving a name to the robot, but in the end they did not do it. They referred to it as “the robot”. Also, they did not talk to the robot when this was turned off.

To summarize, the robot was sometimes perceived as repetitive and somewhat boring, particularly at the end, as happened in the previous two long-term studies, which might also be related to the novelty effect [69]. Before the study, the participants showed low expectations on the robot and thought that it would be suitable for other types of people. They did not attribute intelligence and emotions to the robot, however one of them perceived a sort of human traits in the robot.

7.2.3 Psychological state of the participants

7.2.3.1 Baseline

The participants seemed to have very social lives. To a great extent, this was due to the many groups and organizations in which they participated (see Section 7.2.4). At the time of the study, J and M had one son living together with them and another two sons. They all had frequent contact by phone and occasionally family weekends. The exception was one of the three sons, who did not want to keep contact with his family. This fact brought great sadness to the family and particularly to J and M, as we will explore later. J and M occasionally met with their extended families as well and kept in touch with them, for example through frequent emails and phone conversations.

The participants also spent a significant amount of time with friends, which mainly came from associations, former colleagues, friend circles, good friends and neighbors. In the latter case, one neighbor was an aged woman who trusted J and M whenever she needed help (e.g. being taken to the doctor) and another neighbor helped taking care of their dogs, reciprocally. Altogether, M estimated that she spent over 10 hours per week with friends, and J estimated that he spent around 5 hours, not counting...
contact through the computer. Thus, it appears they had a great social support. They also stated explicitly that they did not feel lonely.

Regarding their personalities, J described himself as happy, friendly and trusty. M described herself also as friendly, and perhaps could be portrayed as an assertive person. In her own words: “I do know what I want I don’t want, and that can be personally confronting”. They probably were complementary in this respect, as M indicated: “if I ask [J] to do something, he always says yes. And occasionally he will say yes, but not do it.” M also indicated she was quicker at solving things. J described M as helpful (he gave the example of her care after his stroke). And they agreed that they “were there for each other”.

Their ways of managing distress varied as well. J stated that if he felt sad or depressed he would wait for it to pass. On the other hand, M said she would discuss the issues with her friends, or sit down with a cup of coffee and a bar of chocolate if she was angry.

When asked about the view of the participants on their own compassion, they mentioned a few charitable actions they did, such as visiting a refugee asylum and visiting a neighbor whose husband was dying in the hospital. J believed he “had compassion” and that he was empathic. M thought she was “good”, empathic and able to comfort people. She emphasized however that she could not “submit/surrender” to some people. It seemed that people tended to go sooner to M to share their problems than to J, whereby she tended to become more involved. M said to J during the interview: “[not helping other people] it is easier for you to just let it be, while I get a feeling of guilt, or at least a feeling that there is something expected of me.”

7.2.3.2 Attitudes towards the intervention and adherence

The participants showed a positive attitude towards participating in the study. For example, in the second interview, as well as in the answers to the weekly open questions, they told they found it interesting and instructive to participate. They both enjoyed participating and contributing to research, as M said: “helping to develop something”. They also did the exercises that the robot proposed them to do during the day, which according to them was not difficult to do. At least M did these exercises intentionally, some times while walking the dog.

None of them had previous experience with meditation. Regarding their attitudes toward the intervention, J and M were curious but had low expectations. M said she might have some difficulty surrendering to the robot. She stated: “I think that I am too restless for that. And I also don’t want that someone else does anything about that, I want to decide things for myself. I’m a bit stubborn.” When asked whether they thought if there would be changes to their lives, J did not think so and M answered that perhaps yes, depending on how she would be approached.

Even though the participants enjoyed participating, they found it alright for the study to be over and they did not miss it during the weekends, nor did they wish to repeat the exercise more than once per day.

The main issue they had with the intervention was its repetitiveness, even though they envisioned a different person almost every time at the sessions with the robot. As J said: “it is the repetition that gives the therapeutic value, that is of course dangerous,
because repetition can also turn boring”. In the weekly open questions, M answered she felt a little bored the last two weeks because the robot and the training were not new anymore, whereby her thoughts wandered more easily. Also, the exercise became somewhat boring for them if it became long. However, as M explained, something that made the program less boring was that she was curious about what types of persons she would have to envision in every session. J also found that the idea of addressing different persons made it less boring. M stated “there was an evolution and that kept it interesting”. In any case, when they became bored they motivated themselves by remembering what they were doing it for.

They said in the second interview and the weekly open questions that they would not continue doing LKM exercises formally on their own after the study. However J would “think more often about it” and M would “apply it when she thinks she needs it”. As an answer to the question next to questionnaires in the last week “Do you miss the robot or the exercise?” J said “No”, but M said “yes”, explaining that more or less once a week (after the study) she thought that the robot would be useful to steer her thoughts better.

Often, the participants considered that the LKM programme was not something “for them”, something they were “open to”. For instance, M explained that she was a busy person by nature and that she would become relaxed by doing sports rather than by “sitting down on a chair and doing nothing”. She also meant that meditation was “fine”, but it was something one can do in many different ways besides paying attention to one’s breathing. They proposed that such a programme could be useful for other people who need more structure in their daily lives. Also, M believed that this type of intervention can help one feel better, but one has first to need it. However, according to her they “need it less than someone who indeed has a problem”. M disbelieved that by repeating something often enough that would become true (even though this was not the aim of the exercises).

There were differences in the style between J and M while they were interviewed. Namely, M might seem more proactive in talking than J. In fact, she contributed with significantly more data than J during the interviews. Also, the main researcher together with a colleague explored a sample videos recorded from the robot interaction to find potential differences in how the two participants reacted. They agreed that J might have appeared as less comfortable than M because he tended to cross his arms as if adopting a defensive position. The seemed to differ also in their way of repeating the four loving-kindness phrases (e.g. “May I be happy”). M improvised more, was more fluent and needed less feedback from the robot, compared to J.

### 7.2.3.3 Mindfulness and loving-kindness

Most of the effects of the intervention reported by the participants had a strong cognitive component. Especially, they reported changes in their awareness towards multiple subjects and situations, what we could perhaps consider a manifestation of an increased mindfulness. This finding is compatible with our expectations, since the intervention was designed to work mainly on a cognitive level rather than on emotions per se [44]. M said “[I am] more aware too, to me it boils down to... I am more aware of things”. She reported on another moment of the second interview that her
way of thinking was a little more structured and positive. J also said “you become more aware, you become more aware of it. Of what you are doing, of the things you think, do, how you relate to other people and such.”

Importantly for the intervention, this enhanced awareness or mindfulness covered the perception towards oneself and other people, as the participants frequently commented. They reported being more aware towards their interaction with other people, for example when talking to someone. J said also that he felt more compassion and thought more about compassion.

The participants valued the effects of their increased mindfulness. For instance, M appeared satisfied about her greater control over her thoughts. She appeared content about the possibility of choosing not to think negatively. To illustrate this, she said: “What I also perceived as positive is that you have control over your thoughts, that you can steer them. Because, yes, if you have many worries, and we have all had that of course, and if you are our age then you have also had periods with big worries, when you do start to ruminate [...] You cannot sleep and your thoughts, you cannot get rid of your thoughts, you know it is not productive and you cannot get rid of your thoughts”. She reported more signs of an enhanced mindfulness in her daily life, as she commented: “[...] walking the dog, walking for a small hour, then your thoughts go in all directions, and what I then noticed, is that I am more aware of being capable of influencing that. My thoughts, always in my life, they go in all directions, but that, you can influence that a bit more than I had been aware of.” Also J seemed to value a greater awareness. Discussing the impossibility of changing unwanted external events, he added that one can at least “handle” such events differently.

Very importantly, we also found effects in the ways how M and J felt toward other people regarding compassion. It seems that there is evolution in the answers that M and J give to the weekly open question “Have you noticed any change in your feelings towards other people?” J commences answering in the first weeks “barely” or “not really”; however, later he reports more awareness in his feelings toward other people, and finally an increased interest. M commences answering “no”; then she also reports more awareness; subsequently a greater realization that everybody has the same emotions as her; next she says she is trying to “put herself in the feelings of others”; and finally she states that she understands better why other people react in ways that she would not wish. Sub-scales Positive Other and Negative Other from the SOFI questionnaire might back these results, as the former might seems to increase over time and the latter to decrease (see figures 7.3 and 7.4).

We can also observe what might seem to be an evolution of the participants regarding their behavior towards other people. Answering weekly to the question “Have you behaved differently towards other people”, both participants answer negatively in the first weeks. However, in the last weeks J and M report again becoming more aware in this regard. M also mentions in the last week that “it takes her less effort to be nice to people when they are unkind”. M mentioned in the second interview how she felt she could be more sincerely interested in other people, in cases where she otherwise would have been “nice” just out of politeness.

In the second interview we discussed one comment that M made in the weekly open questions. She claimed to have become more aware of the fact that all people
have the same inner life, “a richer inner life, just like myself, in every person. I of course have many thoughts and feelings, and of course everybody has those”. She said that that perhaps allowed her to empathize better with other people, since one better understands that people “does things”. The consequences of this stronger realization, according to M and J, is maybe that one has a little more compassion for people. M claimed to feel a little more empathy than before.

There also seemed to be an evolution in how the participants felt toward themselves, according to their answers to the weekly open question “Have you noticed any change in your feelings towards yourself?” Expressions such as “barely”, “little”, “no change”, “maybe” appear on the first two weeks, but their answers become progressively more positive in favor of the intervention. In the case of J, he ends becoming more aware of his feelings towards himself and better accepting his own feelings. In the case of M, she begins noticing better how she thinks about herself, moves to being more aware that everybody shares essentially the same feelings as her and finishes better accepting her less good qualities. These outcomes could perhaps be supported by the results on sub-scales Positive Self and Negative Self of the SOFI questionnaire, as the former might seem to increase with the sessions and the latter to decrease (see figures 7.5 and 7.6).
M commented once in the second interview that she had always been rather critical towards herself. She added that since the intervention this became more “structured” and that perhaps she accepted herself a little better, less critically and strictly. She thought that this happened due to the loving-kindness part of the exercise that aims at oneself.

The participants commented also on the effects of the intervention on how they felt towards people that are a little “difficult” to them. In line with the comments mentioned above, M told how after the intervention she was more aware of the emotional life of those difficult persons and of how they too experience happiness and unhappiness. This, according to her (J agreed), created some empathy with the difficult people. To illustrate this, M said: “(the intervention) makes you think a bit more about someone you don’t like that much [...] and also realize that that person is the way he is, and that when he responds a bit unpleasantly [...] then you try to empathize a bit more with such a person”. She thought that in such situations maybe she also appeared more friendly and that maybe she would behave in a more heartfelt manner towards them.

To summarize the evolution of the psychological state of the participants, we found multiple indications that the LKM program worked as we intended. Namely, we
found that the level of mindfulness of both participants increased, as did their sense of compassion towards themselves and other people.

### 7.2.4 Daily routines and changes

In this subsection we will briefly describe the daily routines of the participants in this study and analyze whether these underwent any significant changes after the interaction with the robot.

We asked J and M how the previous day went for them to get a general impression of their daily routines. M got up at 7:30 and went shower at 8:00. She then went downstairs and prepared tea and breakfast. J helped, coming downstairs at around 8:30. They then sat while eating and having some coffee after breakfast. They played games at the same time, which they always did together. If their son is downstairs he would play and have a cup of coffee with them. They also read the newspaper, which normally took until 9:30-10:00. M then took out the dog and J went to take a shower. Afterwards, M did some house chores, such as taking something off the wall (those days they had construction workers fixing a part of the house) and vacuum cleaning. Subsequently, M was busy cooking and J went to the library. Later, J spent some time in the garden and M went to practise fencing. In the evening they read from books and watched TV together.

J and M had rather busy lives, participating in a great variety of activities. J's favorite activity was playing tennis, which unfortunately he could not play anymore at the time of the interview. However, he regularly visited his tennis friends at the tennis court for a coffee. He missed hiking and biking as well. J was chairman of the tennis association, and also of the gardening club, with which he still spent a significant amount of time. Further, he made collages and read a number of scientific publications. Having such hectic lives appears in opposition to the majority of elderly people, who according to Horgas et al. [64] spend a great portion of their time resting and watching TV.

Most of the leisure activities of the participants had a great social component. Continuing with J, he was also member of an association for senior people from the university and in the client council of a rehabilitation center in Enschede. Especially M participated in many social groups, with a total of eight committees and councils where she performed a great variety of activities, some of which she chaired. An ethical commission was the group which kept her busiest. Further, M practised fencing, walked the dog, and some times did sewing, crafting and carpentry.

Similarly to our findings in the previous long-term studies (see section 5.2.4 and section 6.4.4) we did not find any changes in the daily routines of the participants beyond their interactions with the robot. They also did not report changes when they were explicitly asked. The changes we would have expected could have been new habits that they picked up, such as those that lead to healthier a life, an enhanced social life, etc.
7.3 Conclusions

We have gathered a considerable amount of qualitative data, supported by questionnaires, about the participants and their reactions to the robot-mediated positive program.

The participants seemed to have happy and social lives, supported by many relatives and friends and involving many hobbies and activities. This may contribute to the participants’ belief that such an intervention (aiming for higher psychological wellbeing) would not be much suitable for them, but rather for other people with special needs. M also thought that meditation was not “her thing” as she preferred to engage in activities that implied more action, such as sports. They considered themselves friendly and with a certain degree of compassion, proven by the help they leaned to other people and some charitable actions.

M and J seemed to appear eager to participate in the study and were collaborative. They were not particularly familiar with social robots nor with meditation or related programs. Their expectations on the program and the robot were rather low.

One aspect we aimed to explore in this study was the adherence to the program. The participants seemed to have enjoyed participating, although they admitted they did not want to continue on their own. They found the exercises as well as the robot repetitive. This might make sense, considering that the core of the LKM exercises consisted in repeat the same sentences. However, they seemed to value the fact that every session was different from day to day and they could think of different persons during their LKM exercises. In any case, we could perhaps foresee that many participants would show a low adherence to this robot program if they did not have external motivations to continue. In this sense, the positive exercise implemented in this study might not seem to outperform the previous two studies in terms of adherence to the task. We must however consider that the participants had indeed low expectations on the robot and the program and were not inclined to meditation exercises, which we could imagine could be detrimental to the adherence.

Perhaps the success of LKM programs resides not in the adherence and enjoyability of the task, but rather on the durability of the effects on the participant. As we mentioned before, LKM is considered particularly effective at outspacing the hedonic treadmill effect [44].

Regarding the research question “can a home assistive robot be effective in providing psychological support?”, we found indications that the program worked in several aspects, which increased progressively over time, much in contrast to the approach we had in the short-term study (see Section 4.5). Namely, it seems that the participants increased their mindfulness in general, became more aware about their compassion towards themselves and other people, and may have become more compassionate. Where the diverse measures indicate these trends, it could seem particularly illustrating how the weekly answers to open questions showed the progressive increase the participants experienced in their mindfulness and compassion towards themselves and other people.

With respect to the research question “how do the perceptions and attitudes toward a home assistive robot evolve over a long period of time?” the main outcomes
were mentioned above, namely, the robot was perceived as repetitive and somewhat boring, particularly at the end. Also, the participants started the study with low expectations on the robot and thought such a robot would be suitable for other people, such as lonely people in a nursing home.

They did not think the robot was intelligent nor had emotions, however it might seem an interesting outcome that M found at the end some human traits in the robot, going against the general finding that social robots are perceived progressively less human-like over extended periods of time.

To summarize, in this study we have found again evidence that a social robot was able to successfully implement positive exercises with participants in their home. Adherence to the task might still be the most important aspect to improve in subsequent future work.
Overall Discussion and Conclusion

This chapter will summarize, interpret and conclude this dissertation. It will consist of a reflection on the findings in this dissertation, contributions, limitations and future work and conclusion.

8.1 Reflection on the Findings in this Dissertation

We proposed three main research questions throughout this dissertation, namely:

RQ1: Can a social robot be effective at fostering psychological wellbeing in the user? In the long-term studies, we also investigated how the psychologically beneficial aspects of the interventions evolved over time.

RQ2: How do the perceptions and attitudes toward a home assistive robot evolve over a long period of time?

RQ3: How is a participant's daily life altered when an assistive robot stays in his/her home for a prolonged period of time?

In the next subsections we will summarize and discuss our findings with respect to each research question.

8.1.1 Findings on RQ1: Did the robots enhance the participants’ psychological wellbeing?

In section 1 we learned that some of the greatest problems of the elderly population are of a psychological nature, including loneliness, depression and anxiety. We corroborated this in a study that we performed to explore firsthand the daily lives of elderly people (see section 3.1). This motivated us to investigate how robots can support older adults psychologically.

Throughout the studies here presented we obtained indeed indications that the robots affected participants positively in various ways. The following is a synthesis of our findings.

In the lab-based study (see section 4.5) we found that participants experienced a momentary enhancement in their positive affect after interacting with a social robot.
that performed the three-good-things exercise. However, this only happened if participants were aware that they were undergoing a positive psychology intervention. Thus, in this study we learned about the importance of how we instruct participants on the robot-mediated positive programs. We did not aim to ascertain what caused the difference in effectiveness between the two experimental conditions. However, we suggested some explanations. For example, participants in the direct condition tended to give more positive answers, and we find in the literature that positive thinking promotes subjective wellbeing [102]. Another possibility is that the participants in the direct condition might have experienced higher levels of hope (understanding hope as a psychological construct [77]). We find in the literature that hope increases the effectiveness of various types of treatments [77]).

In the first long-term study (see section 5.3), whereby a home robot aided the user to perform a breathing meditation exercise, the participant denied any awareness of improvement on his psychological wellbeing. However, after analyzing the data from the heart sensor, it seemed that some slow and progressive improvement appeared in the breathing exercise. Namely, HRV values tended to increase (which could be indicative of a deeper concentration and greater relaxation) [115] and heart rate tended to decrease. This could indicate that the participant experienced some degree of improvement at performing the breathing meditation exercise. Thus, the task seemed to have caused a positive effect in the user even without his awareness.

The second long-term study (see section 6.5) addressed similar questions to the first one, with a stronger focus on a robot that would appear as a companion to the participant. In this study, the three-good-things exercise was carried out similarly to the lab-based study (see section 4.5). One of our findings was that the evolution of the psychological state of the participant seemed to be greatly linked to his perception of the robot, as first entertaining and later more monotonic (novelty effect [69]). He stated that he felt a little more content during the interaction with the robot than he did before the robot came. After the whole interaction he gained a “positive sense”, valuing more the things that he did throughout the day. He attributed this to the positive exercise. We know from literature that practicing the three-good-things exercise does boost positive affect [43]. In addition, the participant also reported to have felt slightly happier during the period of interaction with the robot and having been in a better mood. This participant, who suffered from loneliness, described his active effort to fight such loneliness. According to him, the robot would have helped him in this respect. Namely, the robot would have taught him to realize the positive things of the previous day. In turn, this realization would alter his feeling of loneliness. In fact, he claimed that just the positive exercise alone (thus, without the effect of the robot) could also contribute to make him feel less lonely. Thus, the findings in this study show us the potential of social robots to foster psychological wellbeing in various ways.

The third long-term study (see section 7.3) was designed similarly to the previous one and included a Loving-Kindness Meditation intervention mediated by the robot. We adapted this intervention from the work by Salzberg [101], Fredrikson et al. [44] and personal correspondence with the co-author of the latter work, Sandra M. Finkel. In this study we found indications that the program worked in several aspects, with
progressive increments in the variables we intended to enhance. Namely, it appeared that the levels of mindfulness of the participants increased, they became more aware about their compassion towards themselves and other people, and they may have become more compassionate. This is in line with what we find in the literature [43].

All these findings seem to support the idea that the robot-mediated programs caused in the participants the effects for which they had been designed. What this would imply, given that we have not created any completely new positive exercise from scratch, is that social robots seem to be an effective means to support exercises from positive psychology and related. This could in the future extend the traditional ways of carrying out positive psychology exercises, such as support from a human coach, computerized systems and paper-and-pencil self-application.

8.1.2 Findings on RQ2: How did the perceptions and attitudes towards the robot evolve over long periods of time?

With respect to the second research question, we obtained a rich corpus of results on how the participants reacted and felt towards the robots. Firstly, in the study reported in section 3.2 we gathered some insights on how older adults perceive care robots. For instance, we learned that elderly people may tend to prefer reliable and instrumental robots to robots that offer company and might be less reliable.

With respect to the timely evolution of attitudes toward robots, with the first long-term study (see section 5.3) we learned that the participant experienced disappointment towards the robot, even when his initial expectations appeared rather low. He was disappointed that the robot did not perform more actions besides rolling and raising its arm. Breazeal [20] discusses the problem of disappointment in the robot in Human-Robot Interaction. She mentions a few aspects of the robot’s capabilities that are often expected to match the participants’ expectations, such as whether people expect the robot to communicate in natural language (see section 3.2.2.2) or whether they expect the robot to understand how they feel. She concludes that the robot should be designed in such way that it leads the person’s expectations to be commensurate with the robot’s capabilities [20]. In the first long-term study, the participant perhaps expected the robot to work perfectly. Thus, the fact that there were numerous breakdowns, interrupting the flow of the interaction experience, might have contributed to this feeling of disappointment.

Likewise, the robot was perceived as a machine or tool. The participant did not experience any feelings or “connection” to it. This could be explained by the simplicity of the robot, the fact that the participant saw how the robot works from the inside and the fact that he had a strong technical background. We also find in literature that the absence or presence of touch and proactivity can influence whether people see the robot more as machine-like or human-like [25].

The interaction with the robot was experienced by the participant as more “fun” at the beginning, becoming progressively more boring, which we could consider an indication of a novelty effect [69]. It appeared that what the participant enjoyed the most was the mere participation in the study, since he had also been a researcher in the past and was interested in new technologies.

In the second long-term study (see section 6.5) the behaviors of the robot were
also found monotonic over time, despite the fact that this robot was considerably more interactive and featured more complex behaviors. Thus, we may have also found a novelty effect [69], whereby the participant thought of the interaction as interesting and exciting in the first week, but this was considered boring during the second (and last) week. This decrease of the interest may have shaped other aspects of the relationship with the robot. For example, the robot changed from being a “buddy”, to being a companion some times, to finally becoming more challenging to interact with and be seen as a machine, similarly to what the participant in the first long-term study experienced.

Also, the participant’s view of the robot’s internal states were likely influenced by the novelty effect. For instance, he might have felt that the robot cared about him at the beginning, but not later. And the opinion that the robot had no own thoughts and opinions seemed to became more pronounced in the second week. For the rest, the participant did not think that the robot had emotions of its own, even though it could understand him, and it appeared to have the benevolent intention of amusing him and motivating him to talk.

Also in the third long-term study (see section 7.3) the robot was perceived as repetitive and somewhat boring, especially at the end, thus showing indications of the novelty effect [69]. The participants started the study with low expectations on the robot and had the opinion that this robot would be rather suitable for other people, for example lonely people in a nursing home. This example was different from the opinion of the participants of the focus groups on robot acceptance (see section 3.2.2.1), who rather proposed “ideal” elderly users with physical limitations, especially regarding mobility, chronic obstructive pulmonary disease, cerebrovascular accident or bad vision. In any case, we cannot make a strong comparison between these robots, since the participants of the focus groups had seen a robot whose functions were rather physical, instead of psychotherapeutic.

Even though the participants of the third long-term study did not think the robot was intelligent nor had emotions, one of the two participants stated that she more and more perceived the robot as human-like in some way, thus against the general finding that social robots are perceived progressively as less human-like.

Regarding the second research question, these variations in experiences could seem quite aligned with what we already found in the literature, for example regarding general disappointment in the robot (a great variety of factors could lead to disappointment of the robot user [42]), and the novelty effect [69]. Also, the robot tended to be viewed as a machine rather than as a companion. However, in the second long-term study (see section 6.5) the participant showed indications of perceiving the robot as a companion to some extent. Also, in the third long-term study (see section 7.3) one of the participants experienced a connection with the robot that we could consider beyond the common relationship we have with most objects. These latter results support the assumption that robots could not only be used to provide us with specific services, but also with a form of companionship.
8.1.3 Findings on RQ3: How were the participants’ daily lives altered when the robot stayed in their homes for prolonged periods of time?

To search for answers related to the third research question, we learned about the daily lives of elderly people in section 3.1, for example that leisure and resting usually predominates in their lives [64]. In the same section, we reported a study in which we gathered firsthand insights on their routines and daily difficulties, and we learned, for example that the interviewed participants tended to make little use of new technologies.

Even though from the beginning we set out to explore potential changes in the daily life of the participants in our studies, we did not find any major changes. The changes we would have expected could have been new habits picked up, such as those that lead to healthier a life, an enhanced social life, etc.

However, we did find small effects that the robot brought about in the lives of the participants. The participant of the first long-term study (see section 5.3) usually held bridge games in his home, inviting many people. During the study, the presence of the robot (even if it was disconnected) aroused the curiosity of the guests, who would ask many questions about it to the participant, thus generating debates around the robot. In the second long-study (see section 6.5), the participant found time before the daily interaction with the robot to prepare for it (he wrote down things he would consider positive to have some material ready for the three-good-things exercise). In addition, after the end of the whole interaction, the participant reported having informally performed the three-good-things exercise on his own, remembering on purpose positive things that had happened to him. Finally, in the third long-term study (see section 7.3), the participants did not report any changes in their routines, but one stated that she had missed the robot once this was removed from their home, because it would have helped steer her thoughts better.

To summarize our findings on the third research questions, it appears that the robots caused a rather small effect on the daily activities of the participants throughout the studies.

8.2 Contributions of this Dissertation

This dissertation has contributed to the advancement of robots for psychological support. Whereas most of the research in psychotherapeutic robots has so far focused on participants that have specific needs (e.g. robots to motivate at weight loss programs, see section 2.2), we foresee a likely usage of the methodologies of these studies also in the general population, bringing similarly valuable results (that is, even if we do not only focus on elderly population).

We have pioneered the use of positive psychology in HRI research. Even though we already knew of studies on positive computer applications (e.g. [103]), to our knowledge the connection between positive psychology and social robots had not been yet established. We also made a special effort to build valid positive programs, based on previous ones that were based on more conventional formats. Furthermore, we have also measured the effectiveness of these programs in the same ways and with the same tools as by other researchers in positive psychology, showing similar results.
In addition, we made a contribution regarding the methodology of long-term studies from which HRI researchers could benefit. The studies in this thesis featured a specific combination of methodologies aiming to maximize the ecological validity. Namely, the studies were carried out in the homes of the participants, whereby we minimized the involvement of the researcher as much as we could. Also, the studies were extended in time so as to give us insight on the long-term effectiveness of the interventions and the evolution of the participants’ attitudes toward the robot. Finally, given the complexity of the phenomena we studied, we opted for a case study methodology to attain in-depth results.

Lastly but not less importantly, we hope that the work presented in this dissertation will positively contribute to society. On one hand, we hope to have contributed to a greater understanding, as well as dissemination, of the problems and needs that elderly people face in their daily lives, especially those of a more psychological kind. They interacted with social robots, which currently are a novel form of technology, thereby becoming more ready for future technological advances. On the other hand, since positive psychology exercises are greatly generalizable, we expect that health organizations and the general public could also benefit from the robot-mediated programs here presented.

### 8.3 Limitations and Future Work

We discussed in the Theoretical Background section a few studies of robots that were designed to foster psychological wellbeing in their users. Most of these robots focused on users with specific special needs, such as children with autism or elderly people with dementia. One of the advantages of bridging the fields of Human-Robot Interaction and positive psychology (see section 2.3), is that positive psychology exercises are greatly generalizable. In other words, everyone can benefit from performing any positive psychology exercise. Thus, we designed robotic therapeutic programs that could be easily generalized.

We learned already from our first studies with elderly people that not only disabilities, but also psychological distress, are commonplace in their lives, for example in the form of fears, depression, despair, etc. This motivated us to design and conduct studies to that explore how to mitigate these burdens with the help of robots. However, as our research progressed, we found that elderly people constitute a group as heterogeneous as any other age group (if not even more). We find aged individuals who live alone and feel lonely, in need of more social contact and barely leaving their homes. In stark contrast, we find individuals of the same age with whom, as an illustrative example, arranging an appointment would prove challenging due to their busy agendas. While it is true that disease and frailty are more common in older than in younger people, there are aged individuals who still show a great physical strength. Some are still running marathons or go to gym every day. Also, new technologies are not only used by young people. More and more, we can find elderly people using the same technologies and applications. Thus, with respect to the assumption that everyone can benefit from positive exercises (in this case, robot-mediated), we suspect that some people would benefit more than others. For example, it might make more
sense to employ techniques oriented to contentment (such as the three-good-things exercise) or compassion towards oneself (part of a loving-kindness meditation program) with participants that feel depressed than with participants that show a great degree of vitality and claim to be living happy lives. In other words: it might be more difficult to make people happier when they are already happy. To summarize all the above, this great heterogeneity in the participants makes it more difficult to generalize results from one study to another, and to design robot-mediated interventions from which all participants could equally benefit.

Likewise, we should always consider individual differences regarding personality and mindsets. The success of an intervention greatly depends on one’s mindset and expectations [77]. Our more illustrative example of this concerns the performance of meditation exercises. Namely, we may suspect that the practitioners that have a more open-minded attitude and are more self-reflective in their nature tend to benefit from meditation to a much greater extent. One reason could be, perhaps, that our previous attitude toward meditation modulates the actual effort and degree of concentration we invest when we meditate.

We should also consider the impact of cultural differences in the elderly people population depending on country. We started this research interviewing elderly people in Spain and conducted the remaining studies in The Netherlands. When investigating these two populations we should not forget the differences regarding, for instance, the degree of individualism versus family involvement, or the greater or lesser influence of religion, as another example.

While we found multiple indications of the effectiveness of the robot-mediated programs here presented, we should remain cautious as to what were the ultimate factors that brought about the beneficial effects. For instance, even though we tried to eliminate this effect as much as we could, the presence of the experimenter might have caused a positive impact in the subjective wellbeing of participants (e.g. if they were feeling lonely before). In the last two long-term studies we tried to minimize this effect by receiving some of the data by email and by spreading out the meetings with the participants. Also, it is not inconceivable that, at least to some extent, participants might have exaggerated their accounts of beneficial effects in order to please the experimenter. They might have believed that they were supposed to show enhanced positive effects after the robot interaction (what we denominate “demand characteristics”). Lastly, we know that hope, understood as a psychological construct, significantly contributes to the effectiveness of therapies in the medical and psychotherapeutic domains.

Future work should address the aforementioned limitations. In addition, we will need to decide to what extent we want psychotherapeutic robots to assist or even substitute human psychotherapists. This will raise not only practical, but also moral and legal issues.

8.4 Conclusion and Afterthought

To summarize, in this doctoral dissertation we have presented studies on robots that foster psychological wellbeing in elderly people. These robots stayed in the homes of
independent living elderly people for extended period of times. The tasks that they performed to assist the user psychologically were adapted from positive psychology exercises. We mainly investigated the effectiveness of these robot-mediated programs from the psychotherapeutic point of view. Very importantly, we also explored the changes that the users experienced in their acceptance of the robot over relatively long periods of time (weeks). We found indications that the programs were effective in the ways we expected them to be. That is, our robot-mediated programs facilitated exercises aiming to foster mindfulness, contentment and compassion in the users, and we found evidence that they increased their levels of these qualities, correspondingly.

Regarding robot acceptance, we encountered several findings throughout our studies, among which the most crucial, perhaps, related to the strong presence of the novelty effect. That is, participants tended to be highly engaged at the beginning of the robot-mediated programs, but their interest decreased rapidly. Occasionally we also found that this decrease in robot acceptance was paired with a decrease in the effectiveness of the psychotherapeutic intervention.

Most studies with robots investigate the physical capabilities of these. Even robots for healthcare mostly perform tasks oriented towards physical well-being or rehabilitation. However, we found in the literature and in our earlier studies that psychological well-being is also crucial for a good quality of life of elderly people. In fact, our first study gave more relevance to the psychological than to the physical burdens and needs. We also argued that robots have a great potential to foster psychological well-being, and we found that positive psychology appeared to be an adequate framework on which to base robot-mediated interventions. Depending on the specific task, these interventions would require robots with greater or lesser social skills. That is, a task that entails very interactive conversations (e.g. the three-good-things exercise) would demand great conversational skills, whereas a task in which the robot guides the participant (e.g. in meditation exercises) would not require such sophisticated social abilities.

As a personal afterthought, we hope that our findings could apply to future applications of psycho-therapeutic robots, and that they will inspire the researchers and developers in this field. We envision a near future in which social robots live with us. Like with any other powerful technology, it will be up to us whether they enrich our lives or they turn out detrimental. In this regard, many people are afraid of the possibility that robots might some day completely substitute the human carers of elderly people. Perhaps, rather than disposing of this technology altogether, we should consider the great advantages it may bring us and commit ourselves to use it wisely.

On the other hand, it was gratifying for us to bring people into contact with positive psychology. We hope to have contributed to making people realize more that happiness does not just arrive from external factors, but that it is modulated by our thinking, and that there are things we can do to improve on this. In fact, flourishing as a human being requires constant commitment. And positive psychology, whose area of study consists in this personal flourishing, could help us shape the daily behaviors of our future robot companions. They could not just entertain us, but also inspire us and make us better. Robots could, why not, as we find in good science-fiction, remind us of the values of being human.


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[34] Lowet Dietwig, Melvin Isken, Geke Ludden, Dirk-Jan van Dijk, Anthony Remazeilles, and Elena Cruz Martin. Florence project, deliverable d5.1: State of the art in robotic aal services, 2010.


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