D6.3: Acceptability of a home companion robot

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1 Summary

The present document serves as the second draft of deliverable D6.3 “Acceptability of a home companion robot”. The results of a study carried out at University of Twente are shown, intended to serve as a preliminary study on long-term acceptance of robots by elderly people. That study was intended to provide valuable guidelines for the next study. The study pointed out that elderly people accept better robots that serve to communicate with their carers, compared to robots that appear autonomous. After reporting that study, the implementation of another, long-term study is provided, which emphasized the importance of stimulating the long-term adherence of the participants to the tasks that involve the robot. This long-term study represents the core of Task T6.2 “Identify the factors that strongly influence long-term user acceptance” and has been carried out by the University of Twente until April 2014.

2 Introduction

Deliverable 6.3 “Acceptability of a home robot companion” concerns the deep understanding of the way in which elderly people come to accept or reject a robot and how this changes over time. We address this issue in the current document three-fold:

1. *A succession of studies to inform the long-term usage of the Accompany robot*

In order to inform the Accompany project with a deep understanding of how people come to use and accept robots in their homes for re-enablement, we a) explored what people’s first responses were to a physical robot in their own living space; and b) explored what happens when an elderly person has a robot in their home for an extended period of time with minimal researcher involvement.

2. *The application of different robot-platforms to carry out a preliminary investigation of how people will react to and use a companion robot*

One of the challenges of the Accompany project was that the project plafrom, the Care-o-bot3 is yet unsafe for autonomous interaction in everyday homes and with the elderly users. Additionally only two project robots were available that have been assigned to summative evaluation studies. For this reason we have adopted a ‘technological probes’ approach to explore what issues arise when elderly people are confronted with robotic companion in their home. In the first study where we explored first reactions to a robotic companion, we used the Giraff robot platform. Also, in order to explore issues of unfamiliarity with a fully autonomous robot such as the Care-O-Bot, we scaffolded people’s relations with their caregivers. This was done by exposing them to the robot with the face of the caregiver on the screen versus when the robot was operating ‘fully autonomous’ (Wizard of Oz controlled). The outcomes of this study indeed indicate that people were more familiar and felt more at ease with the ‘caregiver’ version of the re-enablement robot versus the full autonomous version. Familiarity and perhaps expertise of the caregiver may have caused this effect. This result shows how important it is for a companion robot to carefully design the presence and interaction, to ensure users will feel familiar with, understand the competence of and accept autonomous robots in their homes.

In the second study, which concerned the long-term exposure of a user to a robot in their own home, we adopted a mock-up version of the Care-O-Bot. A Magabot robot was adapted to have a similar look and feel to the Care-o-Bot robot. This allowed us to investigate a future situation where a companion

will be used in the home. As such, it is a method of futurist research, where a technological probe is deployed to investigate a possible future scenario. As far as we know it is the first study of its kind, where a large autonomous robot was deployed in someone's home. The outcomes of the study gave the research team a wealth of experience on how to conduct such investigations in the future, regarding experimental protocol and setip. For instance, it was important that no researcher was involved on a daily basis. Many studies offer positive results of long-term robot exposure and we felt this was due to researcher's frequent visits. This posed many challenges as the robot needed to operate autonomously without daily visits by the research team. The robot's action capability was therefore limited and carefully scripted. Even though this impacted the study (the user found it difficult to adhere to the robot over time because of the repetitive nature of the therapeutic intervention), we gained interesting insights about how a user's thoughts, feelings and opinions of a robot in the home changed over time.

3. *As found from our earlier work (Deliverable D6.1) the acceptability of a robot for physical reenablement will also depend on users receiving 'psychological re-enablement'*

The Accompany robot platform is developed to offer elderly people physical re-enablement, i.e. assist the user in being able to carry out certain tasks on their own. However, since an automous robot brings a lot more agency compared with, for instance, a walking device, the acceptablility of such a robot is not just dependent on its competence in physical assistance [1]. In previous work (D6.1) we found that in order for people to accept a physical re-enablement robot in their home and to adhere to the therapeutic assistance it may provide, it is imperative for users to experience a higher level of self-efficacy, in order to reduce psychological distress and to feel in control of their situation. Therefore, we pose that physical re-enablement is always paired with other support such as psychological support. In the Accompany project the physical re-enablement is supported by efforts in interaction design (WP2) to offer a novel, empathic and engaging experience while controlling the robot, and in D6.3 we have sought to gain a deeper understanding of how a person's psychological health could be supported by a physically present robot. Our findings indicate that adhering to a re-enablement robot is likely to deteriorate over time even if people improve at the exercise offered by the robot. The main advise for the Accompany research team is to carefully consider the need for users to stay motivated, and experience significant self-efficacy in long-term robot use at home, which the Accompany robot needs to support as part of the physical re-enablement service it provides.

Two studies are reported in this deliverable. The first study (see Section 3: Preliminary Study) focused on the use of a robot to motivate elderly people to participate more in social and common activities. Users were exposed to a Giraff robot in two different conditions. In one condition, the robot acted as a telepresence robot through which carers communicated with the elderly users. In the other, the robot appeared as acting autonomously (Wizard of Oz controlled). Interviews and sessions including exposure of the participants to the robot served to gain insight into their attitudes toward assistive robots that might some day stay in our own homes. Thus, this study represents our first exploration of elderly's interactions with robots in a home-like environment.

Subsequently, a study is described whose goal is the long-term assessment of user attitudes and responses toward a therapy robot that offers psychological re-enablement. A long-term (3 weeks) evaluation was conducted with a participant in his home. The robot offered psychological re-enablement by assisting in mindful-breathing exercises to reduce stress and depression. Due to the exploratory nature of the study and its ecological approach, we have greatly relied on qualitative

methods, such as interviewing and diary keeping. This study serves as second part for deliverable D6.3 “Acceptability of a home companion robot” as it studies the long-term acceptance of users.

To summarize, we envisaged an incremental succession of two studies. That is, first a short-term study with a robot in a home-like environment, followed by a study that shows the conditions and results of a long-term interaction with a home robot. The findings from these studies will be considered alongside the acceptability results obtained from the evaluation of the Accompany scenario 2 which will be reflected in D6.5. .

3 Preliminary study

3.1 Introduction

The aim of this preliminary pilot study is to explore meaningful exercises for a robot and elderly person to carry out together in the context of re-enablement and to explore the ways in which a robotic research platform can be deployed in a home for long-term acceptance research.

Lately, substantial amount of research has been reported on the use of robots for elderly. This research ranges from motivating elderly people to exercise [2], as their companions [3] or to remind them to take their medicine [4].

This study consisted of three design stages with two user tests in between. The first design stage involved a literature research about the needs and interests of the elderly people, different strategies that motivate elderly people and the effect that robot interaction and robot's physical design have on (elderly) people.

The Accompany project concerns elderly living independently. The participants lived in their own apartment near or as part of a facility where they can meet others and if they wish, eat and participate in joint activities. The focus of the explorative study was to find a meaningful exercise in re-enablement and explore how to research the way people respond to robots as preparation for the long-term experiment. We were particularly interested in the support of elderly peoples' participation in social events.

Research questions

There were a couple of questions that inspired our explorative study:

- How do people respond to robots in their home setting?
- What can we learn about deploying a robot in the home to inform our long-term studies to be carried out as part of D6.3?

These questions were of different nature compared to the more general questions considered in deliverable D1.1 concerning user requirement. The main difference here related to incorporating the robot and its long-term use in this user study, while user requirement studies in WP1 related to gerneal user requirements that could be met using a range of technologies including a companion robot and a smart home environment.

3.2 Related work

In this section we discuss existing theory on motivation and the effect of social participation on elderly people's lives. We will also describe relevant previous work.

Vallerand and O'Connor [5] describe a framework for motivation in every day behaviour of elderly people. They mention four types of motivation types: Intrinsic, extrinsic (self-determined), extrinsic (non-self-determined) and amotivation. Intrinsic motivation is doing things because they are worthwhile in themselves, without a reward. Self-determined extrinsic motivation is doing something because of a self-determined reward: for example, playing brain gym because you believe it will make

you healthier. Non-self-determined extrinsic motivation is when the reward comes from someone else. Amotivation is when you feel an activity has no extrinsic or intrinsic value.

Kwan and Bryan [6] present a study that tested whether affective response to exercise leads to greater motivation in terms of attitudes, subjective norms, self-efficacy and intentions to exercise. They found that people who feel good during exercise have more positive attitudes to exercise even three months later. They also have more intention to exercise again. The Apathy Evaluation Scale is a method of rating a person's feelings over the previous 4 weeks. According to Resnick et al. [7] this scale can also be used to be measure motivation in elderly people.

Fritsch et al. [8] carried out a study on the social isolation of elderly people. They found that the amount of social interaction people have decreases with age. 45% of the elderly people they interviewed said they wanted more direct social interaction, and 58% wanted a simpler way of finding contacts. One of their main conclusions was that there is a strong need for an online network that makes it simple for elderly people to contact each other.

Elderly people were not only found to want more social contacts, an active social life was found to have a lot of positive effects on people's health as well. Crooks et al. [9] did a study on the occurrence of dementia among older women. They found that people with a larger social network have better cognitive function and less dementia. Lack of social contact is even linked with self-neglect in elderly people. In this state, elderly people fail to or are unwilling to maintain their basic needs. According to Burnett et al. [10], there is a significant correlation between having a small or non-existing social network and self-neglect.

Fasola & Mataric [2] present a socially assistive robot that helps elderly people during exercising. It does so by monitoring the user and providing motivation for completong the exercise using speech. Three different types of exercise games were available: a workout game, an imitation game and a memory game. A survey was held to evaluate the usefulness of the robot as perceived by the participants. The robot was perceived to be more than moderately helpful.

Wada & Shibata [3] report a study where elderly people were given a small seal robot (named Paro) that acts as a companion. The robot looks like a small harp seal, has white fur and behaves similar to a real baby-seal. Their idea was inspired by the positive effects that animals are reported to have on the health and stress levels of elderly people in combination with the fact that animals are not allowed in most homes for elderly people. The robot was found to have a positive effect on elderly people: they communicated more with each other and had a better reaction of their primary organs to stress. Kidd et al. [11] also used the Paro robot in two nursing homes to measure whether robotic interactions generate more social activity. Based on their findings they conclude that Paro is certainly entertaining to many people and it gave people something to talk about with each other.

Looije et al. [4] focused their research on the question whether a socially intelligent robot is able to change the behaviour/lifestyle of a diabetic. For their experiment they used the iCat, a socially intelligent robot that is able to express emotions through facial expressions and speech. They created a list of guidelines for personal assistance and health devices and evaluated whether the application of these guidelines had any effects on user preferences. After incorporating the guidelines to the iCat, the authors found that the Icat was preferred to a text interface.

Pollack et. al [12] describe the design of a mobile robot assistant that helps elderly people remember routine activities such as eating, drinking and taking medicine, and also guides them through their

home. Breazeal [13] highlights a few interesting implementations of social robots that can be used in healthcare applications. Finally, Hutson et al. [14] produced a set of requirements for social robots that help the elderly by reducing their loneliness and improving their mood.

In conclusion, we found that there is work available that suggests the adoption of robots to improve elderly people's social participation, affective state and health is possible. We could not find any studies that assessed the impact of robot assistants on elderly person's health over the longer-term. The studies by the paro robot are the most closely related and suggest indeed a long-term impact an elderly peoples' social engagement and affect, however Paro is very limited in its interaction behaviours and tested with elderly people that are not capable of independent living. The Paro robot serves as a comforting agent in this scenario.

3.3 The Giraff robot

In this section we describe the robot that we used to explore elderly people's responses to robots. The Accompany project revolves around the Care-O-Bot 3 as developed by Fraunhofer. This robot is currently a research platform and under development, yet unsuitable for autonomous use in one's home due to safety considerations. Additionally, only two project robots have been available and have been assigned to *supervised* summative evaluation studies. Due to this, we used a Giraff robot as a technological probe for this study. Same as the Care-O-Bot 3, the Giraff robot is not anthropomorphic in design, although it has a friendly appearance. It is also approximately as tall as a person and has wheels to move around.

The Giraff robot (Giraff Technologies AB), is originally a telepresence robot which was specifically developed in the context of elderly care (see Figure 1). The Giraff is based on existing telepresence technology that is normally used in global collaboration to attend meetings remotely. With Giraff, this technology is made to look a bit friendlier and simple. Its current deployment involves remote visits by caregivers and family members.

Figure 1: Giraff robot

The Giraff is based on normal PC hardware, and runs Microsoft Windows 7. It is 1.5 m high, with a screen in portrait orientation at about face height. The robot can drive using a base with wheels. It is controlled remotely through a WiFi network connection with software that allows the videoconferencing as well as the controlling of the movement of the robot and the volume of its speakers and microphone sensitivity. This software is fairly easy to use even by un-experienced users. The robot has two buttons, a green one for accepting calls and a red one for hanging up or refusing calls. It also has a volume knob. The Giraff can function for about an hour before needing to recharge.

3.4 Interviews

Interviews were held both with elderly people at the day activity facilities and with caregivers that work there. The interviews took place in retirement homes in both Gronau (Germany) and Enschede (The Netherlands). Interviewees were either residents in semi-independent units or full independent units where they sometimes joined the activities of the centre. Interviews were held with 14 residents in elderly homes, 9 in Gronau and 5 in Enschede. Interviews were held with 5 caregivers: 3 at the Gronau location and 2 at the location in Enschede. The main difference between the two locations is the language used for the interviews (German in Gronau and Dutch in Enschede) even though both locations are about 10 KM apart, the national border runs in between and in Gronau the elderly people that are resident or that spend time during the day-facilities of the elderly care centre are predominantly German, in Enschede they are predominantly Dutch. The interviews were held to get an impression of how elderly people may respond to robots in the home prior to our long-term study.

The interviews are divided into two main parts. The first part concerned the activities that elderly (do not) join, why they (do not) join them and how they are and can be motivated to join. One of the aims of this part of the interview is to get information about certain aspects that may influence the amount of participation in activities. Another aim was to gain information about reasons why elderly do not join social activities. A last aim was to get information about how to motivate elderly people.

The second part concerns the interaction with the robot. During this part of the interview, three scenarios were given. The first one introduced a caregiver that visits elderly people to ask them to join an activity. In the second and third scenario the caregiver is replaced by the Giraff robot, either as telepresence for the caregiver (with the caregiver on screen) or as a more autonomous robot (with an avatar on screen). The aim of this section of the interviews was to get information about the attitude of elderly and caregivers towards the idea of motivating elderly in this way and about using the Giraff. The full questionnaire can be found in Appendix A.

3.4.1 Elderly interview results

The most popular activities mentioned by elderly in Gronau were open days (which involve listening to music), walking together and playing bingo. In Enschede most popular were bingo and listening to music. Rather than talking about unpopular activities, the elderly started talking about why they could not join a particular activity. The two most important reasons why elderly do not participate in activities were physical impairments and whether they liked the particular activity. Furthermore, one resident in Enschede also mentioned that she had too many activities planned outside of the organised activities and another mentioned that she did not participate because she did not know a lot of people. In Gronau one other reason mentioned was their habits: if people are used to being alone, then it is difficult to motivate them to join social activities

Participants both in Gronau and Enschede did not report to have a lot of experience motivating other elderly people they know. They mentioned that talking positively about a particular activity helps others to join, also because some people may have the wrong idea about what the activities entail. In Enschede, some participants mentioned motivating others by going to their home before the activity to pick them up and join together. One resident in Enschede mentioned that it is no use to motivate someone else, because everybody gets enough information about what activities can be done already, so if they wanted to join they would be there.

Interviewees mentioned not to have (much) experience with technology such as mobile phones and computers. In Gronau there were 3 residents with a mobile phone and in Enschede the interviewees were found to use a landline phone, a television and/or ceefax.

In general, the residents like the idea of a real person knocking on their door to ask them to join an activity. Only 2 of the interviewees in Gronau and 1 resident in Enschede did not like this scenario.

The idea of a robot to interact with received mixed acceptance. Four of the residents in Gronau did not like the idea of interacting with a robot at all, while 2 liked it, leaving the other 3 undecided. In Enschede 2 people did not like the idea, while 2 of them thought it would be an interesting experiment, leaving 1 person hesitant, because she could not imagine how this would work in reality. A reason why interviewees did not like the robot as mentioned in both locations is that they did not know in advance nor could imagine the robot. That is, they would need to get used to it. In Enschede it was also mentioned that they did not like the idea because it sounded fake and impossible. In Gronau interviewees mentioned that it is not important who comes to ask them to join an activity, but the most important aspect is that it helps.

3.4.2 Evaluation of caregivers' interviews

Caregivers on both locations mentioned that there are a lot of elderly people that join activities. The caregivers in Gronau mentioned that there are groups of people that do activities together outside of the organized activities. From the interviews caregivers seemed to feel that there is no real relation between the extent to which elderly participate in activities and how many visitors they have, how much they communicate with others, and how lonely they are. In Gronau however caregivers mentioned that elderly people's mood play an important role in trying to motivate them to participate in activities. In Enschede it was mentioned that when elderly get a lot of visitors they may not feel the need so much to join organised social activities.

Listening to music is a very popular activity in both Gronau and Enschede. In Gronau family can visit during the music activities, which is an important factor to them for participating. Another popular activity in Gronau is sports, while in Enschede this is bingo. In both elderly homes there do not seem to be explicit unpopular activities, but activities that demand intellectual effort seem to be the least visited.

The caregivers in both locations mentioned many reasons why elderly usually do not join activities. The most important mentioned are the physical health of the elderly person, their personality, their habits and routines, the way the activity is presented to them and what they know about the activity.

Caregivers seem to differ on whether it is possible to motivate elderly people to be active. In Gronau caregivers felt they could, while in Enschede it was mentioned that this is only possible if the elderly really wants to. At both locations it was reported that elderly might feel better after they participate.

In Enschede an intake appointment is kept when a new person signs up and they are asked what activities they like and want to do. Often, new participants start slowly with only one activity at first. When an elderly person does not join activities, the staff sometimes will ask them why they do not join. In Gronau, caregivers felt motivating elderly people can be done by using keywords that are dependent on the person and by having an emotional report with the person. Also by making the activity attractive and use the motivating factor of having relatives join. This last factor was also mentioned in Enschede. Both homes mention that when motivating elderly, it is important not to be pushy.

The idea of a real person knocking on the door of the elderly to ask them to participate in an activity is accepted in both locations. The real advantage of this sceanrio is that it involves personal contact. A limitation is that it depends on the person whether this will work. Staff in Enschede mentioned that they already do this, but only with activities that elderly have signed up for. The notion of letting elderly people search for specific other people to join an activity is received differently in the homes. In Gronau they think it is obvious that this should be possible, but in Enschede they think that elderly will not use this ‘service’, because they will not start searching for others by themselves. Also, staff felt that residents prefer to see the same face every day.

The caregivers had more negative associations than positive associations with the idea of a robot motivating people to join activities. They think it will probably lead to loss of personal interactions and the elderly will probably not trust or like it. Furthermore they expect a lot of complications. For instance, they doubted if it would work, because someone may not be able to stand up by himself and the robot would be unable to help them get up. However, there were also some positive expectations. For instance, the staff felt they would certainly try it and they thought the robot could function as a reminder for activities. Overall, staff prefered the notion of a real person through telepresence on the robot compared with an autonomous robot. In fact, staff thought that elderly people would be uncomfortable with an autonomous robot facilitator to such an extent that we decided to start our exploration with robots as technological probes with the scenario of a telepresence robot. This was decided so that we were sure the leap from a caregiver to an autonomous robot would not be too large to be comprehended by the elderly participants.

3.5 Exploring deployment of a robot for elderly with a technology probe

In order to have a first exploration of how to deploy a robot in the homes of the elderly people, we exposed some of the participants at the day activity centre to technological probe. The probe was a Giraff robot (see Figure 1). The Giraff robot had the possibility of being remote controlled by a staff member (telepresence robot, the staff member’s face is visible on the Giraff screen) and the possibility of seeming autonomous. In the latter case the robot was still remote controlled by a researcher but the suggestion is offered that the robot moves autonomously, also on the screen of the Giraff was displayed a minimalist graphical depiction of a face.

The avatar program runs on a remote laptop computer, and uses the Haptek player (Haptek Inc.) to render a minimalist 3D face. The Haptek player can also render a voice with lip sync by using a text to speech engine. The player runs inside an ActiveX control (only on Microsoft Internet Explorer) of a simple website. The avatar speech is controlled using javascript. Using the website, we can make the avatar say the lines of the script. To send the sound to the robot in the highest quality possible, we used

a program called Stereo Mix Plus to capture the sound of the prototype and relay it to a virtual microphone. The avatar image is then captured using Manycam and sent, together with the sound, to the Giraff using the Giraff software (Giraff Pilot). This setup allows us to interact with a user through the avatar in a comfortable way (see Figure 3).

The prototype is fairly simple: it has a pre-set script for interaction. The robot (either telepresence or autonomous) starts by saying hi and asking the user how they feel. The robot then suggests an activity, and asks the user if they want to join. The robot closes the conversation by saying goodbye. The timing of the script is remote controlled through a laptop.

The Accompany project focuses on an autonomous robot in the home for independent living and re-enablement. Nevertheless, in this exploration we worked with the scenario of an autonomous facilitator as well as a telepresence facilitator. The reason for this was that in the interviews it became clear that the elderly persons had many difficulties with the notion of a fully autonomous robot. In fact, the staff thought that it may be too disturbing. Because of this reason we explored first with the notion of a staff member remote controlling the robot (telepresence) and followed this with the scenario of an autonomous robot facilitator.

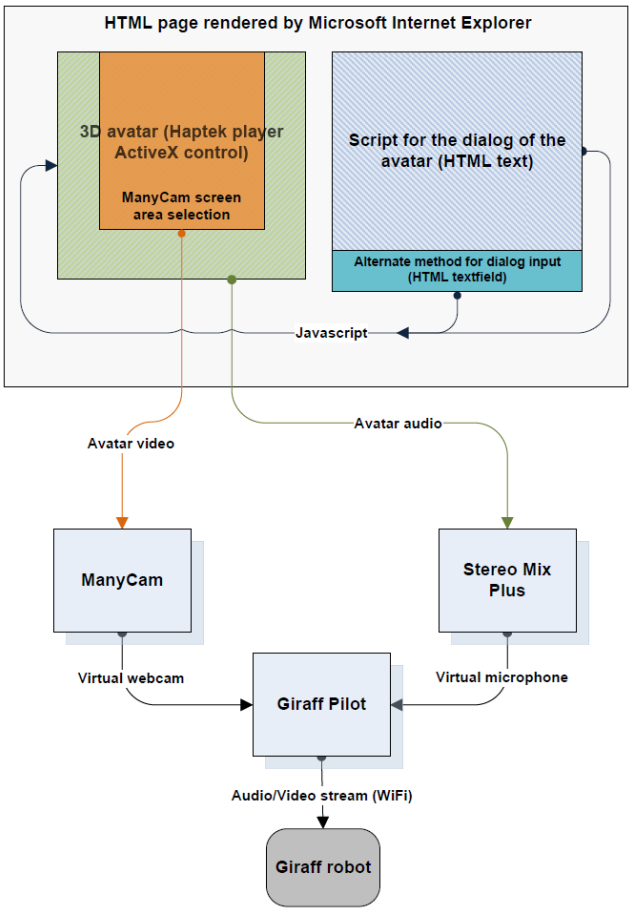

Figure 2: Schematic of the software components of the prototype

3.6 Exploration on Location in Gronau

The first probe assessment was carried out at the elderly activities facility in Gronau Westphalia in Germany that is close to the Dutch national border and to the city of Enschede in the Netherlands. In total ten persons participated in this study. Four of these participants could be categorised as Motivated Users (3 female and 1 male) and 4 could be identified as Less Motivated Users (all female). Also, two persons from staff participated. The participants were a subselection of the people who were involved for the earlier interviews.

Every participant was visited upon appointment. A Staff Member with Social Care diploma from the facility functioned as the remote staff member in the case that we explored with the telepresence robot scenario.

The study consisted of seven parts:

1. Researchers meet and greet the participant in their home

2. Prepare equipment, explaining the study and signing of consent form

3. Conversation with the social worker as a remote presence on the robot

4. First interview

5. Conversation with the ‘autonomous’ robot

6. Second interview

7. Thanking for participation and debriefing

The study was carried out in the homes of the elderly people. In order to get to the shared activities room, they needed to traverse their floor toward the communal section. The Giraff robot was placed directly opposite of where the elderly person was seated. The researcher who operated the Giraff robot on the laptop was sitting in an opposite corner of the room. In the telepresence scenario everything was kept in the same order. The only difference was that the laptop was brought into the hallway and placed on a table. The social worker would remote control the giraffe and talk to the elderly people through a laptop from the table in the hallway.

Two researchers were present during the experiment. When they entered the room, after greeting the elderly, the equipment and actions were prepared. One of the researchers mainly prepared the technical equipment of the robot. The other researcher informed the participant, prepared the laptop, the interview and a smartphone to record the whole experiment. This student also introduced the elderly to the goals of the study, gave the consent form to them and explained the procedure that would follow. During that time the robot was placed in front of the person. Soon the social worker would have a short conversation with the person through the robot. After this conversation, the first interview was given. Afterwards, the equipment and technical settings were changed for the second part of the experiment in which the robot would speak with the person with an avatar on screen. The conversation with the social worker through telepresence was personal and about a different aspect each time because the social worker had a personal rapport with each of the participants. The discussion with the robot revolved around joining social activities.

During the experiment in Gronau we learned how the robot probe performed, and what was missing or did not perform well. The prototype was changed to reflect these findings. We found that the script was not flexible enough to allow for the differences in responses the participants gave. One such occurrence was when the robot asked if they wanted to join the activity. If the test subject answered 'maybe', the script had no option for that. We changed that by adding the sentence 'Then I hope I will see you at the activity'. Sometimes the test subjects would suggest an activity that they wanted to be organized in the future. The script had no option for that. Therefore, we added a sentence called `we will pass your suggestion on to the caregiver'. We took this as inspiration and had the robot ask for suggestions for new activities, if the participants did not mention any. To add more flexibility to the prototype, we also added a free input box for text. This box allows the operator to send any sentence to the avatar, so that the robot can say it.

3.7 Preliminary Results from Exploration with robot as technological probe

The experiment including the transportation of the robot, the preparation of the equipment and conducting this experiment passed without having any bigger problems. Only two times problems with the connection of the Giraff network occurred which incomprehensibly showed a full network access. This could be fixed quickly after relocating the router and restarting the system. Additionally, the text input of the avatar had to be changed during the experiment due to some confusion in the conversation content. Only one male participant took part in this study. An explanation that is likely for this is that male residents are the minority and are also less motivated to join social activities in general.

In Enschede there were five participants, each of them had also participated in the interviews.

Due to time issues, the caregiver and volunteer did not get to test the Giraff completely. The caregiver used the Giraff software to talk to the participants through the Giraff, but she did not move the Giraff.

Telepresence robot probe vs autonomous robot probe

The interaction with the social worker as displayed on the robot's screen in both groups was experienced as quite good and clear. Participants mentioned finding it amusing and liked the interaction with the social worker on the screen. Some mentioned that they found the voice much better and more understandable than the autnoumous robot (N=2) or that they just like it very much although it was unusual (N=3). Two others smiled and said that "it was good" and one added that it was "as if she was standing next to her". Three mentioned they would accept it when the social worker visits them in this way, but pointed out this should happen only when there is no other possibility for the social worker to inform and assist them. Only one participant was totally opposed to the telepresence interaction, she would prefer the social worker in real life than on the screen. Another participant, thought that the conversation was "cold", despite liking the experience of the telepresence interaction. This statement was also given by another participant, saying that she would rather prefer to have a real conversation. It seemed to her "it was like a telephone call" and she would accept it in the case it is necessary to quickly inform someone about something important. With regard to coming into the room to suggest an activity and try to assist the person only two participants found it acceptable but stated that it only should happen sometimes and only if it is the only solution for it without replacing the social worker. Two other persons said that it can be used for future generations of elderly people who are already used to technical interactions. All participants agreed they would join the activity that was suggested to them by the social worker in the conversation. No further improvements were

suggested but only the fact that the social worker looks much better on the screen than the avatar in the autonomous robot.

All participants generally accepted the appearance of the avatar on screen in the robot condition. Two people mentioned that it is “a nice girl” and another said that” there is nothing special about her”. For two participants the appearance was perceived as a bit weird or unfriendly at first sight but changed into more friendly as the avatar started to speak. Three participants said that the first thought about the avatar was that it is “something new to talk to her”, that it is “interesting and new but weird” and a “nice girl”. Another said “Oooh how weird” adding “people have never seen that before” and “I am happy about the progress in technology”. Another mentioned the same adding that it is “nice to see the progress in technology” although she pointing out that this kind of conversation seems to be nothing for her age. One participants who though it might be nice for generations to come, immediately pointed out that she has no interest in these kinds of technologies at all by saying “I must state quite clearly..I do not accept it”. For two participants, the conversation and the robot were perceived as a bit stubborn due to the artificial speech. The voice itself was clear for every participant although it could have been friendlier, as one participant remarked.

The voice of the autonomous robot in Dutch (for the explorations done in Enschede) was a real limitation. Only 2 of the 5 participants could understand or hear it well enough to have a conversation. The participants were not too enthusiastic about the robot coming by to ask them about activities. Finally, the 4 of them did say that they would not have a problem with the robot coming by if it was not too often (about once a week). However, the voice must be clear and understandable. Also, similarly to in Gronau, the participants see this visit more as a reminder of an activity they would already join than as an invite to a new activity, because they are already very busy. One of the 5 participants really did not want to have the robot come by her door. 3 of the participants could not really imagine how they would talk to the robot in the future. For the other 2, one of them could imagine herself talking to the robot, but not getting to know it. One said she would probably talk about particular subjects more if she would see the robot more often.

All the Dutch participants liked talking to the caregiver through the robot and even 2 of them thought it made no difference talking to the caregiver personally or through the robot. The other 3 however preferred talking to the caregiver in person. However, if the caregiver would not have time to come in person they would not mind talking through the robot.

The evaluation of the responses of the staff (social workers)

Only 2 social workers in Gronau were exposed to the robot and experienced talking with the 'autonomous' version and remote controlling the telepresence version. In general, they experienced controlling the robot as challenging. The reasons were mostly to do with the usability of the interface “I cannot adjust the tempo “and “it works much better with a mouse than a touch field". The situation of talking to someone through the robot was experienced as dubious (one staffmember) on the one hand but that something she could get used to on the other, because “it reminds me of a telephone call only that it is possible to see each other” (the other). Anyway the disadvantages reported were that it is difficult to talk because the use of their own nonverbal behaviour is missing. Also, recognizing the gestures and facial expressions of the person thal a social worker is talking to is missing because it is too far away to see it well. One of the social workers added that it is difficult to concentrate on the conversation because they are not used to it. Despite of the many disadvantages one social worker was pleasantly surprised about the robot with avatar and found it sympathetic even though she had been

sceptical. Both social workers even pointed out that they could imagine the robot to be used for big halls in which the robot could go from table to table in order to inform everyone about meetings which would be very useful. Both social workers agreed that the interaction the robot had with the elderly should be a consideration for future generations of elderly who are more used to technology. They thought elderly might be curious about it, but “the people prefer social communication". However, in big facilities the technology was thought to be helpful if accepted by the people. Strongly accepted by both social workers was the aspect that the robot can be used to remind people of something. It should be used in short communications with elderly to assist them in different situations like asking how they feel, mentioning changes or informing them about new plans in the retirement compound.

At the Enschede location, the caregiver that had remotely operated the Giraff said she actually did not pay much attention to the elderly person on the screen, because she was too busy making sure that she herself could be seen on the webcam. The caregiver mentioned that using a robot in an elderly facility was something that still was beyond the imagination of the residents. Similarly the volunteer caregiver mentioned that she thought the participants had been positive of the idea because they could not really imagine it happening soon. The volunteer mentioned that she was afraid that people would think 'oh that is easy, now I do not have to walk to the elderly, but I can talk to them from a distance', while she feels that personal contact is very important. Also the caregiver mentioned that it the telepresence robot was somehow a way to try to make it a bit personal while simultaneously taking away personal contact. The caregivers felt that the interaction with the ‘autonomous’ robot needed to be different, not only the voice which had been difficult to nderstand but also the appearance, they felt a more natural interaction would be essential.

3.8 Discussion and Conclusion

The goal of our project was to assess people’s initial responses to a robot in the home. Also, we wanted to explore the challenges for running a long term study with a robot on location.

As a meaningful topic, we decided to focus on motivating elderly people to participate more in social and common activities. This decision was made based on related literature, in which we found that elderly people who are more social and active are healthier, more independent and have a higher quality of life than those who do not.

We investigated the responses of elderly people and the people who care for them. During the interviews we found that most residents were quite sceptical about the idea of a robot in the home or at the day-activities centre. Considering a robot that would actively seek them out and ask them to join an activity, the participants seemed open to the idea, but all had a strong preference for a real person coming to get them.

During the sessions where the participants were exposed to a robot probe either in telepresence or autonomous mode. The text to speech software that was used was hard to hear for some residents. As we found in previous studies [15], elderly people have a difficult time understanding robot voices. Whether this is because the unnatural sound of the digitally produced voice is unfamiliar, whether the amplification is difficult to hear when hearing deteriorates, whether important non-verbal cues are missing or whether the context of the conversation with the robot was so different from their usual conversations that the participants simply could not cope is unknown. It does seem that when a robot uses natural language to communicate with elderly people, especially when this is automatically generated, this is extremely challenging. The Accompany project does not focus on natural language

interaction and the trend that we notice in our studies is an indication to us to find non-verbal ways to interact with elderly users. For the long-term experiments therefore, we will not engage the use in spoken language interaction.

The participants had been negative about the idea of a robot coming to visit them. However, in the explorative study with the Giraff as technological probe, the same participants were more positive. Most could see the robot as a useful technology to go door to door and remind people who had signed up to come and participate in a certain activity. Our explanation for the more favourable attitude toward the real robot is that there were researchers present who prepared the robot technology, facilitated the interaction experience and held the post-session interviews. It seems not unlikely to us that the elderly people who were visited were positive toward these young researchers and were therefore favourable in their judgement of the robot. In previous studies also [16], [3], where favourable atttitudes and responses toward robots were found for elderly users, researchers had a very active role in data collection. In a short term experiment, being present during the session and for longer-term studies visiting the participant often to collect data or debug the technology. Our assessment is that future studies should minimise the contact between researchers and the elderly so that a more true response of the participant toward the robot can be measured. This can be done through online data collection (the robot as subject of analysis but also as an active data collection tool). Another approach when investigating user responses to a robot over the longer term is to have a control group that is not exposed to a robot where the researcher visits just as frequent. If the control group also increases in mood and health then it is clear this is because of the visits by the researcher rather than the robot's activities. For the long-term experimentation we will take this learning into account by minimising the interaction between the participant and the researcher by carrying out the data collection through the robot as much as possible.

The elderly perceived the robot that was presented as 'autonomous' (remote controlled but seemingly autonomous) as a robot with limited use. Residents felt it would be a good tool to remind them of activities for instance or just to bring a quick message about something urgent. The telepresence robot that offered the caregiver or social worker on the screen was experienced as an extension of the caregiver. Elderly people overall felt it was quite similar to talk with the caregiver and could imagine themselves interacting with the caregiver in this way even though they would prefer a personal visit. In the Accompany project, our role is to look at robot roles and behaviours that are congruent to those roles. However, the trend we just described tells us that the positioning of the robot may be equally if not more, influenced by the extent to which the elderly person perceives the robot as an extension of the care-facilities he/she makes use of. For instance, we suspect that in case of recovery after stroke, when an elderly person has a robot at home temporarily from the carefacilities that support their re-enablement, the robot may be experienced as simply a tool or as an extension of the care facility. We think this may be stronger when the robot continues exercises and routines that were initiated during hospital stay or with caregivers. For the long-term experiments therefore, we consider carefully controlling for the participants' perception of the robot as an extension of the care-facility or the university carrying out the study.

4 Study on Long-Term Acceptance of Home Robot

4.1 Abstract

This section describes the design of a first iteration of long-term studies that we carried out as part of task T6.2 “Identify the factors that strongly influence long-term user acceptance” (see Section 4.5: Time plan). In this study we assessed user responses toward a re-enablement robot over a period of several weeks. The study is of a multi-method ethnographic type with one participant, an elderly user and a companion robot that stayed in the participant’s home for the whole duration of the study (a so-called N=1 study). Data were collected to gain in-depth knowledge of the evolution of a person’s attitudes toward and acceptance of the robot. Since this is, as far as we know, the first study of its kind to carefully evaluate a person’s changes in attitudes and behavior regarding the companion technology over a longer time period, we also report on the effectiveness of the study’s methodology.

4.2 Related Theory

4.2.1 Robots at home for prolonged periods of time

Numerous studies have been carried out on robots that shared the home space of the participants. A paradigmatic example, of a service robot in this case, is the Roomba: a highly autonomous vacuum cleaning robot. In several studies, Roomba robots were provided at households in order to study various aspects of the short-term and long-term interaction, e.g. [17], [18]. Sung et al. [17] found that after the participants had intereacted with the robot, they valued it more than before, in terms of intelligence of operation, entertainment value, emotional attachment and overall impression. They found no significant increase in ease of use and usefulness for cleaning. Forlizzi et al. [18] carried out a longitudinal study where families lived with both a Roomba robot and a conventional vacuum cleaner. Roomba seemed to have a greater and more lasting effect on people than the conventional vacuum cleaner. The robot influenced cleaning activities according to gender, age and generation. For example, men and children took a more active role in cleaning. Sung et al. found that developing intimacy with the robot seems to improve happiness, increase lifelike associations and value it more [17].

Beside service robots, other studies have focused on home robots whose main function was that of a companion or entertainer. For example, Klamer et al. carried out a 10-days study with three elderly people and a Nabaztag robot, where participants evaluated several factors of the interaction with the robot, such as utilitarian, hedonic and social factors [19]. Even though disagreement was often found in their evaluations, 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 an increased amount of social behaviors toward the robot, as found also in experiments with the iCat robot [20].

Few studies have been undertaken with a focus on robots to motivate the users in their own homes. In a study by Kidd and Breazeal [1] a robot 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 the

participants used the robot for longer and had a closer alliance with it, although the differences in weight loss between the three systems were minimal.

Finally, the following research is another case of Human-Robot Interaction extended over long periods of time. The Aurora Project aimed at helping children with autism through the interaction with robots. In a longitudinal study, Robins et al. [21] allowed autistic children to play with Robota, a humanoid robotic doll. This longer interaction period permitted a better exploration of the interaction space of robot-human and human-human interdependence. A meaningful outcome in this research is that the children, once accostumed to the robot, opened themselves up including the investigator in their own world and willing to share their experiences with him and their carers. This research was not conducted in the homes of the participants, but in their school. However, it exemplifies the importance of a long-term approach in research when robots participate in programmes of intervention/treatment.

4.2.2 Psychological wellbeing of elderly people and robots

Not only physical causes, but also psychological and social factors determine the independence of elderly individuals. 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 [22]. Other authors showed evidence of the relevance of self-efficacy and coping in the wellbeing of elderly people [23]–[26]. In a first study, we conducted a contextual analysis of elderly people's daily life. It revealed insightful aspects about their interests, hopes and dreams, as well as their needs. A key finding in the study was that psychological distress appeared to be a major burden in the life of independent elderly [27]. These psychological aspects are important not only because of the distress they cause, but also because of their association with disability [27].

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 [28], seems to have a high prevalence among elderly people. About 3% have severe depression and 10 to 15% suffer from mild to moderate depression [29], [30]. According to Steffens et al. [31], 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 [32], it seems 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.

A classical example of robots to improve elderly people's mood is Paro, the seal robot. In studies, Paro is typically brought to nursing homes where older people hold the robot and interact with it [16], [33], [34]. 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 studies. Some of the reported positive effects of interacting with Paro are general improvement in feelings [16], [33], [34] and reduction in depression [16]. One might wonder why Paro has been so successful and broadly employed in elderly care.

Some authors have compared the effects elicited by a pet robot to the effects of a living animal, a toy, another robot or the same robot switched off. For instance, Banks et al. [35] found that both a living dog and a robotic dog (AIBO) effectively reduced the level of loneliness in elderly people who lived in long-term care facilities, with no significant differences in performance. However, when Tamura et al. [36] compared the performance of an AIBO robot with an electronic toy dog, the latter was preferred

to the former, probably because it resembled a dog better and triggered memories of past feelings of comfort. Kidd et al. [11] had elderly people interact with a Paro and a semi-robotic toy (a doll). They identified usability shortcomings in Paro, for example those related to its too large size and weight (considering that elderly people tend to be more frail). The same authors also found that the user evaluations were more positive if the robot was switched on. Taggart et al. [37] investigated this last aspect in more detail and reported a wide range of reactions to Paro when switched on, while when switched off users tended to remain quiet and unresponsive to the robot.

Other studies have specifically focussed on robots to motivate older persons or alleviate their depressive symptoms. In a study by Fasola and Matarić [38], a socially assistive robot played with elderly people through a series of interactive activities. Its performance was compared across two conditions. In one condition the robot implemented behaviors that are 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 of the motivating condition over the neutral condition.

Thus far, robots should be considered as a valuable asset for the wellbeing of elderly people. This wellbeing includes psychological aspects and has more opportunities of being positively influenced in long-term studies.

4.3 Problem Statement

For our experiment we wanted to gain deeper insight into the processes, feelings and attitudes people experience when having an assistive robot at home for a prolonged period of time. In order to do so, we were inspired by the work of Wallace et al. [39] who more recently have used cultural probes as initiated by Gaver et al., e.g. [40]. In order to elicit responses in individual users [40], often the work is autobiographical or based on one-case examples. For our study also we choose to analyse in-depth one participant representitave of ACCOMPANY's target group, that is, an independent living elderly person. Single case studies are more common recently in the field of Human Computer Interaction [39] and even in medical sciences [41], we felt that using such an approach allows us to gain a more in-depth, and qualatiative understanding of the person's complex thoughts and emotions. As we are limited by the participant numbers, due to time-constraints enforced by the long-term nature of the study and availability of a single platform, such qualitative single-case studies are one of the most suitable approaches available.

In view of the above we arrived at the following research questions:

RQ1: How do the perceptions and attitudes toward a home assistive robot evolve over a long period of time?

RQ2: How is a participant's daily life altered when an assistive robot stays in his/her home for a prolonged period of time?

RQ3: Can a home assistive robot be effective in providing physical and psychological re-enablement?

These research questions became the three areas of interest that were explored in the long-term study described in the following sections.

4.4 Methodology

4.4.1 General design of the study

In order to find answers to the abovementioned research questions, we have 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 would be of the ethnographic type, performed through interviews and diary keeping following [42]. 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 a 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 will take place in a private environment (the participant’s home) also limits our choice to some extent.

Our goal was to create an 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 [42], [43]. Additionally, quantitative measures were taken of the acceptance toward the robot and effectiveness of the exercise to also offer the participant a structured format to express their 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 would serve to bring a heart signal sensor to the participant, which would be employed as part of a breathing exercise (see Figure 3). This exercise would be performed with the help of a tablet as well. The same tablet had also the function of communicating with the robot. That is, the robot would occasionally “propose” to the participant through the tablet to do the exercise, but also if the participant by his own initiative decided to do the breathing 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.

Figure 3: Participant holding the tablet. The robot stands next to him.

4.4.2 Instruments and materials

Robot

The robot has been designed to be similar in appearance to the Care-O-Bot 3(see Figure 4). Its base consists of a Magabot platform [44]. A rigid torso has been added, as well as an arm that can rise. The robot software is based on Arduino and its batteries allow 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. Infrarred sensors located beneath the robot's base allowing it to follow the rails (further details in Section 4.4.4: Procedure).

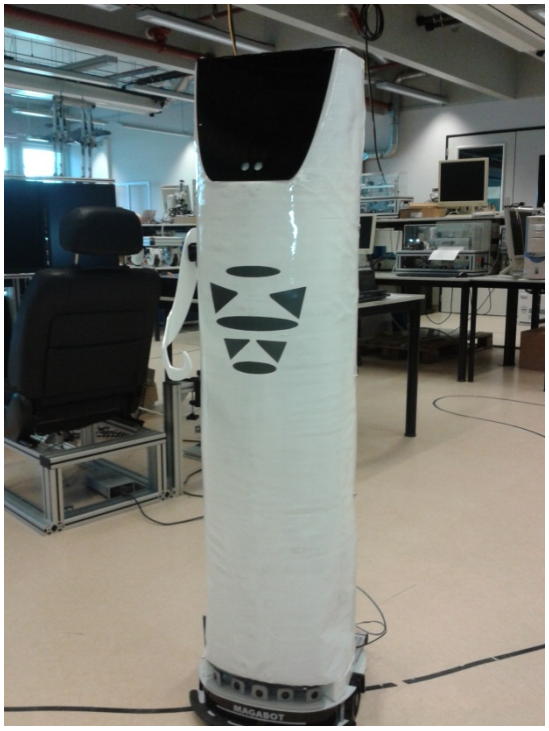

Figure 4: Robot prototype for the long-term study

Tablet and applications

A tablet served to communicate with the robot and to perform the breaathing exercise. The tablet is an Asus Transformer, with 10" display and with Android operating system. One self-made application, called "Magabot App", serves to communicate with the robot and initiate the breathing exercise. The first interface of the application has a simple appearance as shown in Figure 5. The buttons "Connect" and "Start exercise" allow the tablet to connect to the robot and to start the breathing exercise, respectively. When the tablet launches the proposition of starting the exercise, a menu is displayed with options. During the breathing exercise a new window appears on the screen. By clicking on "Connect" the user connects via Bluetooth to the heart rate sensor worn by the user. By clicking on "Start", a visible countdown that starts at 15:00 minutes would commence. Heart Rate and HRV

values are prompted online and an arrow indicates whether the heart beat is increasing or decreasing. A button with the prompt “Done” finalizes the exercise

More about the tablet application is explained in Section 4.4.4: Procedure.

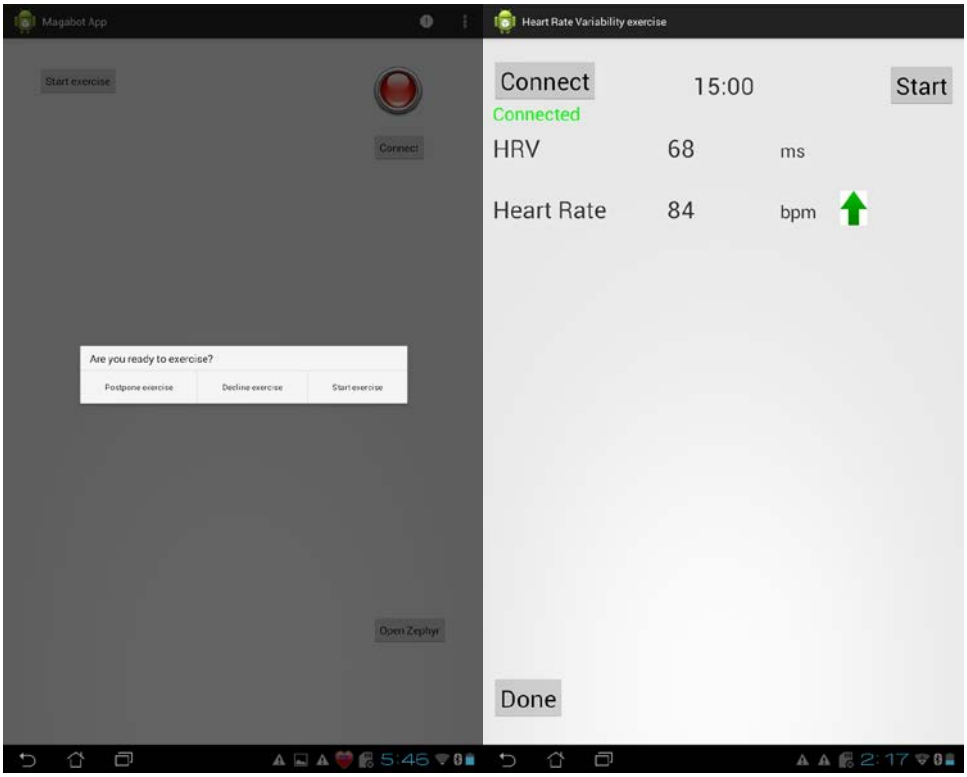

Figure 5: Left, application window showing the message that it is time fort he daily exercise. Right, application window visible during the execution of the breathing exercise.

Heart signal sensor

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

4.4.3 Measures

We were interested in the evolution of three areas of the participant’s life: his perceptions and attitudes toward the robot, his daily routines and his physical and psychological health. These three areas were explored through quantitative and qualitative measures. The quantitative measures, consisting in the scales and questionnaires 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 (see Appendix). The questionnaires were administered using the tablet interfance and the items that compose the questionnaires appeared in a different random order every time.

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 a diary (see Appendix for the three). The participant filled in the diary every evening.

In addition, objective measures were recorded, consisting of 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 [45] was recorded from the 15 min duration of each HRV exercise session. Likewise, mean, 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 specific measures were taken in the study:

1) (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. [46]. 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 [47]. 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 [48]. 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 at the end of this section).

2) (Changes in) participant's daily life

The participant was asked to provide us with relevant information about (changes 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.

3) (Changes in) health and psychological balance

The Personal Opinion Survey (POS) by McCraty et al. [49] was used to assess stress levels and both positive and negative emotional states. This questionnaire is composed of 60 5-point semantic differential items (see Appendix). 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 randomised order every time the participant filled them in so as to reduce learning effects.

More qualitative data were collected through the interviews and diary.

Interview

A semi-structured interview [50] with the participant took place at the beginning and at the end of the long-term study (see Appendix). 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 [51]. 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.

Diary

Every evening the participant 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?"). 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.

4.4.4 Procedure

Actions of the robot

The whole study lasted three weeks, during which the robot stayed uninterruptedly at the participant´s 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 would aid the user every additional time when he asked it to do so (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 three random occasions throughout the day (the system was set to three random times according to user's preferences). The participant communicated with the robot through a tablet (see below "Communications between system and participant").

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 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 (see Appendix for protocol) was carried out and audio recorded.

In the second meeting, the participant learned and practiced the breathing 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, work 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 questions or suggestions.

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 user´s 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 for 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 sat on the couch and pressed the action possibility "Start exercise" on the tablet. The exercise was then performed as in the daily procedure.

Aditionally, the system from time to time proposed 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 indicated that something went wrong in the study, for example that the robot stopped moving or did not operate in the expected way. Pressing the break-down 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 threat the comfort of the user), a phone number was provided to immediately contact the experimenter. In addition, the phone number of an experimenter´s 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 breathing exercise.

Breathing exercise

The participant performed a breathing exercise aided by the application on the tablet and the heart signal sensor. The exercise was based on a mindfulness meditation program [52]. Mindfulness meditation has been proven to reduce stress and anxiety as well as depressive symptoms [53]. It seems to contribute also to an improved cognition and concentration, among others [52].

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 (see the specific intructions in Appendix).

While the exercise is being performed, heart beat signals from the sensor are streamed to the tablet, where these are saved and later sent by email to the main researcher. These data 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 [54]. Thus, we expected that if the breathing exercise had positive psychological effects, these might be observable in terms of higher HRV levels.

4.4.5 Analysis

Since only one participant took part in the study, we offered the questionnaire format as an structured way to obtain data. Thus, even though it would not allow deriving strong conclusions, it would serve as a 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, would be 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 analysed based on an inductive content analysis, as in [55]. That is, key points were extracted, clustered by topic and arranged in accordance with the three research questions.

4.5 Results and Discussion

Before we report and discuss the results, a brief biography of the participant will be helpful to understand our 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).

4.5.1 Brief biography of the participant

One elderly person participated in this study. For confidentiality, the participant will be referred to as E. N.. E. N. is a male participant of age 74. He lives 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 ago. He has always been a cheerful person, however this terrible experience saddens him to a great extent, which has 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 does not receive any kind of elderly assistance. He does not need it because he has a very active life and appears to be physically and mentally healthy. He spends a lot of time with friends and with his favorite hobby, card playing. Regarding familiarity with robots, he has seen robots on television but has almost no experience with them, although he has daily experience with new technologies.

4.5.2 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.

Despite this initial declaration of low expectations toward the robot, we believe that 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 moved. However, they were surprised that the robot could just only move and raise the arm. The variable Perceived Use (Figure 6) 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.

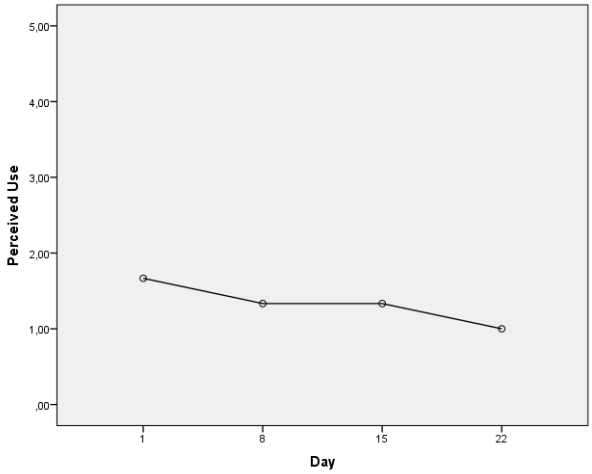

Figure 6: Evolution of Perceived Use during the whole interaction.

All the data support the idea that the robot was regarded as a mere machine. 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 7, left) and Perceived Intelligence (Figure 7, right) were quite stable over time, but also very low. In the case of intelligence, in the diary E.N. refers to the robot as a "pretty stupid thing". The results from the Source Credibility Scale (Figure 8, left), which measures trust, seem likewise stable and very low, which is again the case for Social Presence (Figure 8, right). 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.

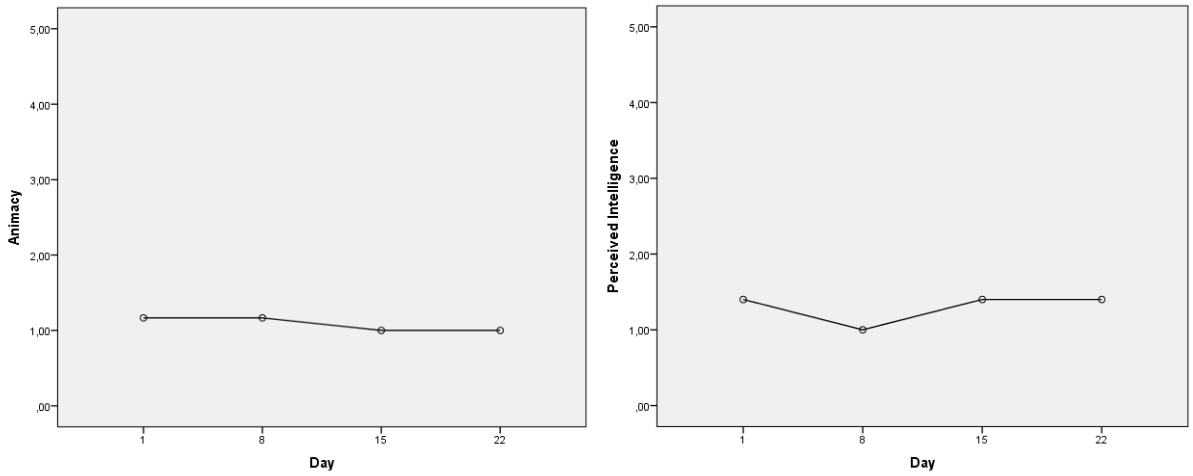

Figure 7: Left, evolution of Animacy during the whole interaction. Right, evolution of Perceived Intelligence.

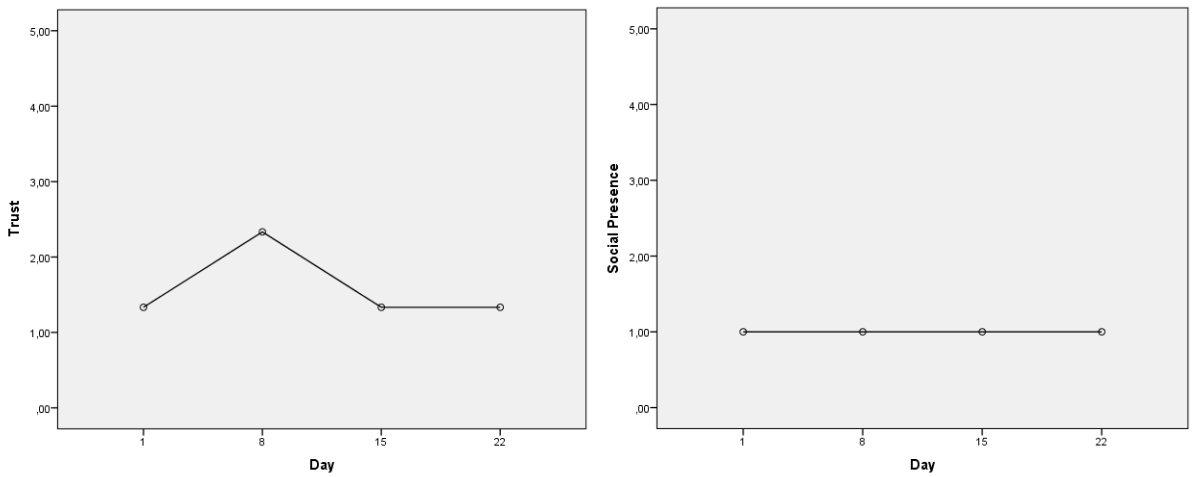

Figure 8: Left, evolution of Trust during the whole interaction. Right, evolution of Social Presence.

Before the start of the study, E.N. considered the idea of having robots at home as interesting. He likes 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 9). 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.

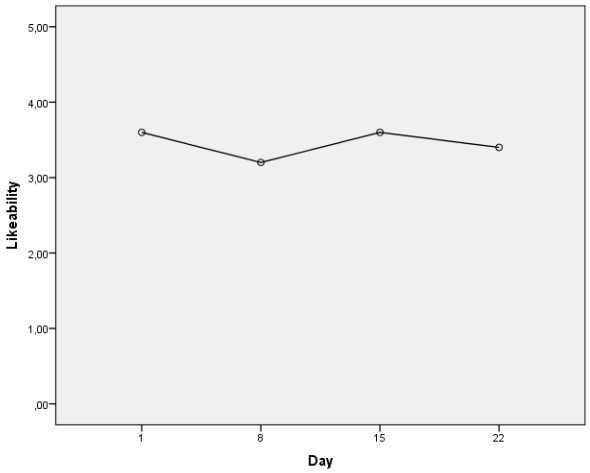

Figure 9: Evolution of Likeability during the whole interaction.

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, becaming then progressively more boring for E. N. The Perceived Enjoyment scale (Figure 10) 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. 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.

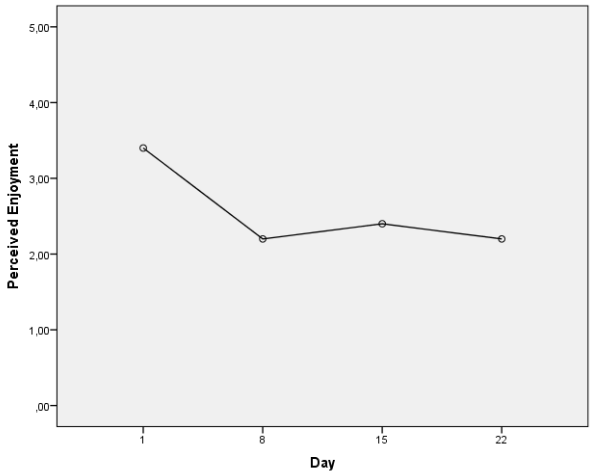

Figure 10: Evolution of Perceived Enjoyment during the whole interaction.

E.N. said that in order for the robot to be more agreeable it should have speaking capability. He reckoned 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 11) from the questionnaires.

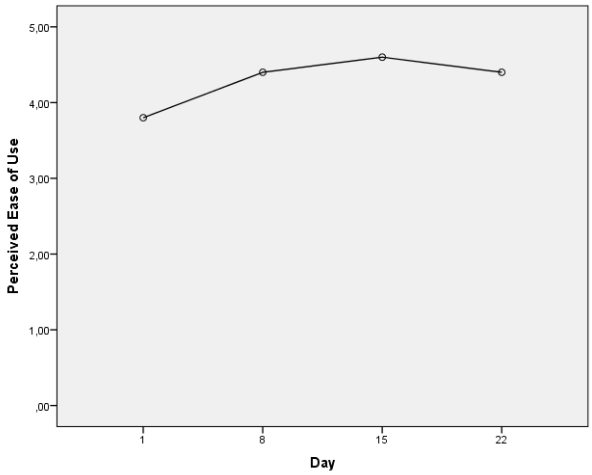

Figure 11: Evolution of Perceived Ease of Use during the whole interaction.

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.

4.5.3 Daily routines and changes

E. N. seems to have a balanced and very active lifestyle. He devotes no time to resting or napping, E. N. is always busy. For example, he goes to sport training on Tuesdays and Thursdays. On Wednesdays he works as a volunteer from home helping other elderly people solve their questions about using computers. He is very active in card playing. On Wednesday he plays cards at an association and on Monday and Friday with friends. Additionally, he plays also in competitions and occasionally in extra occasions.

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 takes about 15 min (yoghurt with cereals). Then he got ready and went to the sport school, which is 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.

He does all house chores by himself. The only exception is house cleaning, for which he hired a cleaning assistant that comes once a week to do the major cleaning tasks in the house. He only cleans the cooking table and the sink. He said "some people would think that I´m dirty. I can use the same cup for two weeks." They had also had a cleaning assistant when his wife was still alive. He recognizes he is able to clean, but he just does not find it useful. For instance, he thinks that ironing is nonsense. He takes the bike when he must shop groceries. He goes everywhere by bike as long as it is possible. Otherwise he would drive his own car.

The same approach goes for cooking. He cooks maximum three times a week, then the food goes in the freezer. He eats very often out with friends, although he does not invite people over to eat very often. He cooks only for dinner, for lunch he eats some slices of bread for example with cheese.

If he has any breakdown in the home, he would fix it himself. "All the technical things, with the exception of electronics. It's something I enjoy to do." He spent his working career as researcher and teacher in a technical field, thus he feels comfortable with these tasks.

E.N. makes great use of new technologies, including computer, tablet and smartphone. He masters new technologies well enough to help other elderly people with computer use. Once a year he also gives a course on computer use for elderly.

Regarding his social life, he spends a great part of his time in company of other people. Most of this time is spent with friends and partners from card playing. But also, he receives and visits other friends very often. He visits his two sons and grandsons once every two weeks, approximately. It is E. N. who pays the visit most times. He has brothers and sisters, but they do not visit each other very regularly. Additionally, on some occasions E. N. speaks with a friend from the U.S. through the computer.

Other hobbies include reading, for example the newspaper, but also books, mostly novels. These can be on the tablet or in paper format. He also likes museums and cinema. However, due to his emotional situation he does not spend as much time on these hobbies as he used to. He barely watches TV.

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 visitors, the visitors were supposed to not 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 breathing exercise was to help the researcher. On the last diary entry he says: "It's been a pleasure to be in your project, I hope I was of help."

Thus, we managed to offer 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 would have been longer, or the exercise more frequent. Or perhaps also if the exercise would have caused a major psychological benefit as described below.

4.5.4 Psychological state of the participant

As pointed out in E.N.'s short biography, the current affective state of E. N. marks his lifestyle to a great extent. The wife of E. N. passed away about one year and a half ago, after a long period of sickness. E. N. tries to cope with his loss, however he still feels greatly depressed. In addition, right before the start of the study he had another big disappointment from a newly started relationship. All this has a great impact on his emotions and also on his daily routines. Even though E. N. might appear now 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 experiences daily.

The following graphs show the participant's responses to Happiness (Figure 12, top left), Depression (Figure 12, top right) and Hostility (Figure 12, bottom). 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 might consider the high levels of Hostility (Figure 12, bottom) also as an indication of his negative emotions.

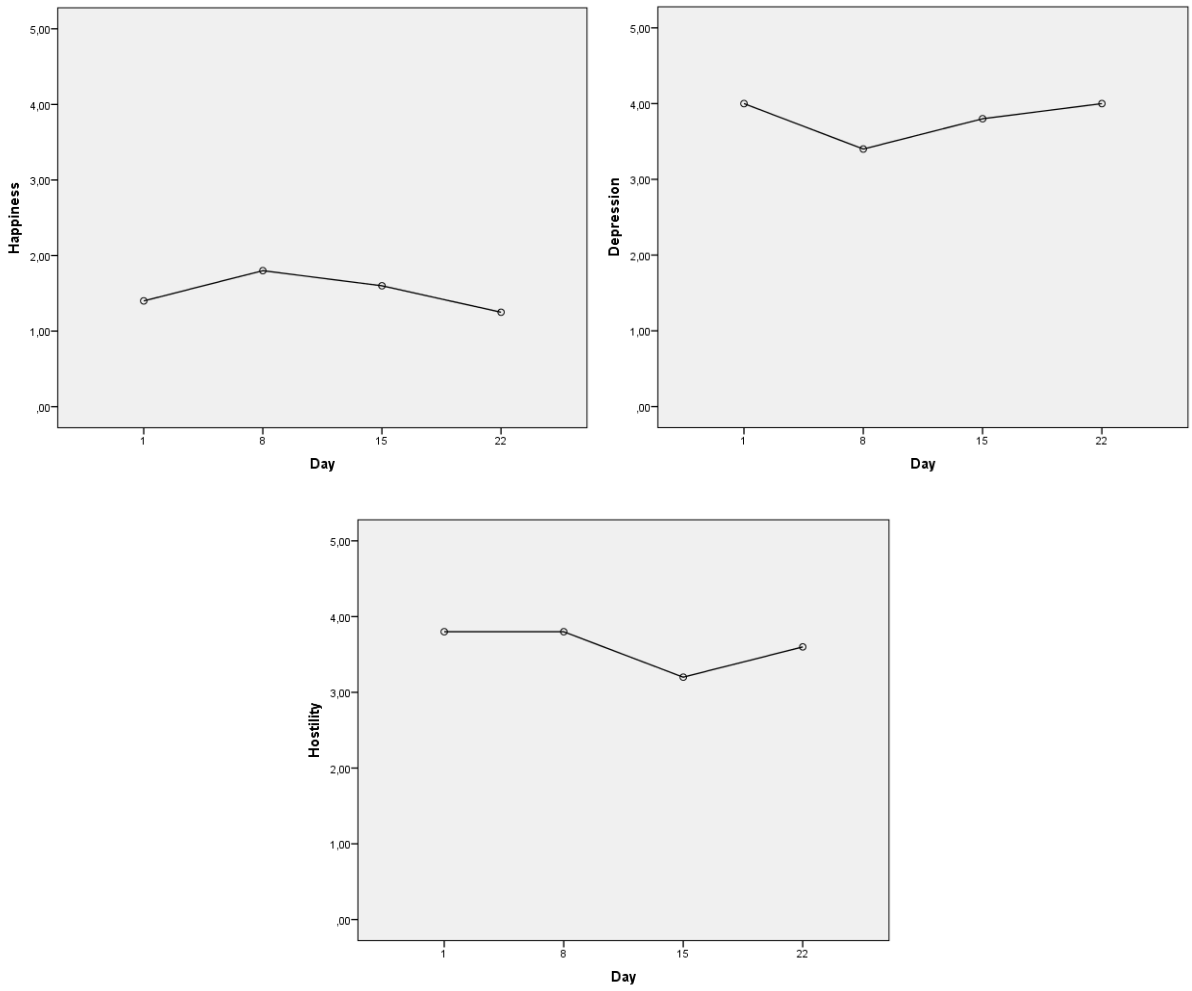

Figure 12: Top left, evolution of Happiness throughout the whole interaction. Top right, evolution of Depression. At the bottom, evolution of variable Hostility.

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 finds solace in his friends. If it was not for their good company, he would have moved away when his wife died. He does not know what to do to relieve his mood. But at least he feels good when he plays cards with his friends.

Even though E.N. suffers from the depressive symptoms described, we can also see his efforts to cope with the situation. As already mentioned, E.N. remains very active and spends a great amount of time in the company of other people. In fact, some scales from the POS questionnaire, which feed into the construct Emotion, show relatively high values. Examples are Vigor (Figure 13, top left), Caring (Figure 13, top right) and Warmheartedness (Figure 13, bottom). 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".

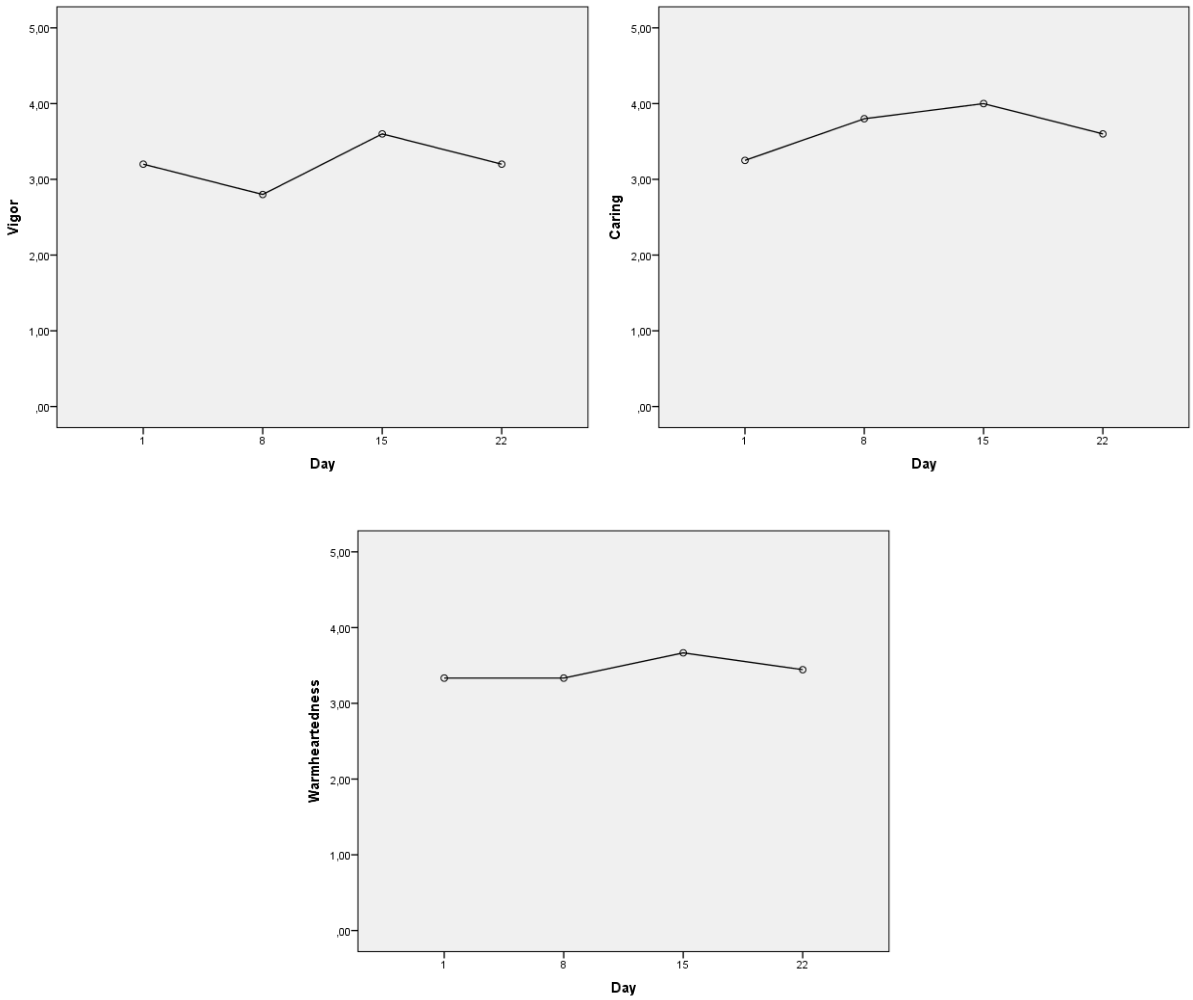

Figure 13: Top left, evolution of Vigor throughout the whole interaction. Top right, evolution of Caring. At the bottom, evolution of variable Warmheartedness.

E. N. used to be a cheerful person. Also, he does not get nervous easily, he is a very calm person. As he says, “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 14).

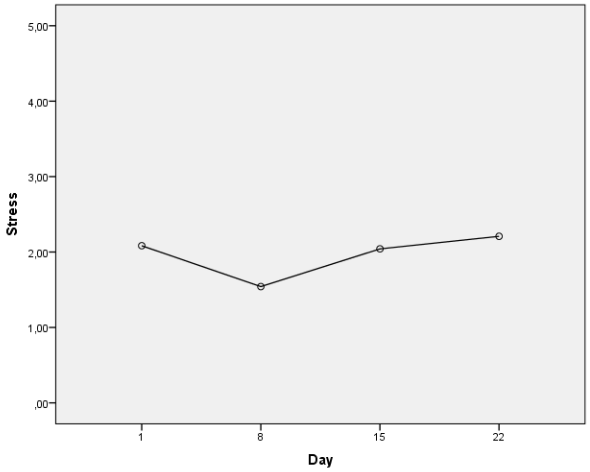

Figure 14: Evolution of Stress during the whole interaction.

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 incongruent with the results from the Heart Rate and HRV sensors (Figures 15 and 16, respectively).

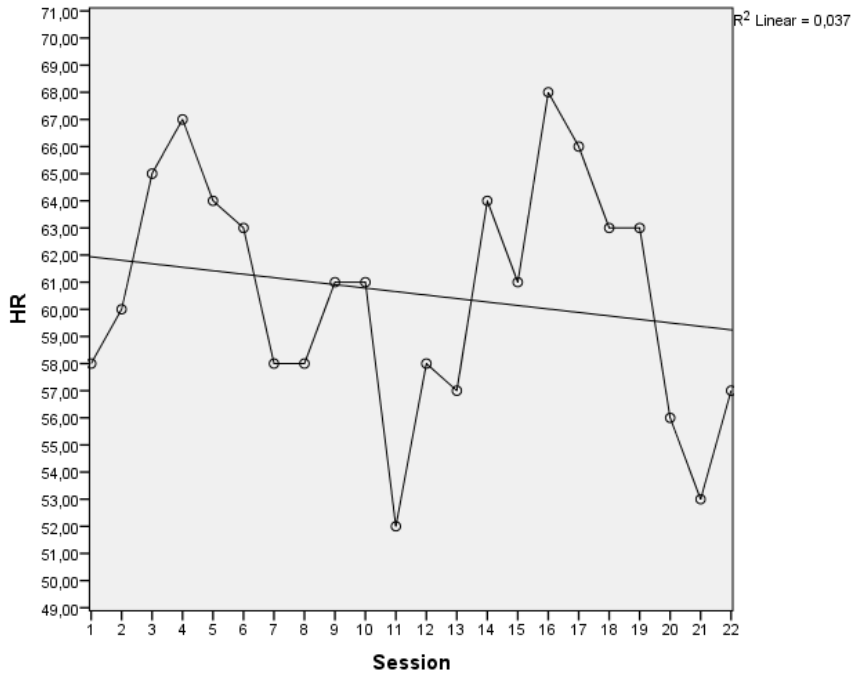

Figure 15: Heart rate values throughout the three weeks. The line indicates a decreasing tendency.

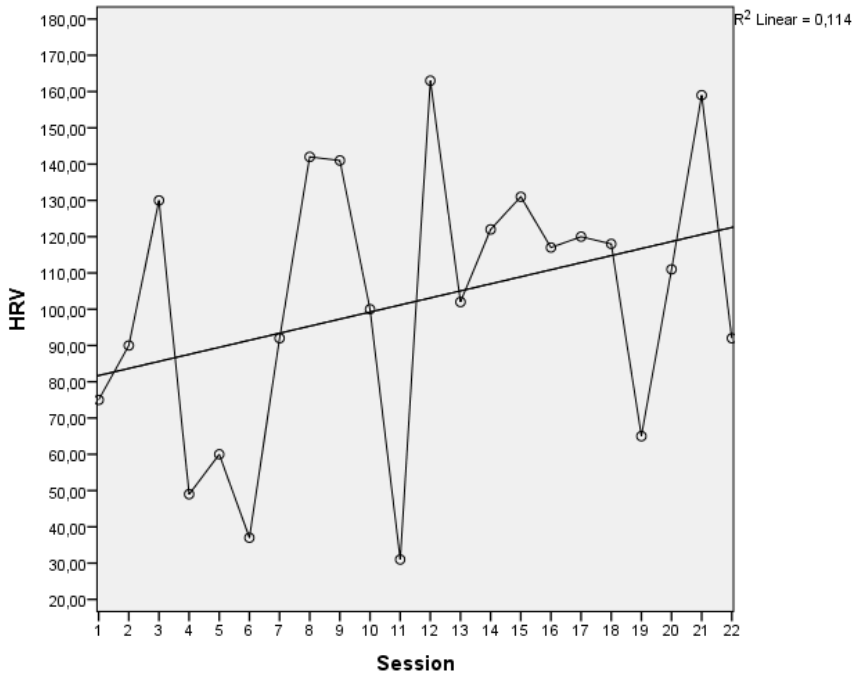

Figure 16: HRV values throughout the three weeks. The line indicates an increasing tendency.

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, we 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 believe that this depends. 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. We 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 [52]. However our participant practiced the exercise for as little as 5 min per day (see Section 4.4.5: Use of system and reflection on the study methodology).

4.5.5 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 consider this frequent contact as a caveat, since we might have caused an impact on the participant's social routines. We also 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 we 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. We did not control for the information exchange that took place between the technician and the participant. 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 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 also fear this might be a reason why E.N. focused so much on the robot technical details when he recorded the diary entries.

There were a few more aspects that did not turn out as smooth as we hoped. On the day prior to the official study start, the main researcher was not available and another researcher had to substitute him and visit the participant to explain the study procedure in detail. Even though we feel obliged to mention this, we do not believe this to have caused any major impact on the running of the study.

Finally, there were two tasks the participant did not perform correctly, which we believe cripples the validity and the extension of our 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 decided that from now 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 spends less and less time on the recordings and that he becomes 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 felt 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. We were aware of the 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 great effort at communicating to the user the importance of completing the target task or exercise (whichever this may be) and doing this correctly. It might not be enough to just hear the user’s commitment to perform the exercise. In our study, the participant stopped doing the breathing 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 our study, the participant became more and more lenient regarding the content for the diary entries.

4.5 Conclusion

The present report shows the results of two studies that aimed to investigate long-term interactions between elderly participants and home robots. In the first and introductory study, we explored meaningful exercises for a robot and elderly persons to carry out together in the context of re-enablement and to explore the ways in which a robotic research platform can be deployed in a home for long-term acceptance research. We wondered how elderly people would respond to robots in their home setting. Also, we hoped to gather experience about deploying a robot in the home, which would feed into subsequent long-term studies as part of D6.3.

One of the main insights gained from the first study refers to the strong view of the robot as a tool that we found in the elderly participants. Later, in the second study here presented, we found more corroboration of this finding. Another strong conclusion derived from the first study was the need in long-term studies of minimizing the researcher's involvement throughout the duration of the studies [56]. This is important so that a more valid and reliable response toward the robot could be measured.

With these insights in mind, we carried out the second study included in this deliverable. We wanted to gain a deeper understanding of the feelings and attitudes elderly people experience when having an assistive robot at home for a prolonged period of time. Thus, in this study an elderly participant lived together with a home robot for a period of three weeks, and we performed an in-depth exploration, to a great extent qualitative, of his complex thoughts and emotions.

We believe that one of the most remarkable facts about the second 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. We also believe that the greatest value of the second study does not consist in the mere research results, but rather in 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 the participant what he/she is required to do. We think that this knowledge would be regarded as useful by other researchers and robot developers and will be used in our next planned long-term study.

All in all, we hope to have contributed with another small step to the current understanding of Human-Robot Interaction in elderly care. In any case, we finalized these studies with a sense of contentment and the certainty that our progressive know-how knowledge will allow us to carry out ever more challenging studies.

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Appendix

Godspeed Subscales

Please rate your impression of the robot on these scales:

Dead	1	2	3	4	5	Alive
Stagnant	1	2	3	4	5	Lively
Mechanical	1	2	3	4	5	Organic
Artificial	1	2	3	4	5	Lifelike
Inert	1	2	3	4	5	Interactive
Apathetic	1	2	3	4	5	Responsive
Dislike	1	2	3	4	5	Like
Unfriendly	1	2	3	4	5	Friendly
Unkind	1	2	3	4	5	Kind
Unpleasant	1	2	3	4	5	Pleasant
Awful	1	2	3	4	5	Nice
Incompetent	1	2	3	4	5	Competent
Ignorant	1	2	3	4	5	Knowledgeable
Irresponsible	1	2	3	4	5	Responsible
Unintelligent	1	2	3	4	5	Intelligent
Foolish	1	2	3	4	5	Sensible

Scales from Almere Model

(All scales are combined and order of items randomized)

Please, indicate your impression of the robot on this scale.

Perceived Usefulness:

1 - I think the robot is useful to me
2 - It would be convenient for me to have the robot

3 - I think the robot can help me with many things

Perceived Ease of Use:

1 - I think I will know quickly how to use the robot
2 - I find the robot easy to use
3 - I think I can use the robot without any help
4 - I think I can use the robot when there is someone around to help me
5 - I think I can use the robot when I have a good manual

Perceived Enjoyment:

1 - I enjoy the robot talking to me
2 - I enjoy doing things with the robot
3 - I find the robot enjoyable
4 - I find the robot fascinating
5 - I find the robot boring

Social Presence:

1 - When interacting with the robot I felt like I'm talking to a real person
2 - It sometimes felt as if the robot was really looking at me
3 - I can imagine the robot to be a living creature
4 - I often think the robot is not a real person
5 - Sometimes the robot seems to have real feelings

Source Credibility Scale (SCS)

Please rate your impression of the robot on these scales. Circle the corresponding number of each pair of items.

1 - Cares about me – Doesn't care about me
2 - Doesn't have my interests at heart - Has my interests at heart
3 - Self-centered – not self-centered
4 - Not concerned with me - Concerned with me
5 - Insensitive – Sensitive
6 - Not understanding – understanding

Personal Opinion Survey (POS)

Below are words that describe the way people feel sometimes. Please indicate how often you feel the following emotions by circling the appropriate number for each item:

Anxious	1	2	3	4	5
Tense	1	2	3	4	5

Nervous	1	2	3	4	5
Afraid	1	2	3	4	5

Stress is hurting my work performance	1	2	3	4	5
I experience physical symptoms due to stress	1	2	3	4	5
Other people´s problems cause me stress	1	2	3	4	5

Excited	1	2	3	4	5
Energetic	1	2	3	4	5
Active	1	2	3	4	5
Vigorous	1	2	3	4	5
Lively	1	2	3	4	5

Happy	1	2	3	4	5
Glad	1	2	3	4	5
Cheerful	1	2	3	4	5
Delighted	1	2	3	4	5
Joyous	1	2	3	4	5

Calm	1	2	3	4	5
Pleased	1	2	3	4	5
Relaxed	1	2	3	4	5
Satisfied	1	2	3	4	5
Contented	1	2	3	4	5

Loving	1	2	3	4	5
Friendly	1	2	3	4	5
Affectionate	1	2	3	4	5
Warm	1	2	3	4	5
Passionate	1	2	3	4	5

Sad	1	2	3	4	5
Hopeless	1	2	3	4	5
Worthless	1	2	3	4	5
Miserable	1	2	3	4	5
Unhappy	1	2	3	4	5

Blameworthy	1	2	3	4	5
Guilty	1	2	3	4	5
Ashamed	1	2	3	4	5
Regretful	1	2	3	4	5
Remorseful	1	2	3	4	5

Angry	1	2	3	4	5
Irritable	1	2	3	4	5
Resentful	1	2	3	4	5
Enraged	1	2	3	4	5
Bitter	1	2	3	4	5

Used up	1	2	3	4	5
Burned out	1	2	3	4	5
Fatigued	1	2	3	4	5
Exhausted	1	2	3	4	5

End of my rope	1	2	3	4	5
Represented by kindness	1	2	3	4	5
Represented by Appreciation	1	2	3	4	5
Represented by Love	1	2	3	4	5
Represented by Care	1	2	3	4	5
Represented by Tolerance	1	2	3	4	5
Represented by Forgiveness	1	2	3	4	5
Represented by Acceptance	1	2	3	4	5
Represented by Harmony	1	2	3	4	5
Represented by Compassion	1	2	3	4	5

Over-critical	1	2	3	4	5
Over-sympathetic	1	2	3	4	5
Over-responsible	1	2	3	4	5
Self-pitying	1	2	3	4	5

Protocol of First Interview

Introduction

The interviewer introduces himself by saying *hello, it´s very nice to see you again, how are you?*

Interviewer thanks the interviewee again for the participation. If there are other people in the scene, these are mentioned and thanked: *and thank you also to you* (3rd person in the scene) *for your help. It is alright that you are here while we conduct the interview.*

The purpose of the interview is explained. *As we explained to you already the other day (*in the first meeting with participant*) I would like to learn more about you and your life at home. This information will be needed to understand the impact that the robot will have on your daily life.*

It is common practice to audio or video record interviews. If you do not mind, I would like to video record this interview. This will allow me to go back in time to review your comments so that I do not become distracted by taking notes.

Audio recorder is prepared and starts recording at this early stage, since interviewees may start to provide valuable information even before the first questions.

All the information derived from this interview will be treated confidentially. There are no right or wrong answers. It is important for my research to receive honest opinions. If you do not have an opinion about a topic or prefer to omit an answer, you are not obliged to answer. You are allowed to leave at any time or to interrupt the interview. Please let me know whenever you have a question.

Interviewer prepares his copy of this protocol with interview questions.

Body of the interview

Open questions are asked first. Specific questions are asked if detailed information has not been provided.

Questions that could cause embarrassment or resistance are preceded by a version of the following cue:

It may be a little embarrassing/personal for you, but I need this information. Remember all data is treated confidentially.

The purpose of these questions is to make the interviewee start talking about anything they want. The intention is to find priorities in interviewee and to start to create a positive rapport (very easy, open-ended questions). Finish after 5 min.

How are you doing recently?

How is everything going?

And your family?

A) Questions on daily life, habits and health

A good way of knowing about the daily life of a person is to ask about a recent day in particular. Try to re-enact in your mind the things you did yesterday. Could you describe, step by step, the activities that you performed? Try to describe also the little activities that you might take for granted.

It is very likely that after the participant´s answer there will still be activities and aspects of the participant´s daily life that have not been discussed. The interviewer will check the following list and further ask about activities that were not addressed. In this case, the interviewer will start for each topic with *you might have forgotten about (*activity*). Could you please tell me more about this?*

List of common daily activities:

Wake-up

Toileting/bathing

Preparation and consumption of breakfast

Cooking

Eating lunch

Resting during the day

Sleep at night

Cleaning

Vacuuming/sweeping

Mopping

Dust

Windows

Kitchen

Dishes

Bedroom

Bathroom

Tidying house

Garbage management/taking out garbage

Examples: separate/recycle, take out garbage.

Laundry (washing and drying)

Make bed

Ironing

Making and repairing clothes

Maintaining dwelling and furnishings

Maintaining domestic appliances and other machines

Example: *What do you do when a domestic appliance breaks?*

(When applicable) Maintaining assistive devices

Maintaining vehicles

(When applicable) Taking care of plants and gardening:

Examples: *water plants, garden, manure, cut lawn.*

(When applicable) Taking care of animals:

Examples: *feed pets, walk the dog.*

Get mail, newspaper.

Shopping and acquiring goods and services

Examples: *buy groceries and other home products, unpacking them, storing them.*

Administrative issues

Bank

Pension

Insurance

Use of technology

Telephone

Watching TV

Music

Computer, Internet, emails

Social life

Family

Partner

Parents

Siblings

Other relatives

Friends

Informal and formal associations

Neighbors, acquaintances, etc.

Recreation

Do you perform religious activities?

How do you find entertainment?

Tell me more about your hobbies.

Do you practice any sport?

So far we have discussed your routines on a typical day. Do you have days when you do different things?

If nothing comes to mind, examples are offered: villa, Sundays, holidays.

B) Questions on psychological health, stress and depression

As I already explained to you in our introductory meeting, you will perform an activity with the robot which will help you reduce your stress levels and improve your mood. Therefore, it is important for us to know at which point we are starting now. I remind you this conversation is confidential, but you do not need to give an answer if you are not comfortable with that.

Do you consider yourself a nervous person?

Are you currently feeling especially nervous or worried?

Why?

What do you do when you are nervous or worried?

How would you rate your general mood? For example, are you a cheerful person or are you rather blue?

How is your mood on the last few days?

Why?

What do you do when you are nervous or worried?

C) Questions about expectations on robot

How familiar are you with robots?

What do you think of the idea of having robots at home?

Do you think this robot will really help you?

How?

Would it help other people?

Do you think there will be a change in your daily life?

And in your mood and stress?

And in the way how you perceive the robot?

End of interview

Interviewer tells interviewee that the interview is finished and asks if there are additional comments or questions.

Interviewee is thanked again.

Interviewing material is collected.

Protocol of Second Interview

Introduction

The interviewer introduces himself by saying *hello, it´s very nice to see you again, how are you?*

Interviewer thanks the interviewee again for the participation. If there are other people in the scene, these are mentioned and thanked: *and thank you also to you* (3rd person in the scene) *for your help. Again, it is alright that you are here while we conduct the interview.*

The purpose of the interview is explained. *As we explained to you already in the last meeting before the study, in this interview I would like to learn how the robot changed aspects about yourself and regaring your daily life.*

As I mentioned in the first interview, it is common practice to audio or video record interviews. If you do not mind, I would like to video record this interview. This will allow me to go back in time to review your comments so that I do not become distracted by taking notes.

Video camera and audio recorder are prepared and start recording at this early stage, since interviewees may start to provide valuable information even before the first questions.

Also, I will repeat again that all the information derived from this interview will be treated confidentially. There are no right or wrong answers. It is important for my research to receive honest opinions. If you do not have an opinion about a topic or prefer to omit an answer, you are not obliged to answer. You are allowed to leave at any time or to interrupt the interview. Please let me know whenever you have a question.

Interviewer prepares his copy of this protocol with interview questions.

Body of the interview

A) Questions about the experience in general

Questions about the experience in general:

Before we narrow down to details, please tell me in your own words how the overall experience was.

Did you enjoy the experience?

What did you like the most?

What would you change?

B) Questions about acceptance of the robot

What do you think about the robot?

Do you like the robot?

Was interacting with robot interesting or boring?

Why?

How would you improve the interaction with the robot?

Did the robot match your expectations?

Why?

What would you change in the system to make it more agreeable?

What would you change in the system to make it more persuasive?

C) Questions about changes in daily life

How was your daily life different compared to before the study?

The interviewer checks the list in the first interview about common aspects of daily life and asks accordingly when the participant did not address an activity.

D) Questions about mental life and the HRV exercise

After all these days, what do you think about the meditation exercise?

Was it easy to do?

Did you enjoy the exercise?

Are you thinking of continuing the exercise after the study?

Do you think it worked?

Are you feeling more or less stress than before?

Are you feeling happier or sadder than before?

What other changes did you experience due to the exercise?

Were there changes in your emotions?

Were there changes in your stress levels?

What would you do to improve the exercise and its use?

What would you do otherwise to reduce your stress?

And to improve your mood?

End of the interview

Interviewer tells interviewee that the interview is finished and asks if there are additional comments or questions.

Interviewee is thanked again.

Interviewing material is collected.

Protocol for the Diary

Please, try to elaborate on the following questions about today:

What were you today doing before and after using the system?

How do you feel now?

How did you feel before, during and after using the system?

How do you feel toward the robot right now?

Did you have any remarkable feeling or though about the robot today? If yes, please explain.

How did the robot influence your routines today?

How did you feel today in terms of vigor and energy?

How did you feel today in terms of mood?

Is there anything else you found remarkable today about your perception of the robot, its effects on your routines or your physical and mental wellbeing?

Guidelines for Breath-Focused Meditation

Sit comfortable with your back straight, but don´t be in a forced posture. Try to be relaxed. Close your eyes and focus on your breath. Throughout the whole exercise you will breathe normally. This exercise is about focusing your attention on your breath, not about changing it in any way. Try at the beginning to notice every aspect of your breathing, such as how your abdomen rises when you breathe in and how it decreases when you breathe out. You will feel also the air going through your nostrils and hear the sound of your breathing. Focus on all these details while you start to relax.

You will soon realize that thoughts and emotions tend to come to your mind and distract you from focusing on your mind. Don´t worry, this is absolutely normal, this is how our mind usually works. Try not to fight these thoughts or emotions with opposition, but rather, try to become aware of them. Become aware of the fact that you are distracted, and then let the thoughts or emotions disappear by themselves in the same way that clouds pass across the sky. Then gently focus again on your breathing. If you find this exercise difficult because you are very distracted, which is typical at the beginning, you can also count every breath from 1 to 10 and repeat this counting until you get a sense of more control over your attention.

Once you gain some practice you might realize that there are many aspects of the breathe you can focus on (sound, the air passing through different parts of the airways, etc.) Where should you focus at all? Try then to focus on your nostrils. Feel, capture the sensation you feel at your nostrils at every moment while you breath.