Mutual Care: How older adults react when they should help their care robot

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Abstract. Care robots for the aging population usually support older adults at home or in a care facility in their daily activities, by monitoring their health status, mediating social communication, or assisting in fetch-and-carry tasks. However, there still remain the older adults' feelings about being cared for by a robot and what the robot possibly could do to make them feel more comfortable with being helped. We argue that the human-robot relationship can be improved with "mutual care" by giving the user simple opportunities to care for the robot as well as to increase the team feeling, and consequently, the acceptance. Based on controlled case studies, conducted at three different European laboratories (n = 49) with two conditions (reciprocal dialogue vs. control), we demonstrate how older adults react to a care robot with reciprocal behavior and how they perceive their relationship with it. We also show that the reciprocal behavior, even in short-term laboratory studies, positively influences the perceived usability and ease of learning of the care robot.

1 INTRODUCTION

Developing care robots for older adults in order to enable a longer independent living at home or to support health personnel at care facilities is nothing new. Several robots already exist, which try to tackle the aging population problem such as Pearl, Robocare, Care-o-bot, Paro, Domeo, MRP, Hector, and Huggable, to name a few [4, 5, 8]. These assistive robots for older adults can be grouped into two main types: robots for rehabilitation and socially assistive robots [8, 11]. Rehabilitation robots are systems considered for physical assistance and are not meant to be social entities, such as exoskeletons and smart wheelchairs. Socially assistive robots can be further divided into companion-like robots and service-like robots. Companions should improve above all the user's psychological well-being, such as the prominent example of the therapeutic seal robot Paro [31]. Service robots should actually assist people in the daily activities of life, such as maintaining the household or reminding of medicine.

If a care robot should successfully enable aging in place, it needs to be accepted by the user. Acceptance hereby can be defined as the older user's willingness to incorporate the robot into her daily life [6]. A lot of research has already been done to explore acceptance in Human-Robot Interaction (HRI) with older adults. Heerink and colleagues [17] argue that this research "can be subdivided into two areas: acceptance of the robot in terms of usefulness and ease of use (functional acceptance) and acceptance of the robot as a conversational partner with which a human- or pet-like relationship is possible (social acceptance)." They further suggest that a complete methodology should incorporate both aspects of acceptance, the functional and the social. In this sense, Feil-Seifer and Matarić [11] also argue that socially assistive robots should complete tasks as well as interact socially with their users. We also think that both aspects are inseparable and should complement each other to facilitate acceptance.

A primary goal of older adults is maintaining their independence and assistive robots have the potential to help them reaching this goal [2]. Yet, how much should the robot take over? It is difficult to draw the line between maintaining independence with the assistance of a robot and becoming dependent of the robot. In fact, this fear of over-relying on the robot is an important issue in the acceptance of robots by older users. Cesta and colleagues [9] revealed that older people, who believed that their health was worsening, feared to become dependent on a robot that would not act the way it was supposed to. For those older adults who may fear to depend on the robot, Beer and colleagues [3] suggest designing the assistive robot in a way that encourages collaboration between robot and human. In this way, older adults would remain active and the robot would only be compensating their limitations by assisting the task. Additionally, Pineau and colleagues [24] underline the importance of techniques that can cope with individual differences, as older users exhibit a great range of skills as a result of age-related decline.

Baltes and Baltes [1] argue that aging might be best conceptualized as a changing balance between gains and losses. Older adults try to cope with their declining physical and mental capabilities by implementing different strategies [24] and they seem to be more willing to use assistive products when they have accepted the change in their capabilities [14]. "People's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" determine how much effort they will expend and how long they will persist in the face of obstacles and aversive experiences [2]. Therefore, it seems important that a care robot, which assists older people in their everyday lives, does it in a way that encourages their beliefs about their capabilities.

To our conviction, a care robot, encouraging older users to stay independent at home, will receive higher acceptance. So, how to achieve a robot being perceived as a helper and not as a technology one is dependent on? As described in our previous work [19], we consider a *Mutual Care* interaction paradigm as a potential solution: The basic idea is to create a social human-robot dynamic of "taking care of each other" (i.e. mutual-aid). One way to achieve this is the application of interaction design

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principles that reproduce the dynamics of self-help groups derived from the *helper theory*, a psychological model describing the helper therapy circle in self-help groups [26]. The reciprocal dynamics of such groups also result in a favorable opinion towards the own group. Applied to HRI, these dynamics will reduce the feeling of being dependent on assistive technology and enhance the feeling of independently aging at place with a technological companion.

In this paper we present our research with the Hobbit system, a *Mutual Care* service robot for older adults, which should support aging in place by the means of fall prevention and detection.[2] The paper is structured as follows: First, we describe our theory, based on the helper theory and the rule of reciprocity from sociology, which leads us to reciprocal interaction patterns as one potential key to establish a feeling of mutuality, which subsequently should increase the acceptance of the care robot. Based on this we derive our hypotheses for reciprocity with the Hobbit robot. Next, we elaborate on the interaction paradigm implemented into this robot. Then, in section 4, we unfold the methodology, the reciprocal task conditions we implemented to evoke a team feeling, and the study design for the three laboratory studies conducted with 49 (70+ in age) participants total in Austria, Sweden, and Greece. In the results section we demonstrate how the reciprocal task conditions caused friendly reactions from the participants and even positively impacted the perceived usability and ease of learning of the robot. We will close the paper with an outlook on future behavioral strategies that we are currently implementing for our care robot in order to study them in the field in 20 private households at our three European testbeds.

2 THEORY AND HYPOTHESES

The *Mutual Care* interaction paradigm focuses on the imitation of social aspects essential for human-human relationships via different interaction strategies in order to increase the user's acceptance towards the robot. An interesting relationship dynamic can be observed within self-help or mutual-aid support groups [26]. A self-help group is an alliance of individuals who need each other in varying degrees, to work on certain common problems. Some members of such groups continuously switch roles between "helper" and "help receiver" and consequently perceive an increased benefit of the group [22] compared to members who only receive help and do not switch their roles. Thus, situations in which one member of the group fails to accomplish a task does not negatively affect the others' acceptance of this member, especially if an often changing "helper-help receiver" relationship is established and the group is perceived as beneficial.

A favorable opinion of the group is not the only benefit for role-switching members of the mutual-aid group. According to the theory, in the process of helping another self-help member, helpers also increase their own well-being and their self-efficacy, one's perceived competence to complete tasks and reach goals [21, 27]. Persons with high self-efficacy - those who believe they can perform well - are more likely to view difficult tasks as something to be mastered rather than something to be avoided. When these persons persist in activities that seem threatening, but are relatively safe, they will reinforce their sense of efficacy after the positive experience. In contrast, people who give up before trying will retain their negative expectations and fears for a long time [2]. For older people, increased self-efficacy could reduce the feeling of being dependent on assistive technology, and enhance technological acceptance and the feeling of independently aging at place.

Mutual-aid groups do not represent all social dynamics in which helping each other is of relevance. There is a delicate balance between helping and being helped. From a very early age we learn about the obligation towards people who give us something. The *rule of reciprocity* (or reciprocation) says that "we should try to repay, in kind, what another person has provided us" [10]. Interestingly, the rule of reciprocity is apparent in all human societies, so its universality applies cross-culturally [10, 15]. This obligation, which is deeply incorporated in the human psyche, makes it difficult for older people to accept help, especially when they are deprived from the possibility to give it back somehow.

Kahana and Kahana [18] identified three preventive behaviors against decline often employed by older adults: health promotion, planning, and helping others. Morris and colleagues [23] interviewed older people, most of which expressed a strong desire for reciprocal relationships in which they help others. They also found out that many older adults experienced a loss that was very difficult to fill, when they no longer had opportunities to influence other people.

Consequently, how do we apply this knowledge to human-robot relationships? Fogg and Nass [13] explored the leveraging effect of the rule of reciprocity to promote behavior change in Human-Computer Interaction (HCI). Their experiment provided empirical evidence that users behaved in more helpful ways (amount of help given, time on task, and quality of work) to a computer that had helped them on a previous task. If the computer had failed to help them previously, users were less helpful.

Social dynamics between humans and robots have been investigated by numerous researchers in HRI [e.g. 16]. In our research, we want to explore the effects of reciprocal behavior by the robot on these dynamics. The *Mutual Care* interaction paradigm suggests that robots, which ask users for help to overcome their physical limitations, will support the users' perception of having a beneficial relationship based on mutuality [19]. This basic idea is similar to the "symbiotic relationship" concept defined by Rosenthal and Veloso [28], however, in the *Mutual Care* interaction paradigm the robot tries to repay its "social debt" of being helped with a favor.

In a helping-help receiving relationship, the right balance is crucial. A robot for older people must be reliable and never fail in emergency situations; otherwise the users would not accept it. Therefore, a care robot that follows the *Mutual Care* paradigm still remains in control of important events and does not take the role of a care-receiving robot as defined in Tanaka and Matsuzoe's work [30].

We believe that one key to demonstrate mutual-aid dynamics between humans and robots are *reciprocity fostering dialogues*. These robot dialogues could be used to establish a recognizable,

[2] http://hobbit-project.eu

reciprocal "helper-help receiver" situation. For example, the robot politely asks the user for help if it cannot accomplish a task. When the user helps the robot fulfill its duty, the robot has the "social debt" to do something else for the user in return, thus it offers the user to return the favor to maintain their "helper-help receiver" balance. To explore this assumption we conducted an empirical user study with potential end users.

The study was designed to investigate the difference in the user perception of the Hobbit robot with a reciprocity fostering and a normal dialogue behavior. The study was based on specific hypotheses towards the establishment and the effects of reciprocity.

Hypothesis 1: In the reciprocal dialogue group, a mutual-aid dynamic between human and robot will be established.

- *(a)* In a reciprocity situation the users will help the robot if it asks for help.
- *(b)* The participants will react with a spontaneous positive emotional response if the robot asks for help.
- *(c)* Once involved, the participants will not stop the helping process.
- *(d)* The participants will give the robot the chance to return the favor.
- *(e)* The participants will react with a spontaneous positive emotional response if the robot asks to return the favor.

Hypothesis 2: The participants will recognize the reciprocal dynamics between themselves and the robot during the reciprocal situation.

Hypothesis 3: The perception of the user's relationship with the robot will last through non-reciprocal interactions.

3 HOBBIT – THE MUTUAL CARE ROBOT

The care robot in our studies was designed to enable older people to stay longer in their homes, following three main criteria:

1. Emergency detection and handling
2. Fall prevention
3. Providing a "feeling of being safe and supported"

It was important that the concept created a maximum of usability, acceptance, and affordability. The functions and the social behavior of the robot were designed to complement each other.

There is this ideal of a robot butler in people's minds inspired by science fiction, which takes over various household tasks, cooks the most delicious foods, and is their best friend when they need one. The findings of Beer and colleagues [3] support this assumption and underline the importance of older adults' need of assistance in various household maintaining tasks such as making the bed. However, state-of-the-art platforms are so far not really capable of doing these tasks. In order to avoid over-promises, the idea for the Hobbit robot (see Figure 1) is to have an affordable technology at disposal that performs meaningful tasks and is "honest" about its capabilities by asking the user for help in reciprocal dialogues and following the basic principles of *Mutual Care* [19].

The detection of falls and calling for help are considered the most popular tasks for a service robot that should support aging in place [6]. Consequently, the main functionality of the Hobbit robot is emergency detection and handling. Although a very important function, emergencies do not occur regularly every day. To allow a daily use of the robot, other functions were also added. These functions provide fall prevention at home by means such as picking up clutter, bringing objects, offering reminders and entertainment which includes mental games. Additionally, the robot is connected to an Ambient Assisted Living (AAL) environment, which issues warnings when something is wrong, and thus keeps the user reassured with calming dialogues that she is "safe and supported".

Figure 1. Hobbit the Mutual Care Robot
"naked" (left) and in cover (right)

The interaction with the user is designed to support multi-modality including automatic speech recognition (with an off-the-shelf solution allowing a minimal set of commands), text-to-speech, gesture recognition, and a graphical user interface with touch, in order to combine the advantages of the different modalities. The touch screen is the most reliable of the options, but requires a rather short distance between user and robot. Speech recognition allows a wider distance and hands-free use, but has the disadvantage of being influenced by the ambient noise level. Gesture recognition also allows a wider distance and additionally works in noisy environments, but needs the user to be in the camera field of view with certain lighting conditions.

Figure 2. Touchscreen Main Menu of Hobbit

Figure 2 shows the touchscreen main menu of the Hobbit robot. There are three commands for daily tasks: “Clear Floor” for the robot to pick up things from the floor, “Learn Object” for the user to teach the robot objects that it should remember, and “Bring Object” for the robot to search and bring previously learned objects. Additionally, there is a “Call Hobbit” command, which can be issued verbally, with a gesture or via stationary call buttons in the AAL environment.

The emergency command “Help Me” is triggered in different ways: via an SOS button on the touchscreen, via a physical button on the robot, via speech or gesture. Furthermore, the robot detects if the user falls while being in the camera field of view.

The telephone connects the user to friends and relatives. Information about news, local weather or from the internet can also be retrieved. Entertainment is provided in forms of music, videos, and games. The user can reward Hobbit by saying “well done” or using the “reward” button on the touchscreen. Likewise, Hobbit can offer a surprise (a randomly chosen entertainment option will be started) or the user can actively ask for it.

During the trials, Hobbit spoke with the same text displayed on the screen. Users could interact with speech, gesture or touch (multimodal dialogues). The interaction was initiated by the user, but the dialogue was driven by the robot. The interaction could only proceed when the user answered the robot’s questions or confirmed its statements (for structured comparable interaction scenarios). The objects the robot was taught or had to bring during the user study were derived from previous requirement studies (medication box and key chain).

More details on the Hobbit robot can be found in [12] and http://hobbit-project.eu.

4 METHODOLOGY

To investigate whether reciprocal dialogues create a feeling of reciprocity and thereby support our hypotheses on the impact of *Mutual Care* on the human-robot relationship we conducted a controlled between-participants laboratory study at three European sites (Austria, Sweden, and Greece).

SAMPLE

Since the Hobbit robot serves the purpose to delay moving into a care facility, it is assumed that it needs to be introduced to the users’ homes at an age before the decision is taken to no longer independently stay at home. The average age of older adults moving into a care facility is 81 years in Austria (according to the in-house statistics of the care facility in Austria we cooperated with), with men on average being slightly younger (76 years).

Consequently, the definition of the target group for our laboratory study was based on the age of 70+. Additionally, we chose a sample that represented the most common age-related impairments occurring at that age [20, 29] by using self-reports of participants in the recruitment phase to assess the grade of impairments in the field of vision, hearing, and mobility. Many of our participants experienced impairments in more than one of the three categories. In total, 44 (89.8%) had some form of multiple impairment (e.g. moderate vision and minor mobility problems) and 78% of the sample fulfilled the impairment requirement of having at least one impairment graded as ‘moderate’.

A total of 49 participants took part in the experiment as primary users (PU) of which 25 were randomly allocated to the reciprocal dialogue condition and 24 to the control condition. In 35 cases these PUs were accompanied by secondary users (SU) – relatives or friends, whose presence was assumed to help primary users feel more comfortable during the experiment. In Austria 12 PUs and 9 SUs took part in the study; in Sweden 21 PUs and 11 SUs and in Greece 16 PUs and 15 SUs. The focus of this paper is on the findings on reciprocal behavior, so the results of all participant data is considered in an accumulated manner not taking into account cultural differences.

MANIPULATION

The experimental trial consisted of the following six tasks:

Task 1 – Introduction: This task was planned as an ice-breaker, in which the participants should get familiar with the robot and the user study situation. The robot introduced itself and explained its functionalities.

Task 2 – Clear Floor: This task was designed as a first neutral reference task, in which no reciprocity stimuli were given. The robot picked up an object from the floor and brought it successfully to the user. There was no need for the participants in both groups to help the robot in fulfilling the task. This type of reference tasks (see also tasks 5 and 6) was necessary to systematically assess the impact of the reciprocity situation on the participants’ opinion towards the robot.

Task 3 – Learn Object: This task demanded help from the participants of both groups due to the robot’s physical limitations. In order to learn an object, the robot needed a special “learning turntable”, which it could not manipulate by itself. So, when given the command “Learn Object”, the robot asked the participant to place the “learning turntable” into the gripper and follow further instructions (see also Figure 3).

Figure 3. Hobbit learning a cup with the help of a user

Help from the participants thus was a necessary part in this task, but the assistance was presented as a part of the procedure, i.e. the robot did not ask for help explicitly. In the reciprocity group, after finishing the learning of the object, the robot thanked the participants for teaching it a new object and offered to return the favor. In this way, the robot emphasized the fact that it could only learn the object with the help of the user. If the participants accepted, the robot offered a surprise (a randomly chosen joke, video or music file) to repay its “social debt”. This action was planned as a priming stimulus for task 4 in the reciprocity condition. Offering the return of favor once before task 4 gave the participant the possibility to familiarize with it, and thus eventually skip it when offered again. In the control group, the robot finished the task after having successfully learned the object. In other words, although both groups had to help the robot, only the reciprocal dialogue condition received a stimulus at the end of the task pointing to the reciprocal situation.

Task 4 – Bring Object with Failure: This task was the main reciprocal stimulus task. In the reciprocity group, a controlled situation was created in which the robot needed help from the participant to reach its goal. The robot failed to find the demanded object, so it returned to the user and asked for help. If the participants accepted to help, they were asked to specify the whereabouts of the object via touchscreen. After another search using this information the robot returned with the object. It thanked the participants for the received help and offered to return the favor by letting them choose from its entertainment menu. On the contrary, in the control group the robot returned to the participants and simply reported that it could not fulfill the task. In other words, no help was demanded. However, the user would have had the option to send the robot again, though no participant did this in our study. We controlled the reciprocity effect by limiting the experiment to the case where the robot always succeeded with the help of the user in finding the object in order to support the reciprocity condition (positive reinforcement). Bringing the object is a functional obligation of the robot. When the user helps the robot fulfilling its duty, the robot has the “social debt” to do something else for the user in return (e.g. by offering entertainment).

Task 5 – Bring Object: This task was another reference task with the same conditions for the reciprocity group and the control group. In this task the robot searched for another object and successfully brought it to the participants. It was important to demonstrate both groups that the robot was also able to accomplish the “Bring Object” task by itself and thus minimize negative attitudes towards the robot's reliability. It also emphasized the switching of the helper help-receiver roles and gave a positive interaction experience after the failure task.

Task 6 – Emergency: This was the last task featuring the same conditions for both experimental groups. It was designed to evaluate an emergency call scenario for the robot, and consisted of a human confederate falling in front of the robot and triggering the emergency dialogue which was then continued by the participant. The dialog consisted of questions about the participant needing help and ended with calling the help center.

Tasks 3 and 4 involved *reciprocal stimuli* for the investigation of reciprocity enhancing dialogues, while Tasks 1, 2, 5 and 6 were neutral tasks.

INSTRUMENTS AND MEASURES

In order to measure if our reciprocal dialogues impacted the interaction with the robot, we used a method triangulation to assess the impact on an attitudinal and an observational level consisting of specifically designed questionnaires and observation protocols.

Our first instrument was the *task questionnaire*, which had to be filled in after each task of the user study. The facilitator posed the participants questions and filled in the answers for them, so that the situation for the users was more like a structured interview than a traditional questionnaire. The questionnaire included general questions on preferred interaction modalities and how the interaction was perceived (in terms of pace or ease of use) as well as questions on the perceived mutual-aid dynamics.

Our second instrument was a *debriefing questionnaire*, which had to be filled in by the PUs and the SUs after all tasks were finished. It included general questions on usability and acceptance (partly derived from the System Usability Scale questionnaire [7]) as well as questions on the perceived reciprocity of the interaction.

Again the facilitator posed the participants all questions and filled in the answers (on a 4-point Likert scale from 1 = “not at all” to 4 = “very much”) for them. The SUs answered the questionnaire by themselves.

Our third instrument consisted of *observation protocols* used by a scientific observer and by the SUs. Both observation protocols included observation categories for the interaction between the user and the robot in each task, which included the task duration, technical problems, and different reactions of the user.

All trials were also video-recorded to fill gaps in the observation protocols after the study.

PROCEDURE

The user studies took place at all three testbeds in a setting consisting of two adjacent areas with separation screens and a doorway in between. The first user studies were conducted in March 2013 in Austria, followed by trials in Greece in April, and finally the trials in Sweden in early May.

At all sites there was a Briefing Area (see Figure 4, left) – a kitchen that consisted of a kitchen corner (sideboard, a small oven, a cooker, dishes, dishtowels, and cutlery) and an eating area with a table with two chairs and a side table. The other area was the Main Testing Area (see Figure 4, right), decorated as a living room with a cozy chair for the PU, a small couch table, a chest with drawers, and a space in the background for the SUs and the observers.

Figure 4. Briefing area (left) and Main testing area (right), both in Austria

At the trials, the following persons were present: The primary user, the secondary users, a facilitator (a researcher who introduced the robot and guided the user through the trial tasks), a scientific observer (a researcher who remained in the background and observed the users' behavior and reactions or incidences during the studies, such as unexpected reactions from the participants and technical problems), and a technician (a researcher who also remained in the background to navigate the robot with remote control and assure that the robot functioned correctly, especially during learning, object recognition and grasping, which were autonomously done by the robot). This semi-autonomous wizard-of-oz setting ensured the same testing conditions for every participant.

Each trial consisted of three parts: (1) the introduction phase, including a pre-questionnaire and briefing on how to interact with the robot and what it can do, (2) the actual user study with the robot (six trial tasks) and (3) the debriefing phase. One trial lasted on average 2.5 hours (including introduction and debriefing questionnaire). If wanted, users could take breaks in between phases or tasks.

5 RESULTS

In the following we present the differences in the perception of the interaction with the Hobbit robot for participants in the reciprocal dialogue condition compared to the control condition. Other interesting findings on usability and acceptability issues as well as on cultural differences would go beyond the scope of this paper, so these aspects will be presented elsewhere.

MUTUAL-AID DYNAMICS

In the reciprocal dialogue group, during the Task "Bring Object with Failure" a mutual-aid situation was created on purpose. The robot failed to bring the demanded object, asked the user for help, and then succeeded with the help of the user. Subsequently, the robot offered to return the favor. The mutual-aid dynamics were explored by using the observation protocols.

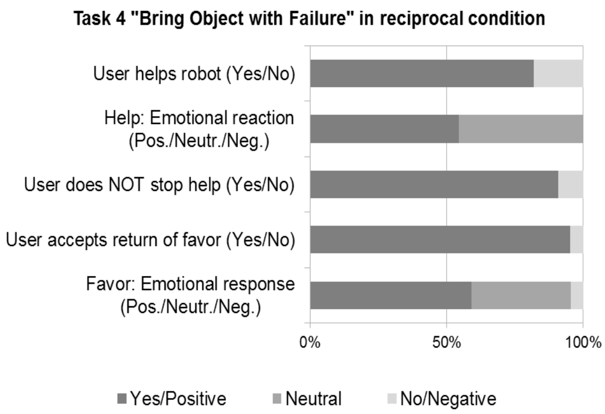

Figure 5. Observed compliance and emotions of the user during Task 4 "Bring Object with Failure"

As Figure 5 illustrates, compliance as well as emotional responses during Task 4 were in general positive or at least neutral during every step of the task. These results support hypothesis 1. The observation of the established mutual-aid dynamics is the basis for the results on the attitudinal level, as discussed in the next sections.

We also compared the "return of favor"-compliance and the complementing emotional reaction of the reciprocal dialogue condition between Task 3 (the reciprocal priming task) and Task 4 (the actual reciprocal task). Figure 6 shows an increase of the "return of favor"-compliance while the positive emotional response wears slightly off: an indicator that the bias of the novelty effect, which leads to high primary ratings, subsides. At the same time, we assume that the learning in Task 3 was not perceived as real help, which could explain why the "return of favor" was less accepted than in the following Task 4. Another possible explanation is the user understanding the concept of the robot returning the favor and actually liking it.

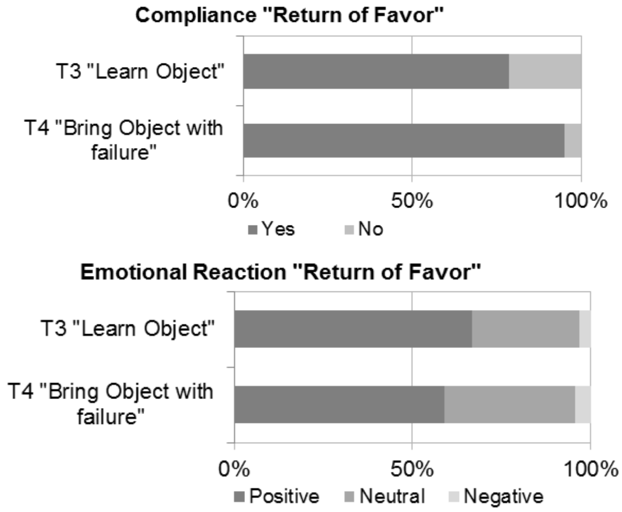

Figure 6. Comparison of "Return of Favor" in the reciprocal condition between Tasks 3 and 4, compliance (above) and emotional reaction (below)

PERCEIVED RECIPROCITY

The conscious perception of reciprocity (i.e. teamwork) is assumed to play a major role for the maintenance of the users' acceptance towards the robot, thus to investigate this aspect, the *perceived reciprocity* was inquired after every task. In the task questionnaire, PUs had the possibility to choose the kind of human-robot cooperation they felt had happened between them and the robot by answering the question "Who supported whom in this task". There were three descriptions to choose from: (a) robot supported the human; (b) human supported the robot; or (c) robot and human supported each other. The third description reflects *perceived reciprocity*.

For statistical comparison of the two experimental conditions chi-square tests were used. We created a dependent variable *perceived reciprocity* by combining the answers (a) robot supported user and (b) user supported robot into the category "non-reciprocal" and leaving the answer (c) robot and human supported each other as the "reciprocal" category.

The chi-square test revealed a difference for the task "Bring Object with Failure" (χ^2 (1) = 4.61, p = .03). This supports our assumption with evidence that the reciprocal dialogue fosters *perceived reciprocity* on the user side on the attitudinal level (see hypothesis 2).

Surprisingly, a significant difference was revealed for the task "Clear Floor" (χ^2 (1) = 8.12, p = .004), whereby the control group showed a higher degree of *perceived reciprocity* than the reciprocal dialogue group. Although we consider psychological priming effects, the reasons for this are unknown and still subject of further investigations.

In the task "Learn Object" we expected some effects due to the reciprocal behavior at the end of the task, however, the difference was not significant (χ^2 (1) = 0.05, p = .825).

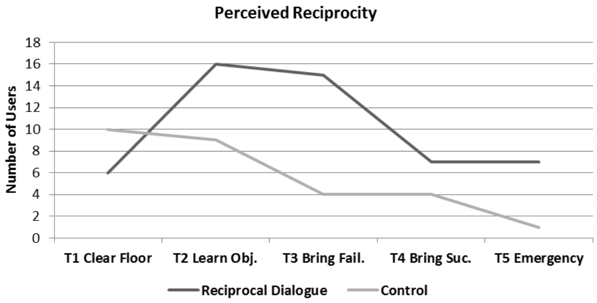

Figure 7. Graphical illustration of how many users perceived reciprocity in the reciprocal dialogue condition (black line) and the control group (grey line). The x-axis indicates the task. The y-axis shows how many users perceived reciprocity.

Figure 7 shows how perceived reciprocity ("robot and human supported each other") of both groups evolved over time between different tasks. It is interesting that the reciprocal group came back to its previous level after the reciprocal tasks, but the control group experienced a rather constant decline. However, the "Emergency" task showed no statistically significant difference between the two conditions to confirm hypothesis 3 (χ^2 (1) = 2.7, p = .10). The data can be interpreted that experienced reciprocity influences subsequent neutral tasks, but further studies are needed to confirm this finding.

USERS' PERECEPTION OF THE ROBOT

Although, statistically, the perception of the users' relationship with the robot did not significantly last through non-reciprocal interactions, we found that the reciprocal dialogues had influenced the users' perception of the robot itself. These results were found using the debriefing questionnaire and analyzed with the Wilcoxon-Mann-Whitney rank sum test.

Comparing the mean ranks of the reciprocal dialogue group with the control group revealed that the robot was perceived as easier to use (U = 373.5, p = .049) in the reciprocal dialogue group. Participants of this group also had the impression that there was less to learn before get going with the robot (U = 391, p = .024).

Interestingly, it seems like the reciprocal condition even had an impact on the perception of the input modalities of the robot. The design of the touchscreen menu (U = 162.5, p = .007) and the font size of the robot's touchscreen (U = 189, p = .010) were perceived as better in the reciprocal dialogue condition.

As the touch screen represented the primary communication interface for most of our users, it is convincing that its perception was influenced by the mutual-aid dynamics. Apparently, the main input modality of the robot appears more attractive if the robot acts in a reciprocal manner, which supports our main assumption that *Mutual Care* increases the acceptance of a robot as assistive technology for aging in place.

ADDITIONAL QUALITATIVE RESULTS

The additional screening of the video recordings revealed three noteworthy phenomena: First, the participants largely enjoyed being surprised and being asked for help by the robot. Frequent reactions to this were positive surprise and laughter or smiles. Second, the majority of participants wanted to be called by their real names by the robot. Whenever their name was mentioned, the response often was a smile or amusement. Third, when asked why the participants helped the robot in Task 4, answers ranged from "because I wanted the robot to succeed", over "because the robot asked me" to "because I want the object".

6 REFLECTIONS ON MUTUAL CARE

In general, the results support some of our hypotheses with empirical evidence and demonstrate that *perceived reciprocity* can be established in HRI with simple behavior patterns and recognized consciously. The reciprocity fostering dialogues implemented in the Hobbit robot created the desired mutual-aid dynamics derived for the *Mutual Care* interaction paradigm. These types of dialogues can easily be implemented in other socially assistive robots by choosing the tasks and situations that call for them carefully. For example, the user asks the robot to bring her keys and the robot comes back saying that it has found the keys in the kitchen, but cannot reach them. The robot then suggests going to the kitchen together. In this case, the user has to get the keys herself, but she does not have to search for them and she remains active. Another example, the robot reminds the user that the flowers look thirsty, apologizes that it cannot handle water safely, but would love to accompany the user by showing her which flowers look the most thirsty. In this case, the user does not forget to water her flowers, remains active and does not have to do the task alone.

7 CONCLUSIONS AND OUTLOOK

When we are talking about care robots in the research field of HRI, we in general consider robots that care for older adults at home or in care facilities. However, what we do not consider is a "helper-help receiver" relationship in which the robot does not only care for the user, but also the other way around. In this paper, we introduced the *Mutual Care* robot Hobbit: A care robot that should support aging in place by emergency detection and handling, fall prevention, and the provision of a safe and supported feeling at home. The human-robot relationship should to our conviction be based on mutuality to increase the user's acceptance of the robot as a helper. One key aspect to establish mutuality between the older adult and Hobbit is to our conviction *perceived reciprocity*. In a user study with 49 participants we could provide empirical evidence that simple reciprocal dialogues can foster the perception of the robot as a reciprocal entity and that they even have positive impacts on perceived usability and ease of learning.

Yet, reciprocal dialogues and other effects of the *helper theory* like increased self-efficacy are just a starting point for Mutual Care as a general interaction paradigm. Another crucial aspect to our conviction is adaptation. For long-term success the robot should adapt to the user's need of a "helper-help receiver" relationship, as not every older adult wants a companion robot and not every older adult wants an assistive tool robot. For our next series of user studies with the Hobbit robot, we therefore want to offer the user the option to choose at a regular basis if they want the robot to be more companion- or machine-like. This will trigger how the robot behaves: A more machine-like robot will not ask for help that often, will not offer to return the favor that often and hardly will surprise the user. Otherwise, a companion-like robot will every now and then proactively approach the user and ask if it can help or entertain. According to our assumptions on *Mutual Care* over a longer period of time users will choose the robot to be more companion-like, as the "helper-help receiver" situation will enhance the acceptance of the robot and the users' self-efficacy in maintaining everyday life. We plan to explore this adaptive approach in the field with users in their private homes in Austria, Greece, and Sweden, where the robot will live together with the older adult for 2-3 weeks.

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