Exploring Human-Robot Interaction with the Elderly: Results from a Ten-Week Case Study in a Care Home

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ABSTRACT
Ageing societies and the associated pressure on the care systems are major drivers for new developments in socially assistive robotics. To understand better the real-world potential of robot-based assistance, we undertook a 10-week case study in a care home involving groups of residents, caregivers and managers as stakeholders. We identified both, enablers and barriers to the potential implementation of robot systems. The study employed the robot platform Pepper, which was deployed with a view to understanding better multi-domain interventions with a robot supporting physical activation, cognitive training and social facilitation. We employed the robot in a group setting in a care facility over the course of 10 weeks and 20 sessions, observing how stakeholders, including residents and caregivers, appropriated, adapted to, and perceived the robot. We also conducted interviews with 11 residents and caregivers. Our results indicate that the residents were positively engaged in the training sessions that were moderated by the robot. The study revealed that such humanoid robots can work in a care home but that there is a moderating person needed, that is in control of the robot.

Author Keywords
Social Robots; Elderly Care; User Studies; Ethics

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies;

INTRODUCTION
As a consequence of to an ongoing demographic change and various associated social transformations there is an increased pressure on the care systems, which is forecasted to grow significantly [16]. Industrialized countries are confronted with a decreasing number of professional caregivers and an increasing number of people in need of care. Providing high quality care for a rising number of elderly people will become a challenge [10]. The shortage of skilled workers not only has a negative impact on the quality of professional care and thus on the physical and emotional wellbeing of caregivers, it also affects the wellbeing as well as physical and cognitive integrity of those who are in need of care. In the view of the complexity of the problem, governments, academia and industries are analyzing various strategies, including robot-based assistance for the elderly, to support their health and safety, and foster social participation (for reviews see [1, 4, 8, 9, 27, 44]).

Despite the wealth of work on social robots in aged care, few systems have yet already made their way into the real world. This may be in part because of the complexity of the care ecosystem, existing prejudices and concerns around digitalization and automation, as well as the huge variety of social practices and institutionalized routines of caregivers and residents into which any technical system must be carefully embedded. In short, there is a lack of empirical data and need for more practice-based studies that examine enablers and barriers of robotic systems in real-world care-settings and over a longer period of time, taking into account perspectives from all stakeholders involved.

In this paper, we present a robotic-based application utilizing the robot Pepper that was especially designed to support older adults and their caregivers in care homes to increase physical and cognitive activity and initiate social interaction. We introduced the system in group settings with residents over a period of 10 weeks and conducted interviews and observations with residents, caregivers and a facility manager. In this way we were able to elicit these stakeholder's attitudes, social and organizational practices, expectations towards the robot, individual and group-based performances as well as social communication among the participants. We distill our findings from the long-term field deployment into lessons learned for future use of robots in aged care.

RELATED WORK

Studies of Social Robots in Residential Care
The main goal of socially assistive robots in elderly care is to provide social companionship [9] rather than physical assistance such as feeding (e.g. [25]) or transport (e.g. [31]).

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As such, the vast bulk of research undertaken in this area has focused on the individual relationship between the robot and those with care needs. Typical tasks of socially assistive robots include cognitive support such as providing reminders of medication intake (e.g. [43, 47]), motivational work to engage elderly in physical exercises (e.g. [17]), cognitive exercises (e.g. [18]) or communication support in the form of the telepresence of caregivers, family or medical staff (e.g. [5]). The most widely studied social robots in aged care are the baby seal robot, Paro, developed by AIST, SONY's robot dog, Aibo, originally developed for entertainment purposes. Other, more complex robots follow a human model, e.g. the robot nurse, Pearl [42], Pepper, or the home assistant Care-o-bot [21, 29].

Research is steadily accumulating mostly qualitative evidence but also quantitative evidence for the effectiveness of these interventions (e.g. [9]). For example, in a systematic review, Kachouie et al. revealed that socially assistive robots could potentially enhance the well-being of the elderly and decrease the caregiver's workload, as assessed from psycho-physiological data like urinary tests for stress hormones and self-reported measures such as the burnout scale for nursing staff [27]. Animal-therapy robots such as PARO or AIBO, have been shown to reduce loneliness and mental stress, and increase verbal and physical activity (e.g., [28, 30, 45]). Challenges in existing evaluation studies include short study durations that can be heavily influenced by potential novelty effects, as well limited sample sizes (most studies reports sample sizes less than 10). Therefore, more robust, i.e., replicable, large scale and long-term studies in real world settings are needed to identify current enablers and barriers for robot-based assistance in practice [4].

Another factor that impacts social robots' acceptance and effectiveness in real world settings are the perspectives of various stakeholders involved. Pino et al. found that people with mild cognitive impairment and caregivers of people with dementia were much more welcoming towards care robots compared to healthy older adults [41]. This shows that current needs are a main driver for technology acceptance in elderly care, both on the side of patients as well as caregivers [8]. While most work introduces social robots in individual encounters with elderly persons, some research has shown that a group setting might be a promising alternative. For example, Kidd et al. found that the effect of a social robot increased in the presence of personnel that were willing to participate in the interaction [30]. Thinking about further adaption of social robots for everyday use in care facilities, factors such as user safety, ethical considerations such as privacy and cost effectives have to be considered also from the perspective of caregivers and care homes [12].

Perspectives of Caregivers and Care Homes

The profession of caregiver is confronted with a growing number of challenges in times of demographic change. Not only does the number of medical and psychological tasks increase with the ever rising age of care home residents, the profession also faces low payment and increasing stress despite the high number of vacancies [46]. This results in a situation that many care homes do not have enough staff, and this situation forces caregivers again to do overtime work [23]. Moreover, in the public opinion, the job of caregivers in care homes is often seen as relatively unskilled labor [24] that could be eventually (partially) automatized. As such, care homes and caregivers have a rather ambiguous attitude towards automatization efforts as researched in the field of social robotics, which have to be empathically addressed in field studies.

Nevertheless, both stakeholders are also open towards technological innovations that potentially help them fulfill their duties in a way that reflects the possibility of job satisfaction and that corresponds to their own ethical attitudes [26]. Previous research has shown that the development of technology in this ecosystem is better done with insights into the lives and daily practices of residents and caregivers in a specific care home, something that typically requires a qualitative approach of data collection [37, 48–50], as the adaption of technology is highly dependent on the context of use as has been pointed out many times in Human-Computer Interaction (HCI) research.

When developing for older adults and the stakeholders engaged with them, the use of 'Living Labs' has become more common in the research field of HCI. Living Labs are either build environments that are close to the real life environments of the participants. Studies there are mostly short-term that go from several hours to a few days [22]. Another approach is to work in situ, i.e., in the places participants live and conduct the research and testing as integrated part of real-life social contexts [38]. Particularly in the environment of care homes, which is a highly sensitive field, the opportunity to engage with various stakeholders over an extended period is invaluable. A Living Lab can provide useful information about the social practices of the participants and creates a situation that is close to a real life environment [11]. It allows testing technical artifacts like robots in an intimate atmosphere and can lead to a more natural usage of the developed technologies [11]. This helps researchers and developers to understand users and their requirements in a contextual way.

In this paper, we report on a ten weeks field study in a residential care home using the humanoid robot Pepper. The robot provided physical and cognitive exercises, as well as social activation to the residents. The goal of the study is to identify potential enablers and barriers of using a robot-based assistance over the long term, obtaining the views of different users and stakeholders, including the older adult residents, the professional caregivers and the management of the care home. Therefore, our approach works with several stakeholder groups and takes a more holistic point of view on field deployments of social robots in aged care.

METHOD

Our study was conducted in an institutional care facility with older adults in Germany. The care home had already experience in working with researchers from other ICT based projects. It is a facility with 119 residents. The aim of the study was to investigate the use of the socially assistive robot Pepper in real-world daily life situations of older adults and their professional caregivers in an institutional care setting.

Study Design and Setup

In the run-up of this study, we designed and developed training applications for Pepper that had been identified based on prior long-term participative interaction processes between the researchers, the older adults and the professional caregivers. The detailed overview of the technical system is described in the following section. We note, however, that the identification of the particular technical requirements of the system is not, even so, the main theme of this paper.

To explore the use practices of the participants in an institutional care setting, our study design included three steps. We started with initial interviews with all older adults and caregivers in the care home to explore the expectations, attitudes, feelings and current exercise patterns of the older adults and the caregivers. Secondly, a trial was conducted where the participants interacted with the robot system over a course of 10 weeks, with two workshop sessions every week i.e. 20 sessions in total to gather insights into use practices in a real-life care setting. Each session lasted between 45 and 60 minutes and was conducted by a research team consisting of two researchers. Each session was conducted and moderated by one researcher who also assisted the older adults when needed. To improve the user experience, a "Wizard of Oz" approach [13, 35] complemented the setup, whereby a second researcher controlled the robot from a nearby but unobtrusive position during all courses. This enables a smooth transition between applications where necessary. The performance and usability of the system was continuously assessed and re-designed based on observations of its use and feedback given by the participants. During all study phases, stakeholders were encouraged to act as co-designers, giving advice and making suggestions as to how to progress. In a third and final phase, we re-interviewed participants to ensure consistency in reporting the study results.

Data collection and analysis

Both the initial and final interviews were semi-structured, but questions were individually tailored where interesting aspects could be examined in more detail. Each interview took about one hour. The guideline of the initial interviews included questions about daily life and work in the care home, the existing approach of exercising and the participants' attitudes, feelings and expectations towards the robot system. The post-interviews focused on the service use and related experiences. The participants were asked to compare their expectations before the study took place with their actual user experiences. We also asked them to describe positive and negative experiences with reference to specific situations, as well as their wishes and claims for possible re-design for long-term usage. Interviews both before and after the field study were fully transcribed and analyzed.

With respect to the workshop sessions, the researcher who moderated the robot course sat beside the older adult participants at a table. Another researcher sat in the back of the participant group, controlling the robot with his computer and writing the field notes. In addition, every session was recorded by a camera in the back of the room. The videos helped us later to analyze the interaction and to reconfirm the field notes. The protocols and transcripts were analyzed by using a thematic analysis approach [6]. Based on the transcripts, researchers performed an inductive analysis of the data, coded it, and generated a series of main themes collaboratively. Coding discrepancies were discussed and eliminated by adding, editing or deleting themes, according to the outcome of the discussion.

Participants and Setting

The participants included in the study were six older adults who were residents of the care home (they will be called 'older adults' or 'residents' in the following study), four caregivers and the former manager of the care home (see table 1). For the study, we received the ethical approval by the ethical committee of the University. All participants received a detailed explanation of the study aims and protocol and signed informed consent documents about their participation.

All six older adults have been living in the care home since for some time. For the study, we chose persons that were not diagnosed with any type of dementia or MCI. Nevertheless, they had different impairments. Most participants were in need of visual and mobility assistance and one resident [Mr. V] was in need of a hearing aid. It turned out that even with his hearing aid he was unable to understand the voice of the robot well enough. For this reason, he dropped out of the study at an early stage and the study carried on with five female older adults participants.

ID	Name	Sex	Age	Role
1	Mrs. M	f	94	Care home resident
2	Mrs. T	f	84	Care home resident
3	Mrs. H	f	91	Care home resident
4	Mrs. E	f	88	Care home resident
5	Mrs. S	f	80	Care home resident
6	Mr. V	m	91	Care home resident*
7	Mr. H	m	62	Caregiver – Social Service
8	Mr. E	m	65	Former Manager
9	Mrs. B	f	48	Caregiver – Social Service
10	Mrs. A	f	35	Caregiver – Social Service
11	Mrs. W	f	62	Caregiver – Social Service

Table 1: List of participants (*dropped out of the study early).

The four caregivers and former manager of the care home attended the workshop sessions and had conversations with the older adults. During the workshop sessions they mostly sat in the background. They were also an important source of knowledge for us in understanding more about the context of the care home and the former exercising opportunities and habits of the residents.

SYSTEM OVERVIEW

Technical Infrastructure

Pepper is a humanoid robot that is 1.2 meters high and weighs 28 kilograms [40]. He is equipped with 2D and 3D cameras and has microphones as well as a tablet for human robot interaction. He has two arms that can separately be programmed to do movements. He is anchored on three rollers and can move around with them on firm ground. The robot can also move his head and hip, and the face looks a bit like a human child with very big blinking eyes (see figure 1).

Using microphones, the robot can interpret the spoken word of humans. However, the speech recognition algorithm is limited and often does not work correctly. This occurred particularly often in group settings, with several persons speaking at the same time or with persons not facing the robot while speaking. To overcome this technical limitation, we used a laptop and a smartphone that are connected to the robot and allow intervention on the operator's part, like in the Wizard of Oz approach [13, 35]. In case the speech recognition failed, the spoken words of the participants were manually entered in the laptop to provoke the desired reaction of the robot. Furthermore, a smartphone was used to make the robot say phrases that were not fixed parts of the program. For example, to motivate a specific person, the robot said things like *"come play with me, Mrs. E."* Although participants knew that the robot was partially controlled by the human researchers, they did not know at what point specific interventions took place. The programs on the robot were developed by our research team following a participatory design process. Together with the caregiver and the inhabitants of the care home we have thought of applications which could fit into this setting and have developed them. Through many iterations with them we arrived at the program which has been used in this study. Some parts of the program were as further adapted during the study, based on the needs and continuous feed-back of the users.

Robotic Intervention Course Setting and Concept

The course took place in a common area room of the care home that is usually used as a meeting room or cafeteria. Participants came for a ten-week period, twice a week at a fixed day/time. Two researchers, one working with the robot and computer, and another one facilitating the interaction with the users and explaining the interventions in case of difficulty, moderated it. The six older adults' participants sat in a semicircle in front of the robot as seen in Figure 1. This setting was used most of the time and only changed when a table was needed, while the caregivers took only part sporadically in the sessions.

A first general concept for the implementation of the intervention was developed based on an initial requirement analysis, interviews with residents and caregivers, and field observations in the care home.

Figure 1: Group setting with the Pepper Robot

The final concept consisted of three phases, which were run through one after the other: (1) *motivational phase*, (2) *physical activation*, and (3) *cognitive activation*.

Motivational Phase

The first phase focuses on slowly getting the participants used to Pepper. To ensure this, it starts with a music related game. Music has a high value in the life of the participating older adults. By using well-known applications and songs, the threshold of the older adults participant's engagement with Pepper was reduced. We chose applications in which the participants do not necessarily have to interact directly with Pepper but have the chance to get used to the robot. Apps such as a music quiz were used, where the residents get to listen to parts of a song and then have to guess the interpreter or the name of the group. In case a good answer was missing, Pepper helped with additional hints. If the speech-recognition misunderstood the answers, we typed in the answers in the program, like a Wizard of Oz.

Physical Phase

The main phase of the intervention is the physical phase. In this phase, Pepper's humanoid appearance is used to demonstrate exercises to the residents. These exercises are based on existing exercise programs like OTAGO and FAME that have proven effective for the health of elderly people in various studies, as well as exercises learned during the initial requirement analysis [2, 15]. Pepper guides and explains the exercises and act as an exercise trainer. Due to technical limitations, Pepper is not able to ensure the control and correct execution of the exercises and movements of the older adults. Pepper emphasizes regularly that the exercises should only be done as far as it feels good and feasible for the participants. Still we had to control the health condition of the participants during that phase, in case someone would get too exhausted, but the program was designed to use sub-maximal exercises. The phase itself is divided into four smaller parts: warm-up, flexibility, strength and cool-down, each lasting about 5 minutes; the parts have been started from the researcher on the laptop.

Cognitive Phase

The final phase of intervention activates the older adults cognitively with a playful approach. In order to present the participants a varied experience, different games have been used to maintain a rewarding character of this phase and to motivate them for their further participation in the project. The games are designed to promote memory, reaction or concentration. Furthermore, the games used were designed to encourage the participants to discuss in the group and reunite them as a group after the second phase. One of the games is a quiz in which the robot acts as moderator and the participants are separated into two groups to compete against each other while needing to discuss within each group. In this phase, it became necessary to move the robot from one person to the next.

FINDINGS

Using a thematic analysis approach, several themes emerged during the process: the context of individual and group-based Human-Robot-Interaction, positive social experiences and cooperation between the participants, attitudes and fears towards the system as well as social and ethical issues. In the following, these themes will be used to structure the results section, illustrating how the robotic-based system initiated a range of impacts amongst participants and their caregivers.

Getting engaged with the system

The workshops included different kinds of activities that aimed to support the physical and cognitive abilities of the participants by getting them engaged with the help of the robot. During the explorative workshop sessions, we could identify many factors how that had an influence on the participant's engagement.

Getting familiar with the system

An important aspect was that the older adults needed to get familiar with the different kinds of activities and the robot. For example, it was a recurrent pattern that the older adults were more restrained and insecure in the very first sessions, while they became more actively when they started to get used to the new setting and the robot. That could be observed e.g. in the activity 'song guessing'. While many of them were still quite reserved in the first session, they began to participate actively on their own from the second session onwards. As soon as Pepper started singing songs that they knew, they began to sing along quietly, to move back and forth slightly or to move their feet slightly to the music rhythm. The older adultss have guessed many of the songs that have been played by Pepper correctly and the activity encouraged an exchange about whether songs were known among the participants or not.

A similar observation was with another music-based activity. While the older adults needed some extra support by the researchers to start singing or moving rhythmically to the songs, this started to change already in the next two sessions, when the older adults at participants get familiar with the format of the activity. From the second week onwards, all physical exercises were executed as explained by the robot and could be embodied by it without further introduction or guidance of the researchers. After a few weeks, the additional videos for explaining lower limb movements were totally removed because the residents knew the expected exercises and were familiar with the tasks. Until then, then older adults' were very actively engaged and mainly focused on the robot during the execution of the exercises but also watched what others were doing when the robot explicitly praised individual participants.

Hence, the two examples also showed the importance of getting a better understanding of the needs of this particular group of participants. Thus, we noticed that the engagement was much higher when the older adults knew the song. Unknown songs did not lead to any movements except when the robot asked the participants explicitly to do specific movements along with the song and demonstrated this with his own movements. As we noticed at this point, we implemented a function whereby Pepper asked for their favorite song to optimize the selection for the next session. The robot 'promised' to practice new songs for the next session to make the sessions as varied as possible and to suit the group's taste.

Overall, the older adults gave us a positive feedback with regard to the study and told us that they felt positive about the interaction. Mrs. M. had the following thoughts about it: *"I liked it all. But in the beginning, you have to, you have to dig in first, of course."* Mrs. H. has made similar experiences: *"It's always been interesting. […] he was good to understand […].* She even told her son about it: *"I told my son about it, then I always said I would go back to the robot today. And then he said yes and laughed".* It was a pleasant course for her; she added that if not *"I wouldn't have come. Then I would have said I was sick."*

Dealing with accessibility issues

During the study, we noted that the participants had to deal with accessibility issues when interacting with the robot. The voice of the robot was a problem. One resident, as stated, left the group, since to his loss of hearing created difficulties. The ability to actively engage with Pepper varied across the participants. The video analysis revealed that some participants were more able than others to follow the instructions by Pepper and to imitate the movements he was demonstrating.

In the videos, it became evident that there were on occasion certain obstacles to common interactional quality. In the course of the different activities, and in some cases, Pepper's instructions had to be repeated several times, sometimes if the robot spoke too fast, or when the applications had to be described if they were too complex. However, it also appeared the residents become more used to Pepper's intonation after a couple of sessions and were thus better able to anticipate instructions.

Attitudes and Feelings towards the Robot

During our evaluation phase, we saw evidence of positive feedback between the older adults. Particularly in the first sessions the older adults showed considerable curiosity about the robot. They looked at him and touched him. They explored his hands and touched his head, sometimes as if you would pet a cat or a dog and started to explore on his reaction. The residents also talked with him, called his name and asked him simple questions like *“how are you today (video 3)”*. The participants were intent on very simple language and often spoke in a very friendly manner. The bodily and verbal reactions of the robot often made the participants smile and even laugh. The attitude towards Pepper was open-minded and rather curious. Thus, Mrs. SL. attended a session as a visitor to see Pepper once: *"I just want to see him and watch him (Pepper)"*.

However, the interactions did not always turn out that well, and sometimes even became a little awkward. Often the older adults asked complex questions like: *"It's nice that you're back again today. Are you happy too?"* In such situations, which the robot had not been programmed for, it answered e.g. *"Excuse me. I didn't understand that."* When the participants then repeated the question, the robot repeated its answer in exactly the same way. This often led to a certain resignation by the residents, because the limitations of the robot’s capabilities became evident. Hence, when we asked the participants how they feel in such situations and if this causes some frustrations on their side Mrs. S responded (in video 11) that it does not bother her at all. As with pets and children. We found that the participants were very patient with the robot. When an error occurred during the intervention. Mrs. S answered in a forgivingly way*: “Well, the little guy has still to learn”*.

There were examples of humor, when Pepper said something that they deemed inappropriate, phrases that did not fit the current social situation. In those cases, the interaction often drifted away from a focus on Pepper and became a shared interaction between the participants. In addition, when enjoyment was evident, it was manifest in joint laughter.

Nevertheless, in the interviews we discovered there was also some concern about the robot. Caregiver M. raised the question *“[...] what happens if he has a malfunction, is he then just driving towards people? [...] What could really happen if nobody is around?”* In addition, some participants of the study told us that they would not be very comfortable if the robot would drive around the care home all the time. For Mrs. H. it would feel like *“[...] the world would be an unsafe place.”* However, in time that feeling changed *“now it is ok, now I know him, but in the beginning, it was frightening.”*

Caregiver A. told us that a participant in the study talked with her about the robot and revealed to her *“She [a participant of the study] told me that it is like a friend to her now. She really has a lot of fun with it. In the beginning she was afraid of it, but now she has a lot of fun with it.”* Most overcame their fears over a short period. Mr. E. the former manager has observed a shift in the feelings towards the robot. *„I remember two years ago, when the Pepper came for the very first time, it was in our restaurant, she [a participant of the study] was sitting far away and looking at it. She said, “No, I have to go now.” She was afraid in the beginning. But now she is in your group and wants to be a permanent part of it.”*

In the interviews with all participants the process of appropriation came up several times. Caregiver M reports**:** *“[the participant] said at the beginning "I enjoyed it, but it also frightens me a little". Then I said, "What are you afraid of?" she says, "It's a machine, I know that. I am not stupid. And then the big eyes [...], but now, now it works, now I know him, [...] but in the beginning he scared me."*

Caregiver A had a similar experience: “*[...] I observed that the inhabitants become really familiar with it. [...] they really find such an access. In the beginning [they said] “hmm”, “what is that”, “what's new” but now I think the residents have accepted that quite well.* It is important to be there on a regular basis for a longer period of time, said caregiver B: “*[...] if there is a regularity behind it, if you not only come every 3 months or so, but if he is always present. [...] because the old people forget then. [...] So then again and again they must be occupied and shown.”* On the question whether the interaction with the robot was still difficult the participant Mrs. E. answered: *“No, now it is good”*.

In the interviews with the older adults, we asked if they see the robot as a creature. We received different answers to it: *“As a creature? No, then he would have to be able to walk. If he could walk, then yes “.* Another participant has a special focus on the fingers of the robot *“What I like about this chap, has always been these fingers. [...] I think they are beautiful.”* Mrs. M. sees something in the robot *“of course, he has his own character.”* However, not all the residents see it that way. Mrs. H. has a different opinion about it, which shows how he understand the robot: *“Isn’t it depending on how you adjust him?”*

Social and Ethical Issues

During the study time, some caregivers addressed the topic of the replacement of workforce. Especially for the caregivers this has been an important discussion point. Caregiver M. has a clear opinion about it *“He cannot replace us. We are 100% sure.”* This opinion results from the observation that *“[...] there always has to be someone around that pays attention.”* Moreover, from the feedback they receive from inhabitants of the care home, they are missing something: *“He lacks a heart, he lacks warmth.” “[...] the last thing we want is that there are only robots around and you [the caregiver] are not employed here anymore.”* Caregiver M see it more as a topic of the future “*I think in [...] five years something like this will exist. [...] it will be in a common area like here, with chairs and the robot in the middle of it. The robot will be activated and then will occupy the participants for one hour or so, I’m convinced that in a closed room something like this is possible.”*

For Mr. E., the former manager of the care home, there will have to be a symbiotic relationship. He sees two groups in the care home *"[...] one group that doesn't want to interact with the robot, they don't see it as something serious and then there is a group that like to do so."*

He has seen a shift in the concerns of the caregiver "*[...] in the beginning there have been fears, also from the workers [...] [they knew] robots in the economic system replace them in workplaces and that's what they thought. [...] They now have learned what he [the robot] can do. Now the caregivers are not afraid anymore and the social service is not afraid anymore, they know that there needs to be someone who controls the robot, who takes care of him. And that's where I see the problem, you need trained staff and the people that are nowadays in the social service are not comfortable with technology."*

On the question of whether the course would have been different if a real person had conducted it Mrs. H. answered, *"I don't know. Maybe the person would have spoken more."* Mrs. M. has a similar opinion *"[...] you cannot compare it to a human."* The participants of the study do not see the robot as a replacement for the human care workers. Mrs. T. has a clear opinion about it *"It is better, when people do it."* Mrs. S. confirms this aspect *"I mean a person is something different. We all know that."* She sees different kind of applications for the robot that could be useful *"He can do other things, like tell you what you are looking for in the shop or show you the way or reach a hand. Nevertheless, in the care he will never be used. If it would come to it, I would be irritated. That he should wash me, or something, no! [...] It is a weird idea. I cannot become comfortable with that idea. Nevertheless, he [the root] could wake me up in the morning, he could come here [in her room]. That I would not mind. [...] Playing with him, that would be another option."* Mr. H also sees alternative tasks for the robot, for instance, "*He could read from the newspaper, if someone has difficulties to read by himself."* But there are also limits, as Mrs. A. points out *"I cannot imagine a robot during a church mass"*.

It was also noticeable that the role of the human actors changed in the course of the sessions. Early on, the caregivers had a larger presence, but their participation decreased after the third session, visiting only sporadically to check the attendance and to see if everything was working satisfactorily. In effect, this was a function of increased trust, and the caregivers were able to use the time for other tasks, e.g. to speak with or help other residents outside the room. Hence, the older adults reported that they enjoyed the time with the researchers. Mrs. E. said in one session: *"I think it's nice that young people are doing this to us old people today. I really find that beautiful"*. Thus, it might be the case that personal contact with the older adults is still an important point in facilitating motivation and engagement in the sessions.

DISCUSSION

In the following, we will discuss the findings of the study we conducted and provide lessons learned as well as limitations.

Accessibility of the Robotic System

An important factor in getting the participants of the study used to the robot was to establish a certain routine and to include persons that they knew. These results are in line with the results of Kidd [30] who found that the participation of older adults increases when including caregivers. Our study took place for a period of ten weeks and has always been at the same time on the same two days of the week. The residents knew exactly when the time for this course would be and even waited for it. One caregiver reported us that this regularity has helped the older adults to get used to it and to build up trust. To conduct this research in a living lab as described by Chi [11], it was important to build up this level of trust. Furthermore, the residents were asked frequently what they liked or disliked about a function of the robot. This participatory design approach is consistent with research in other care homes, even without the use of robots [37]. Having said that, we sometimes found that the older adults did not always express their likes and dislikes directly, tending instead to talk about, for instance, music and other interests. This was scarcely a problem since understanding participants' interests enabled us to make informed decisions about the robot intervention programs, which we adjusted continuously during the study. The robot and its behaviors became something that the older adults helped to develop and represented their ideas of how it should work. Again, this is consistent with the work of Lee [32].

Nevertheless, for all the participants, it was not always easy to predict what the robot was doing. Its actions often remained unclear to them. The robot was sometimes moving with his hands or moving around in the room in ways that participants found difficult to account for. These features are programmed and are intended to make pepper more human-like, but when the *reasons* for a certain behavior are opaque, users are reminded of its robotic nature. This barrier is difficult to overcome. Judgements concerning how human-like a robot should be do not depend on physical movement alone. Movements have to be interpretable. Interactional quality, in our view, depends precisely on the degree to which this is the case. Previous studies have shown that humanoid design often results in a higher degree of 'likability' [19] but arguably interpretability is equally important.

Attitudes related to the Robot and Course Setting

The findings of our study show that Pepper can quickly become familiar to the residents of a care home. In the beginning, the caregiver and older adults reported that they were reluctant to use, and sometimes even afraid of, the robot. They did not know how the robot worked and sudden movements or situations in which the robot was driving towards one person frightened them. However, these feeling changed quickly when they got to know the robot and got a feeling for how the robot worked. Some residents even called him by name or petted his head. simple and friendly interactions reminded us somewhat of interaction with very young children or even pets and is consistent with previous studies which demonstrate a changing orientation to technically limited applications [28, 30, 39]. Some of the older adults told their relatives about the robot and discussed it with them. Others talked with residents that did not take part in the study about the sessions and the robot. These two examples show that the robot became an object that the participants liked to talk about and was something that they thought about. Nevertheless, the robot remains something that they did not fully understand. They saw it as a machine, but as a complex one that was somewhat opaque to them. The things the robot did were often surprising for them. One of the reasons for this might have been because they did not have the possibility to customize the applications of the robot which made inferring the reasons for its actions more difficult. As discussed by Pino it is crucial to consider the needs and expectations of the caregivers and older adults [41]. Therefore, the possibility for caregivers to individualize and change the applications is likely to be productive. The end-user development method described by Liebermann et al. [33] could enhance the interactivity and transparency of such a system, since the caregivers and care home residents know their needs best. This extension would possibly have the potential to overcome the transparency otherwise lacking and might result in a deeper understanding and extended use of such a system.

Social consequences

The study has shown that the residents of the care home in which we tested the robotic system are willing to receive guidance through a robotic support system together with a human. They follow the commands from the robot and imitate the movements the robot is showing them. The robot was able to get attention from the residents for the duration of a course, but it was not able to function completely autonomously during that time. The aid of humans was needed by the robot and desired by the participants to make the course work smoothly. This lack of automation might lead to an expectation mismatch, as argued by Breazeal [7]. The robot with his humanoid appearance looks like if he could work autonomously, but in reality, needs the help of a human to work in complex social situations.

Some major constraints prevent the solitary use of such a robotic system in this setting. For one, even though the applications were designed without the intention to use the "Wizard of Oz" method [13, 35], the robot was not always capable of understanding and responding to the voices of the older adults correctly. It became necessary to type the answers of the residents into the program via a smartphone in real-time. Secondly, the robot does not know the position it has in a room. That makes it difficult to move from one person to the next. In the game sessions it was necessary to be in front of the robot. The moderator had to move the robot from one participant to the next participant so that they could read or see what was shown on the tablet. This problem might be solved in the near future, since there are research groups working on this [20]. Nevertheless, this remains one of the challenges in this study. Thirdly, the older adults were willing to engage in the interaction but sometimes situations arose, in which they have shown themselves to be reluctant in trying out applications. Trying things out was often the result of acts of persuasion by a moderator, or after watching others accomplish tasks. In many cases, they changed their mind after a first interaction and were happy to use the application at the second time and until the end of the study. It seems that the personal connection between the participants and the caregivers or researchers played a role in persuading them use the system.

The last point concerns the norms and values of the residents, who were quite clear that they did not see the replacement of human caregivers by robots as feasible, likely or desirable. There was, however, acceptance of additional services, like this course, which supplement human provision. Robot intervention, in short, was seen to be desirable, when it enhanced the level of activities in the care home.

Ethical Issues

Humanoid robots are often depicted in a language which humanizes. They have often been referred to as "he" or "she" and given names. Even in natural sciences, humans sometimes use biomorphic descriptions [14]. Humanoid robots specifically designed for interaction with humans are usually intended to remind us of living beings. An example from the animal world is the Paro robot, whose appearance is reminiscent of a seal. Paro was specially developed for persons with dementia. It interacts with people in a simple way, for example by reacting to physical stimuli or demanding to be touched [45, 51]. Robots of this type are sometimes referred to as emotional robots [3]. Their use is aimed at satisfying psychological needs, which include, for example, the need for society and the need for commitment [3].

Pepper is a humanoid robot, its shape being inspired by a human child's appearance and it is able to move some parts of his body in a manner which apes human movement. Some early results have shown that it can enhances pleasure for people living in a care home [48]. These results are in line with the findings of our study. Pepper was accepted as a training instructor and guided them through different physical and cognitive activities largely to their satisfaction. Interviews with the participants made it clear, however, that at all time they knew that they are interacting with a machine. The humanoid design, while having some affective consequences, did not in itself enable participants to draw inferences about behavior in the way that they would with other humans. Robot behavior, it seems, remains partially unaccountable, perhaps because of the absence of 'repair' possibilities. The users are unable to adapt the system by themselves and therefore have a reduced understanding of how the system works. Such possibilities can, of course, be introduced with more sophisticated prototypes.

Another ethical challenge that arose during our study, was the lack of sustainability. With this specific group of older adults, we conducted the study during a 10-week period. Further we did some interviews before and some after this period, but nothing substantial happened after that. The study was implemented as an activity for the inhabitants of the care home. Usually these activities are designed to be offered for an indefinite time and only terminate if there are not enough people interested or other circumstances makes it necessary. An exercise and gaming course like we did with the robot is something common in the care home. They are offered by the caregivers or by volunteers. During our study we built relations with the older adults and got to know and like each other. Further the residents got used to doing such an activity twice a week. Even though we included the caregiver in the process, it was not possible to maintain the activity after the end of the study. While this might be normal for research projects, it is unusual for care homes to participate in such studies and left them with a gap to fill. In passing, we should note that a similar situation arises in respect of relations with researchers who built trustful relationships which could not, nevertheless, be maintained indefinitely. On the other hand, the care home could also offer other courses -without robot support- in which the older adults could train and perform physical, cognitive and social activities together with other residents and the well-known care staff.

Lessons Learned

During this study, we learned a few lessons that we believe might also help other researchers and developers to do further work in this area. Eight lessons seem significant to us.

(1) The older adults enjoyed the interaction with the robot and engaged with the system during the 60-minute sessions. During the course, the participants accepted the robot as a training guide. They were willing to receive guidance from the robot and followed its instructions in physical training and gaming situations, although human moderation was occasionally necessary.

(2) The older adults made it clear that they do not want robots to replace caregivers. They like the interaction with the robot, but it is something additional for them. Caregivers can accept such a robot as a support tool for specific tasks of activation, but not for real, intimate, or medical care work. The work that could be done by the robot belongs to other support services.

(3) Having a group setting has had a significant impact on the engagement with the robot. Often situations arose in which individual older adults did not know what to do, because they did not understand the robot completely. In these situations, they relied on each other to make sense of robot behaviors. Furthermore, the group often laughed together, something that would probably not have happened if they were alone, implying that social bonds played an important role.

(4) Including the caregivers of the care home in the course setting and, in the development, has enhanced the trust of the participants in the study and in the robot. We believe that without that, the engagement of the participants would have been significantly lower.

(5) The robot Pepper showed several technical limitations for older adults that have resulted in a reduced accessibility for them. The problems are in regard to the speech recognition, navigation and the touchscreen. The limitations made it necessary for some control of the robot by a moderator or by wizard of oz.

(6) Participatory design and the living lab approach is an essential prerequisite for understanding the needs, attitudes and practices of the older adult participants. We gained significant insights into how such a robotic system should be designed and what purposes it might serve integrated in this specific environment.

(7) For the residents and the caregivers, the robot and its algorithms are not transparent. For them the robot is a complex technical device that is not under their control and where accounting for its actions is not always straightforward. The end-user development method which was reported by [34] could possibly fill this gap in the future.

(8) A moderating person is specifically needed to facilitate the interaction with the robot; sometimes the functionality of the applications need to be explained and the robot needs to be moved from one place to the other or someone is needed to motivate the participants to interact with the system.

Limitations

The participants and the researcher have built a close relation to each other. Some of the participants were in tears at the end of the study when the researchers left the care home. Therefore, it could be that some of the positive effects cannot be solely attributed to the interaction with the robot. Some of the reactions might have been triggered by a kind of 'Hawthorne' effect [36].

From a technical point of view, we had some limitations regarding some malfunctions of the robot. The user experience might have been disturbed by this. It sometimes happened that the robot applications did not load in the timeframe that was intended or that the sensitivity of the touchscreen was unsatisfactory. These technical issues might have affected the overall experience.

Despite the careful selection of the participants of the study, a general transfer of the findings to a broader population cannot easily be made. The sample size and diversity of the participants is not significant enough for this. The findings should be seen as preliminary. The lessons learned are valid for our group of participants and the specific setting. It remains unclear if the results could be applied for other groups or settings. Further research is clearly necessary.

CONCLUSIONS

We observed that the older adult participants of the study are willing to receive guidance from a robot during a physical and cognitive activation course twice a week over a period of ten weeks. This is a role that typically has been filled by caregivers or volunteers. Nevertheless, the degree of automation of such a system is far from being complete without guidance from a human, and the participants stated that they feel more comfortable in a group setting, together with human care staff that they know personally. Therefore, humanoid robots cannot -at least at present- be something that replaces caregivers, and it remains clear that the acceptance for this is low. Nevertheless, carefully designed humanoid robots like Pepper with the designed software from us, constitute a valuable diversion and entertainment support tool for serious gaming and for prevention goals like physical or cognitive activation in elderly care. Such preventive activities are demanded every day in elderly care, and the lack of trained staff is problematic, especially in face of the demographic transition and associated consequences for future care systems. Furthermore, such a robotic system, if appropriately designed and put carefully into real-life practice, can have positive impacts on some of the care home inhabitants, and thus serve as a support tool for gaining more individual human-human time in such a restricted care setting, since this would give the caregivers more time to interact with persons in need of care.

For the future and as an outlook from this work, we would need to investigate larger numbers of participants in different settings. But first, human robot interaction designers need to enable more functionality, transparency and adaptability of such robot solutions, in order to make that feasible in a broader range of different care home settings.

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