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Designing meaningful, beneficial and positive human robot interactions with older adults for increased wellbeing during care activities

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Abstract. This research explores the benefits of introducing humanoid robots into different active ageing and aged care settings. We visited active ageing groups with a focus on dementia, knitting and a men's shed. We also took the robot to a residential care home to especially set up events. Exploring assumptions of older adults and staff about the capabilities, purpose and intelligence of the robot played a large role in understanding how robots should be introduced. We found that implementation and interactions need to be carefully crafted in advance for developing trust and interest, and for creating a shift in feelings of control in older adults as well as staff. Benefits, meaning and comfortable interactions are created through building on existing skills, familiarity and past experiences. When done successfully, older adults were seen to engage in playful and empowering ways, enjoying the interactions with both the robot and the wider group with positive effects beyond the time the actual interactions took place. The article summarizes the findings across the different settings. It presents recommendations for introducing older adults to interact with humanoid robots, supported by motivational goal modelling and technology probe techniques. We consider our research in group settings to be relevant for the wider acceptance of the use of robots. We discuss that researchers should set clear goals for the interactions between the robot and older adults and gradually introduce the technology to older adults in a participatory way in group settings before attempting one-on-one scenarios with them.

Keywords: Human-robot interaction, Humanoid robots, Older adults, Technology engagement, Dementia, Designing interactions, Motivational models, Technology probes

1.1 Introduction

There are often fears and negative assumptions around robot use. Despite this, research articles in social robotics argue that older adults - particularly when socially isolated - can benefit from interactions with humanoid robots [1]. However, scenarios on how to introduce, tailor the robot's functions, and establish benefits of robot use over time is scarce. Through our study of humanoid robots in groups of older adults, we found that discovering beneficial and engaging use scenarios takes time. Implementation needs to be conducted with care challenging the cost-benefit for using robots in one-to-one settings. We suggest that the benefits, emotions and user goals need to be better understood when interacting with humanoid robots before introducing them widely to older adults without expectations on how they should be used. In particular, we discuss emotions arising from and goals for human-robot interactions. We base our approach on Human-Computer Interaction (HCI) literature on tools and techniques for technology design to make recommendations for designing human-robot interaction in care settings for older adults to increase their wellbeing.

The Nao robot has been used successfully with young children in rehabilitation [2] as well as in physical exercise at schools [3] showing positive effects on children's and emotional wellbeing [4]. We investigate the benefits for care groups of older people – some of them living with dementia. Part of our rationale for the investigation is the high demand on carers and the need for new and different forms of stimulation [5]. Research is needed to bridge part of the credibility gap between the extremely positive expectations and claimed potential for the role of robots portrayed as social companions [6] and negative attitudes [7]. We aim to critically explore and discuss the benefits of human-robot interaction for older adults in care settings.

Researchers face many challenges when investigating the use of robots in social situations, some of these being of an ethical nature concerning the acceptance of people and understanding how the relationship that older adults establish with the robot can benefit their social interactions (e.g. [8]). Humanoid robots are not off-the-shelf products that can be turned on and seamlessly used. Introducing a robot in a social context makes the robot part of the social situation, where people have different capabilities and where there are contextual circumstances that may be specific to the user group [9]. Hence, there is a need to consider the personal preferences, capabilities and circumstances of the user groups when designing interactions with robots. In order to explore the benefits of the robots we have to prepare interactions carefully in complementing the expertise of different disciplines including human-robot interaction (HRI), human-computer interaction (HCI), software engineering (SE), design and psychology. We look at it from a social relationship point of view.

1.2 Social Robotics

Social robotics is an emerging field (e.g. [3,10,11]). Socially assistive robots and their acceptability and success have been investigated in residential care settings [12] and their ability to support the process of care giving to increase well-being of older adults is promising [13]. In particular companion robots have been promoted to address social isolation - for a comprehensive overview on companion robots refer to Robinson et al [14]. Beneficial scenarios and goals around socializing are subtle, ill defined and expectations differ from user to user. This is where our research is located. One of the best known robots is the PARO seal companion; it has been increasingly successful among elderly living in nursing homes [1]. While this robotic technology has been praised, there has also been criticism claiming that the PARO is patronizing and childish [5,15]. Sharkey [16] discusses the pros and cons of HRI in elderly care and its impact on human dignity. She points to the risk of "developing robotic 'solutions' to the problems of aging that result in a reduced rather than improved quality of life for older people.” (p.63). One of the important factors she points out is the possibility for the older person of having a choice of interaction. Similarly, Sharkey and Sharkey [17] discuss ethical considerations of robot care for the elderly. The main ethical concerns they raise include reduction of human contact (also discussed by Sparrow & Sparrow [18]), loss of control, loss of privacy, loss of personal liberty, deception and infantilization. Some of these concerns are summarized by Turkle [19] with the term ‘inauthentic relationships’.

We consider the introduction of a robot into a group setting the ideal environment to avoid these pitfalls and investigate the benefits of HRI in an ethical manner. In a group the robot is not taking away any opportunities for human interaction and leaves the control to the individuals whether they want to interact or not. Previous works have found that group settings have a significant impact on the engagement with the robot [20] and that robots encourage social interaction in a group [21].

The Nao Robot

This research looks specifically into the role of humanoid robots and their benefits for group activities of older people some of them living with dementia. We used NAO robots (referred to hereafter as Nao), which are autonomous and programmable humanoid robots that were created and developed by Aldebaran Robotics (rebranded as SoftBank). They are 58 centimeters tall and weigh roughly 4.3 kilograms. The name Nao is derived from the Romanization of the Mandarin Chinese word for ‘brain’ (‘nǎo’), and the English word ‘now’. Development of these robots first began in 2004, however, the first public release of the robots was in 2008. Since then, there have been five release versions of Nao, with the one used for this research being released in 2014. Development began under the name Project Nao; the project was started to produce an intelligent humanoid robot for the consumer market. Currently Nao is largely used as part of education, research or by developers. While this robot now is not modern anymore and many new robots (such as Pepper and Valkyrie) have emerged on the market and created interest in the robot (research) community, we have continued using the same Nao. We consider the continuation important to investigate key benefits for users beyond new technical features and technical specs. In order to do this and push towards robot human interactions that actually increase wellbeing we think it is important to investigate the same robot and build on growing knowledge and programs. It is noteworthy that this has caused some challenges in updating software and backwards compatibility once the focus of interest by the wider research community was not on the Nao robot anymore. This is also a consideration in terms of how we plan technology development if we aim to render it a true consumer product offered to aged care providers.

The need for meaningful activities and a holistic approach

There have been many robots in the past that have failed for social purposes because people simply did not feel comfortable in their presence. The small Nao robot, while being humanoid but not too similar to a human being and having a wide range of functions, is promising to be used as social robot. Here we are particularly interested in social interaction between four groups of older adults in care environments. We took the robot to a residential care home and visited three active ageing groups with a focus on, knitting, a men's shed, and one specifically focusing on dementia. It can be a challenge to keep people living with dementia occupied with engaging activities due to their often short attention span and declining mental capacity. Humanoid robots provide a more sophisticated presence – an important aspect in social interaction [22] – which we expect to be helpful to increase engagement. Another advantage of the robot was that we do not have to take into account input devices which can be problematic due to limitations of older users' abilities such as sensory and motor impairments or simply a hesitation to touch new technology. However, older people do have diverse needs and interests depending on their life experiences and circumstances. Meaningful activities that enhance those people's life and in addition support the care of activity groups and carers are crucial [23]. In order to be successful in providing stimulating activities including a robot, we need to understand the situation of these specific user groups to set realistic goals. We need to design for the whole socio-technical system and not merely rely on the functionality of the robot. This is in accordance with Young et al. [24] calling for a holistic approach to evaluate interactions with robots, which also include perspectives on social mechanics and social structures.

1.3 Method: Learning from HCI approaches for exploring social HRI

Here we describe the approaches we applied to better understand the potential of humanoid robots contributing to older adults' wellbeing in care settings. Breazeal et al. [10] advocate for understanding multiple dimensions (cognitive, affective, physical, social) to design robots that can be beneficial in the daily lives of people. We concur and suggest in addition that it is not only about the design of the robot but its application and designing beneficial use scenarios. Breazeal et al [10] further suggest that successful design of robots requires a multidisciplinary approach. The team that conducted the present research consisted of a digital media designer, a robot engineer, a user-centered design specialist, a psychologist and a software engineer. The shared interest of all team members is in the design of meaningful technologies for older adults. Their common trans-disciplinary field is Human-computer Interaction (HCI). HCI has traditionally been multidisciplinary and its research and design approaches very much user focused on achieving benefits in technology use for very specific user groups.

Here we build in our applied approach on the HCI knowledge of participatory design [25,26] and mutual learning [27], technology probes [28], goal modelling with a focus on emotions [29] and the overarching concept of situated action [9].

Situated action

From a participatory perspective, we recognize that older adults and prospective users of the Nao robot in our research can share their experiential knowledge about what they want for their life [30], which is grounded in their knowledge about the context they are immersed in [25]. However, they do not have any expertise or experience in robots and many of them have little if any experience with the use of any modern technology. As they do not know anything about the robot and the robot does not know anything about them, we need an approach to bridge these gaps over time. Hence at the beginning we were in a situation where we would bring along the robot and observe what actually happened between the group members and the robot immersed in the different care contexts. This concept of situated activities has been described in detail by Lucy Suchman [9]. Suchman's concepts of situated action [9] and thinking about technologies not as 'smart' but located in a social and material context are helpful when thinking about interactive technologies in particularly social robots to create beneficial use scenarios. To be true to Suchman's notion of situated action [9] and acknowledging that the older adults and staff are the experts of their life context, we decided to follow an approach informed by the principles of participatory design that provides them the tools to share their knowledge with the research team [31,32].

Participatory design and mutual learning

At the core of participatory design is the "democratic participation and empowerment" of the user [33]. Ertner et al. [34] conclude from a substantial review of participatory design practices to empower users is not only a moral, but also a complex and challenging undertaking. In our case the challenge was that we needed to give user groups of older people who had no experience with robots a strong voice and find out how their use would fit into their life and routines. This meant that participatory design was a mechanism, getting knowledge from participants as they benefit from interactions with researchers and with the technology. This approach is closely related to the concept of "mutual learning": "That is, designers learn from the participants about their experiences, practices and situations, and participants learn from the designers about potential technological options and how these can be provided. Everyone involved learns more about technology design." [27]. However, this is not a conventional application of participatory design to develop a product, but of an existing product to explore its use. Sanders et al [35] suggest due to the growing field of participatory design and every project being unique that "it is necessary to decide which design approach(es), methods, tools and techniques to use in a specific project". We combined participatory design with technology probes and motivational goal modelling describing the reasons below.

Technology probes

Technology probes are well suited to participatory approaches to design as they are able to explore imaginative, investigative, emotional, discursive, reactive, disruptive, reflective, and playful participation [36]. Technology probes [28] support the design of technology in understanding its use in the everyday context. Technology probes are prototype-like devices that are specifically designed to collect participant data and motivate redesign [37]. They are particularly suitable for vulnerable users [38]. Through their ability to capture the nuanced aspects of everyday life in a care setting, the results of technology probe analysis offer a useful starting point for programming meaningful interaction scenarios for older adults. Information and story generation are two important benefits that we see in the use of probes as participatory artefacts. That way the probe technologies become bridging elements or "information vessels" [39] that allow the social activities in the home to permeate discussions of field researchers and engineers responsible for programming the robot. In our project the direct participation of the older adults occurred via the Nao robot. The robot as technology probe meant to learn how interactions should be designed in carefully introducing it to the groups in different settings, iteratively adding new use scenarios based on the data of previous visits and the feedback received. The technology probe results can be re-expressed in terms of the motivational models which are well understood by the engineer programming the robot.

Motivational goal models and technology probes

Motivational goal models are particularly suitable to be combined with technology probes in field studies [40]. Firstly, we see motivational goal models as a suitable way to express field data between visits with a focus on what people want and what their motivations are for interacting with technology – here the robot. Data gathered using probes are fragmentary and unstructured, the process of translation from field data to the abstract generalization required to program the robot is challenging. A process of combining technology probe data collection and motivational goal models allows us to talk about intangible outcomes; such as that arising from fieldwork which can be surprising, complex, but subtle. The models provide a place where abstract interaction data and in particular those concerned with emotions can be represented and discussed among researchers [40,41]. There are three goal categories: What a technology should do, how it should be and how it should feel (do/be feel Method according to Sterling et al. [29]). Secondly, motivational models are part of a development methodology and can be combined with motivational scenarios, roles and domain models [42], each of them describing and providing context of the domain, which is important because contextual information offered by technology probes is often lost after data analysis. A key element of the goal models constitutes user emotions and when discussing goals from visit to visit we paid increasingly attention to the emotions groups members felt and what made them comfortable in terms of emotions the Nao robot seemed to express.

Understanding emotions

Interpreting emotional body language of robots is increasingly important and subject to recent human-robot research (e.g. [43,44]). Breazeal et al. [10] suggest that users of robots need to engage not only on a cognitive level, but on an emotional level to be beneficial during interactions. This follows a more general trend in the relevance of emotions to technology design over the last two decades. For example, Boehner et al. [45,46] introduce a model for emotions in affective computing. They model emotions as interactions: they are dynamic, culturally mediated and socially constructed. This means that emotions are not discrete, and they are experienced by people depending on their own situation. Therefore, they propose that technologies interpret emotions through interactions instead of detecting and categorizing them. This is similar to the construction of emotional goals, one of the three goals categories in the above mentioned motivational goal models [29]. It is the emotional goals that in this method guide the development and evaluation of use scenarios.

Iterative visits in the field and data collection

Our multidisciplinary research investigated the integration of the humanoid Nao robot into care group settings of older adults through iterative visits in the respective locations that the groups met (situated research). During every visit the values of participatory design were applied and attention paid to the context of each group and its individuals. A range of activities or interaction modes were investigated including demos, exercise and dancing. A mixed method approach consisting of interviews, observation, researcher notes, video analysis, and interaction studies were applied to evaluate the level of engagement and how the groups reacted to and interacted with the robot. The project has ethics approval of the Swinburne University Human Research Ethics Committee (SUHREC #2012/305). After the visits the team members discussed their observations and notes in debriefing sessions and defined goals for the next visit based on strong themes coming up. This is comparable to the procedure of reflexive practice described by Ertner et al. [34]. The identified goals can be systematically organized in motivational goal models (a practice that has been developed and formalized by some of the authors). We suggest motivational goal modelling as an approach for future implementations and as a framework for planning the introduction of robots for social purposes in care settings. In the findings we do not only discuss what it means to implement a robot as a technology in a care setting, but the benefits created of the robot in the groups in regards to wellbeing, social relationships and individual benefits over time.

1.4 Four case studies using the Nao in the field

Preparing considerations

Major consideration is needed when the Nao robot is applied in the field. This is especially true when the Nao robot is interacting with people unfamiliar with robots. These kinds of interactions include many unpredictable factors. This was the first time the engineer, while having worked with robots for years, used the Nao robot in the field. Hence, the overarching objective of this project of conducting research on designing and preparing interactions that provide a real benefit for the human side of interaction – in this case four groups of older adults in varying care situations – was new terrain for the robot engineer. Our iterative research unveiled that the standard settings of the NAO robot were not suitable for the intended audiences and their context in order to engage them. Everything the robot did was discussed ahead of the onsite visits, and the interactions were carefully planned, designed, and took the whole team to prepare.

Interaction stages

Across all case studies we used the Nao robot in different ways adopting interactions to the specific groups according to what we had learnt about their needs and interests. However, there were similar stages of interactions, analogous to a play with several acts. There was always an introductory part, a demo and a meet and greet as part of the first encounter with the robot. These stages got tailored to each group over time. They included (i) introduction of the robot, (ii) demos, (iii) meet and greets (Wizard of Oz), (iv) Joint activities robot and group (physical exercise, dancing, fashion show). For a more detailed summary refer to Pedell et al. [47].

Overview

When we brought the robot for the first time to the active ageing group at a local council "it" was met with a lot of skepticism. People had no idea what a robot could do, and many (including the staff) were uncomfortable and had a negative perception of robots. In this first encounter we very much showed off what the robot could do and answered questions following a Wizard of Oz approach. We learnt that in order to be beneficial – and with a higher aim to be good for wellbeing we had to better integrate the robot into the lives of older people and create some purpose. Hence the second time we went to the council's knitting group asking whether they could help creating some clothes for the robot to maybe come up with a theatre show to have a concrete purpose. Also, we named the robot Kira, as we wanted to give her more of an identity for the introduction, and making it easier to refer to "her". It is noteworthy to say that staff from the first group then informed us that the group had kept talking about the robot all afternoon and we should go back there, too.

Case study 1: Active ageing knitting group

The knitting group created a boost of understanding for the project and approach. While the group was doubtful why a robot would need some clothes, they were ready to help as is their disposition when asked to apply their knitting and crocheting skills. The act of measuring was a key part of the process. The robot sitting in the middle of the table was first looked at, then cautiously waved at like she was a puppy or a little child in a cautious cute, half hand wave, but then became subject to detailed measuring. It was obvious that the group members started to get comfortable seeing the robot as just another "creature" in the need of some tailored clothing (they had done this many times for humans every age and size, penguins rescued from an oil spill and some general purposeful household crafting) and settled into a routine for a job to be done. At this moment the older adults truly started to interact with the robot moving from the role of spectator watching a robot demo to actor. Kira was pushed, prodded and professionally measured (figure 1 left). Suggestions to send them a printed version of the robot specification with mm detailed measurements was just waved away. The researchers could also see that the specification document would not have given the right measurements as there were no circumference measures of the chest, hip, head and upper versus lower arm. Once happy to have acquired the necessary information in swift motions and all noted down and enquiring what exact clothes we had in mind (which we just left to them) we were sent on our way. Only a few weeks later we were told that a set of clothes had been prepared and the crafting members were keen to see the clothes on the robot.

Figure 1 Measuring (left) and fashion show (right)

Due to technical issues with Kira, an alternate Nao robot was taken back to the knitting group for fitting. When this new Nao was introduced to the knitting group, there was a round of laughter that set the tone for the rest of the visit. The new robot was called Max. The clothes crafted by the knitting group were for Kira "herself" and were mainly female oriented, baby pinks, pastel blues, floral headbands and frilly skirts. The older adults found it amusing that a "boy" was trying on Kira's clothing. The only visible difference between Kira and Max was their color, one was blue and the other was orange. This, and the introduction to Max helping with the fitting for the day allowed the older adults to meet "someone" new. They talked to Max and explained things like "now this was for Kira but let's try it on!". Everyone was eager to see their handcrafted clothing on Max. There was no competition among the group, just excitement and a great deal of lively conversation. The Nao programmer and robot researcher faded into the background, and the older adults had seamlessly become the facilitators of the activity. Max was their dress up doll, and they took it amongst themselves to drive the fitting, taking turns and stepping back to assess their craft, making comments on fit, style, sizing, and overall look.

We decided to organize a fashion show in the dementia respite group (first group). Kira was parading up and down the floor with the different sets of clothes on to everyone's amusement (figure 1 right). The engineer had programmed a cat walk movement into the robot. The invited creators of the clothes were standing on the side commenting on fit, realizing that some clothes would slip more on the smooth surface than on other "creatures" or be in the way or get jammed in the joints when the robot was walking or waving its arms. One outfit with a little skirt, tied top and head band became the favorite and most used outfit as it enabled free movement and had a perfect fit (see figure 2 left). Woolen caps were used in moderation as we had to learn that robots actually lose 100% of their heat over the head and prevented ventilation resulting in shut down caused through overheating (see figure 2 right). A story often told taking off the hat at the beginning of a visit. The creators of the crafted clothes got a lot of praise to their great pleasure and enjoyed the applause for every new outfit. The wardrobe of clothes since became a fixed element of all of Kira's outings reinforcing her persona. With a dressed Kira we never again encountered the same level of hesitation and fear at first contacts with groups as we had before.

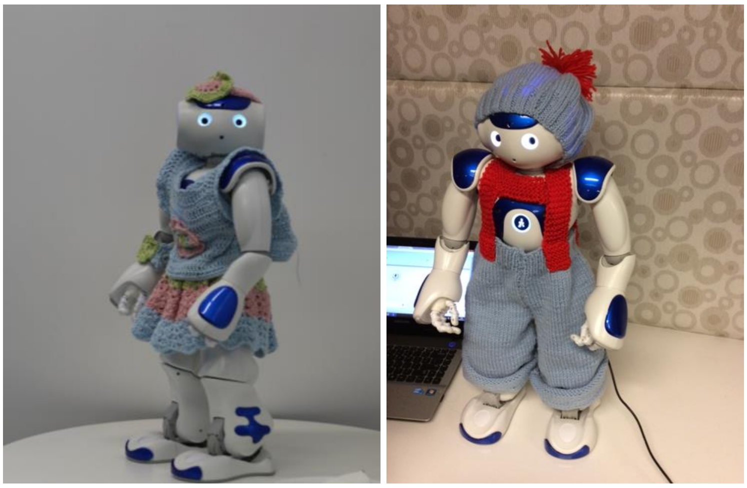

Figure 2 Kira's favorite outfit for exercise (left) and with her woolen hat (right)

Case study 2: Dementia respite care as part of the active ageing program

Having learnt the importance of tying robot interaction into enjoyable, familiar and skillful activities we went back to the first group. Within dementia care, music therapy is used to control mood and problem behaviors, and even reduce the need for some pharmacological and physical treatments [48]. Music has been demonstrated to provide meaningful engagement for people living with dementia [49]. There is growing evidence to demonstrate musical memory's robustness, which is often spared by the disease [50]. Hence, music related activities are promising, as music can be played by the Nao robot. Also mobility is important in dementia care. Robots have been suggested to deliver interventions to prevent physical decline for the elderly as such activities can be programmed and help to remain independent [14]. In this regard we saw opportunities for the robot to contribute to wellbeing and health in a preventative and enjoyable way.

First we did need to understand the situation of the group and their preferences better to leverage opportunities for physical activities and music. Physical exercise and dancing were activities all group members would participate in at the same time and was also something they clearly enjoyed. Kira was programmed to complete a set of 16 different movements regularly conducted physical exercises, and one song was chosen for dancing. "Give Me a Home Among the Gumtrees" by John Williamson was recommended by the carers as less mobile group members would sing along. The engineer programmed the robot based on a manual of the exercises created by the council with photos of the exercises and descriptions. He had to work from the carers' exercise schedule and pre-plan the structure, order, and timing of the interactions. The dance was created through a video taken of one of the staff members singing and dancing along to the song. At the next visit Kira introduced herself as someone who also needed exercise and wanted to join in as she felt a bit stiff.

As the exercises were done sitting in a circle, it was decided that the robot should also sit on a little stool and put on a table for better visibility (see figure 3). Maintaining stability in the sitting position was a concern in itself as the Nao robot balances better when it is standing, squatting or sitting on the floor but would have been harder to identify with by the older adults sitting themselves.

Figure 3 Exercise with Kira who is sitting down

Successful interactions during the physical exercise regime included looking at Kira and copying movements. When the group "realized" [Kira] was also doing the exercises, they would shift their attention from Sally (staff member) to Kira. Overall the staff supported the interaction with referring now naturally to the robot as Kira and addressed her directly with questions and comments such as: "How are you going

Kira?" and "Knee up, here we go Kira, you are not very flexible, are you?". Sally also reinforced the role of Kira as an instructor saying: "Now we do one round on one foot only, like Kira…". There were certainly limits to the movements Kira was able to be programmed for. When the instructing staff would do an exercise that the engineer had not programmed she said for example: Kira can't do this one as she does not have five fingers, but we are doing it." The incapability or limits of movements did not seem to bother the participants at all. In contrary there was a sense of pride when they were doing things that Kira was not able to do or did it in a more flexible manner. But there was also sympathy with Kira when she wobbled on her stool trying to keep balance or 'keep up to speed' with the movements as all participants were aware of their own physical limitations. This made her more relatable and caused additional interest in the participants, what she was actually able to do and what not. Movements Kira did particularly well were often complimented with positive responses by the group. In sum the group did not only show high emotional engagement with Kira but also positive response to her incapability during some of the exercises.

The dancing along with music worked particularly well. The song "Give Me a Home Among the Gumtrees" was presented by Kira in the correct timing and exact sequence, benefitting from the creation of a video demonstrating the movements going with the song by the staff member. Every group member was involved in some way according to their capabilities – either dancing along and/or singing along. If not able to dance, they would get up and clap or tap their feet along with the song watching Kira who seemingly would look at them with her big round eyes. The staff was again dancing side by side with the robot on the table. In this activity with Kira participants were showing sustained engagement which was attributed to Kira's presence.

One visit while dancing on the table Kira stumbled and fell all the way to the ground. Attention immediately turned into concern. As a result of the fall Kira had a twisted foot and when the engineer tried to bend it back she would start screaming "ouch". Concern then turned into shocked faces and inquiries. The staff was trying to lighten the situation in asking if we needed to write an incident report. Sympathizing positively with the robot and showing this high level of emotion triggered us to look more closely into the range of emotions and reactions Kira was able to do.

During one of the visits in the dementia group, the older adults were all sitting in a large semi-circle facing towards a table with Kira sitting on top. Towards the end of the visit, and while Kira was received well by most, there were a few older adults that didn't take kindly to Kira at the beginning. They showed signs of disapproval including body language of crossed arms and legs, shifted body weight and refusal to "meet". When the question was raised whether Kira has emotions or not, one male group member walked up and said: "Excuse me, but I do not think that you feel anything!" Which Kira responded to with breaking out in tears (Staff: "Oh, you are breaking her heart") followed by a burst of angry fist shaking. While this was quite unplanned, it turned out to be the perfect fit of this reaction to the whole situation, and the whole group burst into laughter including the old man who slapped his thigh and laughed his way back to his seat. Kira then bent forward and started laughing, which made everyone laugh again. While this was an unplanned, unpredicted scenario, it showed that the older adults had become comfortable with engaging with Kira on their own accord.

Exercise from there on was conducted on the floor to prevent further falls. During one visit, when trying to get on her feet from laying on the ground, Kira would lose balance and fall over – during the second attempt the group would cheer her, on being engrossed in this sequence. When she fell over again we needed to pick her up to make sure the foot would not twist again which resulted in Kira kicking her feet looking like a toddler having a tantrum. This resulted in group members being reminded of their own children when they were younger or their grandchildren, as they told us, which led to a wave of sympathy and laughter.

The group shared some interactions that can be classified as social with each other (such as laughing together) as well as with the robot (being confrontational, empathetic and firing the robot on).

Realizing how common walking frames were (filling up most of a room next to the group room like a parking ground) a sequence was programmed of Kira staggering around with a walking frame (figure 4 left). This frame was designed and 3D printed with great effort by the designer on the team to further relate Kira to something older people are familiar with. When Kira started using the walking frame, participants responded with interest and surprise. Also the staff seemed puzzled, and asked: “Why does she have a walker?”. After this initial surprise that created some discussion around walkers and a high level of interest, the ice seemed to be broken. Participants were interested in Kira and the meet and greet was much livelier than in the previous week. There were discussions around the capabilities and role of technologies and the stigma around assistive devices such as walkers, wheelchairs and walking sticks.

Figure 4 Kira with walker (left) and Kira on the chair (right)

According to staff members not accessible to our own observation some group members were more engaged in exercise and increased overall interaction and liveliness in exercise sessions between our visits: “when Kira is there, it seems to enthrall them and they’d copy her moves, which they weren’t doing before. And we’ve noticed in the weeks after that, that they were becoming more active.” A long-time staff member of the group, claimed that she had never seen "the whole group concentrate so long on one thing." Kira was also seen as supporting the active ageing program in making staff's life easier as some sort of novelty and need for always changing stimulation … "I think [Kira's possibilities] are endless, I really do. […] I think you could utilize her endlessly throughout the day. I would love to have her sit down with some clients and give a history run…or even an opportunity for clients to sit down and listen to poetry." For things like that staff would often "revert to iPads, but to have [Kira] would be even more beneficial." One particular success was pointed out by an observing staff member who commented about one of the participants. According to staff, one of the elderly members would often tend to be extremely agitated, jumping up and walking around. However, during the exercise session it was pointed out that "There is no music and Victor is sitting still - this is unheard of."

Case study 3: Men's shed

The third group that we visited was a locally organized men's shed. It might not be obvious how this group fits into the care agenda with the other groups. In Australia, men's sheds are highly successful groups of older men meeting in a space with many tools often as part of a community center where they do wood work and other crafts while socializing and talking. It has been shown that the talking had highly positive effects on the overall wellbeing through increased mental health [51]. Hence men's sheds are seen as therapeutic, especially for a generation where sharing problems and admitting to loneliness is not a common part of everyday life and, in particular, for men. We were invited by the local organizer of the men's shed to demonstrate the Nao and initiate a discussion on robots. Similarly to other visits we prepared a show and tell. The presentation setting was broken up when one of the men suggested to put Kira on one of the built rocking horses. As with the knitted clothes the association of the robot with a created artefact initiated laughter, but also a connection. People were joking, yelling and losing any reservation towards the robot. One man offered to build a chair for Kira and got his folding rule out to measure upper body to leg ratio. Again, shortly after the first author got message that the chair was ready for collection. The only request was to get some photos of Kira using the chair (figure 4 right).

Case study 4: Residential care

The residential care setting proved to be difficult despite some experience with other groups. The first visits were organized in a way that all residents were in the main community room to give them the experience and making them part of this "special event". Due to the size of the group (about 60 people) the robot visit became a big show and interaction was impossible. We were surprised by the number of people who had been gathered for the weekly mass service and stayed on for our visit. By microphone the first author was introduced as the MC of the event after mass. As we were usually just dropping in on the activity groups, observing and integrating ourselves into whatever activity was taking place the mutual expectations on this visit were not discussed in detail. The set up arranged for us threw the team a bit of balance. With difficulty we could at least prevent to set up the robot for dancing on the altar left from the Mass service as we were worried this would offend some older adults. While enjoyable for the older adults supporting the demos with clapping and attention this visit was mostly reduced to a show with some demos, storytelling and the robot being carried around for everyone to be touched in a brief meet and greet (see figure 5). One astounding small interaction that kept repeating while walking around with the robot was how several older adults cautiously lifted the little skirt with thumb and index apparently curious what they would see underneath.

After clarifying that this was too big of a group, another visit was organized. However, this group seemed to not work for exploring our aim on researching beneficial interactions either. This visit coincided with a group of Kindergarten children. While the children were enthusiastic about Kira gathering around her the older adults wanted to interact with the children. Hence this set up of competing interests and stimulation did not work well in terms of an enjoyable interaction. The children were distracted and obviously attracted to the robot while the older adults neither got anything in terms of positive interaction out of the children nor the robots. While some older adults smiled at the joy of the young kids some others displayed disappointment not being the focus of attention. It would be interesting to explore in more detail how intergenerational interaction could be mediated by humanoid robots.

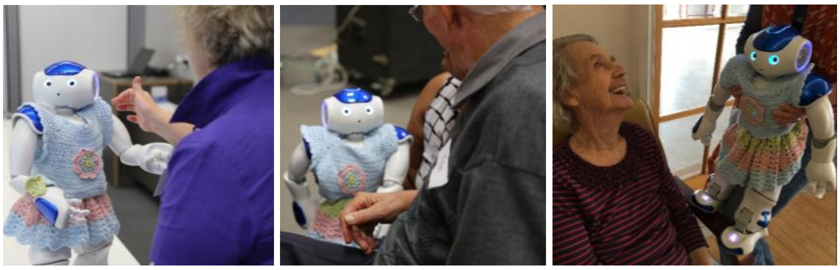

Figure 5 Meet and greet in residential care

1.5 Discussion

While sceptical at the beginning, this research turned into a project with several groups of older adults benefitting from interacting with the robot. From a spark of curiosity we were able to create programs for highly successful and engaging interaction scenarios. At every visit we learnt more about beneficial interactions of older adults with the humanoid Nao robot Kira in different care settings of active ageing groups. Most groups benefitted from the contributions and learnings of the previous groups. Each group added to the persona of Kira through accessories and stories. Rich stories were created about her acquaintances, “travels” to other groups and what happened there. The clothes became a constant accessory and part of the identity of Kira and we took the chair and 3-D printed walker to several visits. Overall Kira was taking something of the previous encounters in form of accessories, stories and our increased knowledge to the next group over time. Our iterative participatory approach combined with several tools and techniques from HCI helped to understand what were useful (and not so useful) interaction scenarios, but also left the power of guiding to the older adults.

The multidisciplinary team was key in developing the approach itself. In addition, the support of a range of stakeholders such as staff was key to understanding some of the interactions, sourcing materials and getting ideas for engaging activities. There are very distinctive roles in the collaboration of creating successful human-robot interactions in a group care setting. It was not the intention to create a more efficient care setting (e.g. replacing staff members). In contrary the staff had a facilitating role between the group and the robot during the activities. This has also been suggested by Carros et al. [20]. The designer of the interactions requires the older adults and staff to figure out what is important to design adequate interactions. This means understanding what exactly needed to be programmed into the robot before a visit. The robot or more general the artificial intelligence (AI) needs a designer to work out where the significance is and the older adults require to see what the robot can do. Hence a spiral of careful informing of each other needed to be set in motion. Below we discuss key insights from our research which we put forward as recommendations. We also emphasize the importance of the procedure of designing interactions around meaningful and familiar activities. This is important as we expect that even with more advanced robots these insights are still relevant. When it comes to design engaging social interactions with older adults the implementation is key.

Creating a basis through humor and turning initial negative emotions into positive

There is a lot of fear of robots "taking over the world" – largely caused by how cinema has portrayed robots, especially AI. Our data suggest that initial hesitation and the observation that at first the older adults seemed guarded, almost off-put by the robot (like a carer who was scared their job was at risk) can be overcome. When older adults and carers experienced how human reliant the Nao robots are (set up, programming, placement), how fragile and 'wobbly' they are (balancing), and how innocent the Nao looks, the carers and older adults realized it was not something to be scared of – rather they empathized with the robot. The persona of Kira as a girl dressed up helped to create interest and laughter.

Humor as one important aspect of social interactions has been investigated before in regard to whether it improves human–robot interactions [52,53]. While some of this research has not been conclusive we found that lightness and humor in HRI is something that benefits groups of older adults when interacting with robots. It is a part of showing the robot's vulnerabilities and helps make the experience comfortable, which is a basic requirement to positive interactions. It needs to be emphasized though that some of the humorous situations were facilitated either by one of the team members or transpired from the coincidental clash of robot and human behavior.

Based on the observed effect of our group members we recommend that robots and people should not be formal and serious all the time. If in the long-term people want humans and robots to socialize together, lightness and humor may help with strengthening this relationship. Adding lightness to the interactions would lead to a more relaxed experience, more enriching and memorable leading to conversation and socialization - increasing wellbeing of older adults over time.

Increasing wellbeing through activity and application of skills

Interactions were most powerful and impactful when group members were able to associate the robot with their own skills and capabilities (e.g. knitting and wood work) and engage with the robot on a level that gave them a feeling of familiarity. They were able to relate to the connection between some of the props or activities from their own life (Kira is sitting on the rocking horse I made). Real ownership in the shaping of the interactions was created when the group members were involved in some actual crafting of the robot's display (Kira is wearing the clothes I knit for her or she is sitting on the chair I made for her). This resulted in feelings of pride and happiness which other less creative group members were able to join and share as an experience.

Where the robot was involved in physical activities (dancing and exercises) it can be argued that the increased engagement by group members (and in one case lowered agitation) that has been reported by the staff members is also directly connected to an increased wellbeing. The more active and stimulated older adults are the more they are able to maintain wellbeing and avoid mental health issues. Important was *how* we used the classic 'home among the gumtrees' song for their dance activity. Using robots to facilitate meaningful interactions through selecting specific activities and music from the "good old days" that encourages them to get up and move (again) was key in the group of people living with dementia.

The best-known set of laws for robots are Isaac Asimov's "Three Laws of Robotics". The Three Laws are: A robot may not injure a human being or, through inaction, allow a human being to come to harm. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law. We suggest that this is not sufficient anymore for social robotics. When we talk about increasing wellbeing we need to strive for robots that benefit human beings through positive and meaningful interactions.

Situated AI for human robot interactions

In terms of AI most interactions needed to be pre-programmed for the robot to do anything. However, this is not seen as disadvantage having observed the strong reservation and fear at the beginning. We do not recommend intelligent robots per se, as what older adults want are technologies that are immersed in the situation [9]. Understanding and designing for the situation can lead to engage with the robot better and helps older adults to feel in control and in the centre of attention. Hence we do need to know about the skills, experiences and goals of older adults before introducing robots. We applied a participatory approach to understand the extent to which AI should be used in the context of our participants and to maintain the focus on people instead of

AI, as suggested by Gyldenkaerne et al. [54] when doing research on AI in healthcare. Based on the results of the four case studies we propose additionally treating the robot as a technology probe informing designers and engineers about the goals in different situations. Treating the robot as technology probe enables flexibility and openness which is practiced by Maldonado et al. [55] in a codesign project involving people with dementia. Insights through such a research approach also holds opportunities for situated AI. The example of Kira prompting a discussion on walkers shows AI in a robot might not mean to solve a problem, but simply to address a topic of concern in an empathetic manner in social situations.

Designing social interactions

Intensive research of the care and group setting is needed before the robot is employed. This includes consulting domain experts and users to explore and evaluate use scenarios before going into the field. Activities and length of deployment need to be chosen carefully to set realistic expectations for the target audience and engage group members in interactions that are based on their interests. The more the group members are able to relate to the robot and are involved in the design of the activities the more likely it is that they engage which has also been shown by other research in group settings with older adults [20]. Providing common ground and a familiar setting are crucial for HRI in a group. Overdoing "novelty" and try to revolutionize the setting can lead to fear and rejection. We recommend a careful balance between stimulation and familiarity needs to be maintained – in particular when introducing the robot to older adults living with dementia. This concurs with Sharkey [16] suggesting with respect to the introduction of robots in dementia care that "many of the benefits that can be obtained are likely to be the result of the skilled and careful deployment of the robot." (p.72).

There are different levels of social interactions that can be considered: (i) Between the robot and the group: Humanoid robots are beneficial for increasing social interaction and mobility in groups of older people when addressing the groups interests and skills – becoming part of the activities. (ii) Between humans: Robots can mediate the interests of several older people resulting in enjoyable shared experiences between humans. (iii) The wider community: Robots can be helpful to talk about sensitive topics in the wider community such as ageing and stigma and challenge our perception on older people and technology and self-perception.

1.6 Conclusions

We aimed to understand what constitutes positive interactions with humanoid Nao robots in care settings with older adults to increase wellbeing. Although there is much debate on social robotics to address social isolation and technical inclusion of older adults we propose that there is not enough knowledge on how social interactions should happen and how to introduce robots in older people's lives. It is necessary to better understand how people engage with robots which in our case took some time and iterative visits in the field. We agree that there is potential for technologies to benefit older adults, but often interaction scenarios are not based on in-depth research with this demographic in their context. Hence, we reported on four case studies demonstrating the introduction of robots focusing on social aspects, context and goals of the older adults involved. We explored and let the beneficial interaction scenarios evolve in a participatory process. We oppose the introduction of robots with expectations already set and recommend and discuss tools and techniques that enable the discovery of meaningful HRI scenarios in the field.

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Biographies

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