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A Long-Term Autonomous Robot at a Care Hospital: A Mixed Methods Study on Social Acceptance and Experiences of Staff and Older Adults

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Abstract Robot technology could be a future means to ameliorate predicted staff shortage in elder care due to the current demographic change. This study focuses on the evaluation of a long-term autonomous robot that was deployed in a real-world scenario at a care facility for older adults with severe multimorbidity and dementia. Social acceptance and user experience were assessed using a mixed-method design consisting of observations (12 h), ten interviews and 70 questionnaires with members of staff. Findings show that the interacting modalities have to meet the very needs of specific end-user groups and that the perceived utility of a robot is very much tied to its tasks and proper functioning. Social acceptance was ambivalent. On one hand the robot was integrated into daily routines, but on the other hand staff was not willing to share their work space with a robotic aid and saw the introduction of robots in eldercare as an inevitable development. Findings on user experience showed that staff and older adults were interested in and excited about the robot. Still it is necessary to equip the robot with meaningful communication abilities as well as cues that enhance the predictability of its behavior.

Keywords Acceptance · User-experience · Elder-care · Long-term autonomous robot · HRI · Real-world deplyoment

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1 Introduction

Due to demographic changes, the population is aging rapidly in most parts of the world. At the same time, a decline of employees in the care sector can be noticed that will probably lead to a shortage of health-care provision in future years. To overcome the gap between the increasing numbers of senior adults in need of care and the decrease in caregivers, many authors suggest that the deployment of robotic aids could be of help [1–8].

To ensure the adoption of robots in their specific field of use, acceptance of such devices by end-users is crucial. Thus studies on requirements for robotic aids, aspects on human–robot-interaction, and acceptance are necessary to guide future technological developments that, in turn, can help to bridge the gap between an ageing society and a lack of staff [4,6,8–11].

Recent robot acceptance studies in elder care focus on either evaluating robots that are introduced into the user's private home (e.g. [7,10,12,13]), or that are deployed in living-lab contexts [14,15] or at care facilities (e.g. [8,16,17]). Most of these studies follow predefined, controlled set-ups, where robots are, for example, tele-operated in a Wizard of Oz-setting or are available to potential users for a predefined amount of time to accomplish predefined tasks [6,8,12,16–19]. Findings of these studies show a multifaceted picture of human–robot-interaction (HRI): older adults seem to have generally positive attitudes towards socially assistive robots that provide social interactions (personalized HRI, restaurant finder) and cognitive stimulation (memory card game) [6]. Furthermore, older adults are especially open to robot assistants, if they perform home-based tasks like housekeeping, laundry and medication reminding, manipulating objects such as finding, fetching or reaching for items, opening and closing drawers or information management (e.g. appointment reminders). Still, senior adults prefer human assistance for personal care and leisure activities [7,10].

A review on assistive social robots in eldercare by Broekens et al. [2] shows that there is qualitative and quantitative evidence for positive effects of deploying a robot in eldercare. Findings of reviewed studies show that the presence of robots in eldercare led to a decreased stress response of users, better health conditions, increased communication, positive mood and decreased feelings of loneliness. However, the authors point out that research designs might not always have been "robust enough" (e.g. confounding variables cannot be excluded in some studies). Another study [20] shows, that older adults also valuate the entertainment functions of robots.

Furthermore, preconceptions and expectations towards robots are multi-dimensional and also ambivalent [3]. In this study it was found that on the one hand, users perceive the benefits of robotic assistants, and that on the other hand also negative implications accompany the introduction of robots into their lives. The majority of older adults who filled out questionnaires did not assume to enjoy doing things with the robot or they doubted that they would enjoy the robot's company. In contrast to this, another sample of interviewed older adults mentioned that they would like to engage in real conversations with the robot. This goes in line with [9,18] who also found that a socially interacting or communicative robot would probably be better accepted and therefore used more often. Furthermore, Frennert et al. [3] found that healthy senior adults would not want to have a robot for their own use but consider a robot appropriate for other peers who are fragile and suffer from bad health conditions.

The studies mentioned assessed older adults' acceptance of robots in very controlled settings like smart home labs or with tele-operated robots or by showing videos or descriptions of HRI sequences. There are no studies available yet that focus on the impact of a long-term robot exposure on user experience and acceptance, where users can interact with an autonomous robot in an informal and non-controlled manner.

Thus, we want to fill this gap in research and present how staff of a care hospital and its residents with severe dementia or multimorbidity accept, experience and react to a newly introduced robotic aid in general. Findings are also seen as a starting point for upcoming developments of the robot and its tasks for follow-up trials. The research question to be answered with this exploratory study is:

How do staff and older adults in a care-hospital accept and experience a long-term autonomous robot in a non-controlled real life setting?

2 Methods and Materials

2.1 The STRANDS Robot

The robot used is a SCITOS robotic platform available from METRA-labs (Germany). Its mantle is green, 1.75 m high and weighs 75 kg. It has a conical form with a transparent plexiglas head and big blue eyes that can blink (see Fig. 1). For navigation the robot gains information from a Kinect camera that is held in position via an aluminium frame attached alongside its head, as well as laser sensors on its front and back. For mobility, a differential drive is installed. Other components are a display and loudspeaker. For emergency situations, the robot is equipped with a bumper that runs around the widest part of the hull. If this bumper is hit or touched, the motor stops immediately.

The objective within a 4-year developmental process is to make this long-term autonomous robot able to navigate and function independently over a longer period of time without any intervention by technicians [21–23]. It should furthermore be able to learn patterns in its environment (e.g. routines within the deployment site, or deviations from it) and adjust its behavior accordingly. In each year of the project the robot is tested under real-world conditions at an elder-care facility in Vienna, Austria, starting with a 15 days deployment with limited tasks for a first introduction of the robot. In this time, staff and older adults should have time to get a first impression of the robot and to perceive its basic setup. This deployment was the basis for an end-user requirement analysis that was

Fig. 1 SCITOS robotic platform

conducted right after the trial [24]. In the following years of the project, trials will become longer and range from one to four months of deployment time. The robot's tasks will be developed according to findings of the requirement analysis [24].

Furthermore we want to already stress here, that developing a care robot is not a goal of the project. Instead we aim to develop an assistant for work chores of different staff groups in elder care and as an additional entertainment device for residents. With this study, we present the results of the robot's exploratory first deployment during the first year of the project, which ran over 15 days to depict probable reactions of staff and older adults when confronted with a robot in their work resp. living environment.

2.2 Trial Environment and Users

The robot was deployed in a 15-day-trial following a 5-day-pilot testing phase at the care-hospital *Haus der Barmherzigkeit* in Vienna (Austria) for the first time from May to June 2014.

The care-hospital provides a permanent residence and nursing service for about 350 older adults suffering from dementia or severe multimorbidity, as well as patients in a vigil coma or with progressed stages of multiple sclerosis. Their health-related circumstances make them a very special and vulnerable group of users. Dementia—in its various forms—is characterized by multiple cognitive deficits [25]. Multiple sclerosis patients are usually younger, suffering from (often progressing symptoms of) spasticity, impairments of speech and mobility, and sometimes also cognitive decline [26]. Due to the progressed stages of neuropsychological impairments (e.g. distorted memory, loss of identity, problems with verbal communication, impaired and limited mobility, and loss of controlling emotions), as well as additional age-related difficulties, the residents of the care site cannot be expected to behave like healthy participants in studies. This has implications for our methodology, meaning, for instance, that questionnaire methods or in-depth interviews had to be ruled out, since many of the patients would not have been able to understand or reliably answer complex questions about usability or their experience.

Apart from the residents, about 465 employees (e.g. medical and nursing staff, therapists, administrators and service staff) work at the care-hospital. Furthermore a kindergarten is situated at the care site. This makes it a very busy location with a great variety of potential robot-users: different professionals, residents with different health-conditions and their visitors, all covering different ages and thus having different requirements that have to be met by the robot.

2.3 Robot Activities

In the first year of the project, the robot was operating in the entrance area and the corridors of the administration wing on the ground floor. Apart from that, a cafeteria and a hairdresser for the residents, a chapel, visitor sections and seminar rooms can be found in this area. The corridors are wide and partly aligned with groups of chairs. During working hours the corridors are very busy. All staff enters and leaves the building through that area. It also links care units, administration wing and therapy wing (on the other side of the ground floor). Therefore, transportation staff can frequently be found moving residents to and from ambulances or therapeutic areas to their units, pushing them in beds or wheelchairs or support them when walking. Other residents are moving along with different walking aids in order to visit the cafeteria, hairdresser or walk outside. During breaks, most employees have their lunch at the cafeteria thus also entering the robot's deployment area. It follows that the chosen deployment area is a very complex space for the robot to move in. For the first deployment, it was chosen to enable a large number of people in the care facility to have a first contact and impression of the robot that would be deployed at this site for the three following years again.

As this robotic system was deployed in a real-life scenario outside the laboratory for the first time, without experience of how residents with the described deficits would react, the activities of the robot were kept at a basic level and included the following:

2.3.1 Autonomous Navigation and Patrolling

During office-working-hours the robot was moving autonomously within the predefined area of the care site. It did so, navigating through the corridors, recognizing people or obstacles in its way and evading or adjusting its speed accordingly. On its patrols, it controlled if doors that should be closed were actually closed, and whether the fire-extinguisher was in its place.

2.3.2 Greeting Task

The robot offered a greeting task on a certain spot in the lobby twice a day. It addressed by-passers asking if they liked to interact with it via voice output. Due to the robot not having a speech-recognition system, interested persons could click through some information about the robot and the research project on the screen. Additionally, the robot read out aloud the visible text.

The start screen simply showed the project logo and an arrow in the lower right corner to click further. The following pages contained text about the project. Users could move backwards and forwards by means of arrow icons on the screen.

2.3.3 Reciprocity

If the robot lost navigation, it called for help by means of a pre-programmed voice output. A short instruction telling the user how to help the robot appeared on its screen. In order to help the robot, users had to push the robot back into the middle of the corridor where a recovery behavior started.

3 Evaluation Framework

Different frameworks are available for studying experiences in HRI and user acceptance [16,21,22,27–30].

As the STRANDS robot's first deployment in a real-life field-trial marked an exploratory trial, and since it was the first time a robot was introduced to the care facility for a longer period of time, the USUS-framework by Weiss et al. [30] was chosen. The advantage of this framework is that it provides a holistic perspective on HRI, targeting the evaluation of the robot's functions, social acceptance of the robot, experiences of users interacting with the robot, and how the presence of the robot influences its environment. The USUS was developed for robots deployed in working environments where an interaction between human employees and the robot is required or desired. As such it was deemed also suitable for the evaluation of our robot deployed at a care-facility.

The USUS consists of a multi-level indicator system. [30] identified four key evaluation factors from literature that are of importance when evaluating how users interact with robots in social situations. These are: *usability*, s*ocial acceptance*, u*ser experience* and s*ocial impact*. These factors further subsume indicators that are representative for the subject area of each factor. The four factors and indicators of relevance for this study are presented in the following.

3.1 Evaluation Factor Usability

Usability is the principal factor in the evaluation of HRI [30]. It refers to the ease of using the robot and the extent to which the robot can be used by its users to achieve certain goals [30]. With its limited tasks for the first deployment, usability is addressed in order to see what purpose the robot could serve during its future trials and what is seen as not useful.

3.2 Evaluation Factor Social Acceptance

Social Acceptance is defined as *an individuals' willingness to integrate a robot into an everyday social environment*, and emphasize the importance to detect reasons why people accept or reject robotic systems in their working environment and what attitudes they show towards robotic aids [30].

3.3 Evaluation Factor User Experience

User Experience is defined as how users experience the interaction with the robot on an emotional, perceptional and mental level. These interaction-experiences are embedded in the specific situation or context in which the interaction takes place.

3.4 Evaluation Factor Societal Impact

Societal Impact refers to the effects on social life that accompany the introduction of robotic agents [30]. The STRANDS robot was deployed for the first time and did not yet offer any chore related or assisting tasks. Consequently, this evaluation factor was not further taken into account, since societal impact could not be observed during this first trial.

3.5 Study Design and Methods

To provide a broader view on the experiences and social acceptance of staff and older adults towards the introduced robot, and to reach as many participants as possible, we combined qualitative (interviews, observations) and quantitative methods resulting in a concurrent mixed methods multistrand research design (QUAL+QUAL+QUAN) [31–35], see Fig. 2.

Qualitative data were gathered from observations during the deployment phase, as well as interviews with staff at the care site at the end of the deployment. Quantitative data stem from an online questionnaire sent out to staff also at the end of the deployment. Participants took part in this study on a voluntary basis and data were treated anonymously. In the following sections the single strands of the study will be explained in more detail.

Strand A: Interviews
Within 1 week after the deployment ten interviews with different professionals were conducted: doctor (1), therapist (1), resident transporter (1), management (2), IT-staff (2), administrative employees (2). This way, the perspectives of different professionals could be assessed. The interviews were semi-structured and based on an interview guideline with 14 open-ended questions (see "Appendix 2") covering the four evaluation factors of the USUS framework. The interviews were carried out in a one-to-one setting and were sound-recorded. After transcription of the interviews, analysis was done using "f4-analysis" software.[1] Due to the exploratory nature of the study, categories and codes were derived inductively from the texts without specifying

[1] Provided by audiotranscription.de.

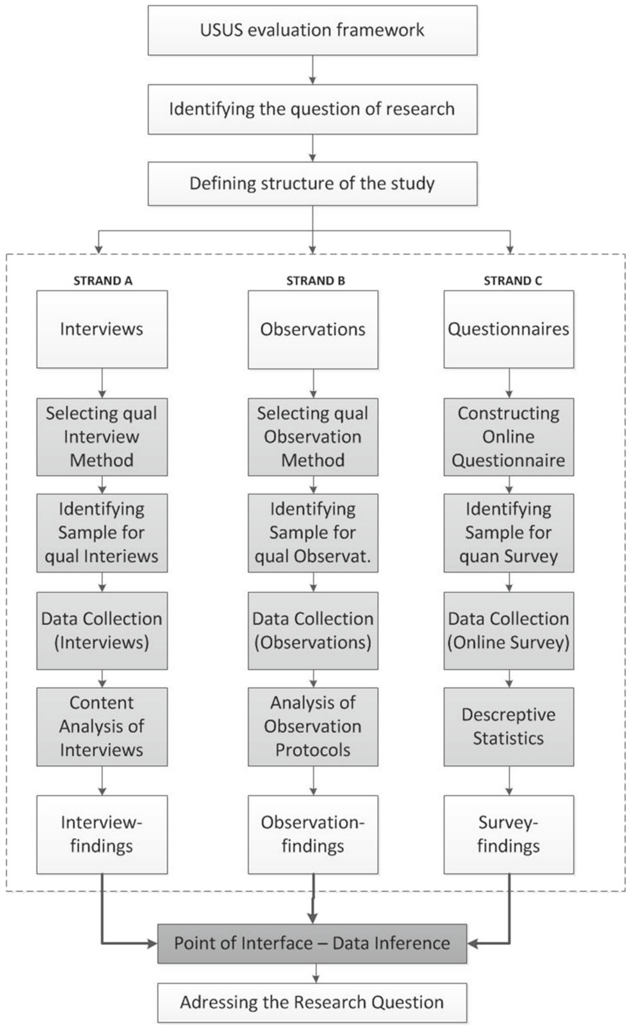

Fig. 2 Pathway from the theoretical background to the implementation of a concurrent mixed methods multistrand design consisting of interviews, observations and questionnaires. Data analysis was followed by the data inference

the theoretical presumptions or categories in advance [36–38]. The analysis procedure followed [36,37]. To enhance interpretative validity, two researchers coded the interviews independently [39,40]. Finally, the code-systems were compared and adjusted in a discursive process.

Strand B: Observation
Observations were conducted throughout the trial as a second strand for data collection. This method was chosen, because observations can provide insights into subjects' behavior towards the robot [38,41] and because most residents at the care-hospital suffer from cognitive impairments or dementia and thus cannot partake in surveys or interviews. In observing their behavior, it was also possible to gain information about how this user-group interacted with the robot.

During the trial weeks, observations took place twice a day: half an hour in the morning and half an hour in the afternoon during the robot's greeting task in the lobby. The observer was sitting nearby but did not interfere. 226 human–robot-interactions were detected in 12 h of observation. Six observation sessions could not take place due to technical problems of the robot.

Observation notes were taken according to predefined aspects:

(1) Behavioral information:
 (a) Who was interacting with the robot: an employee, a resident or a visitor?
 (b) Type of interaction: what was the user doing with the robot?
 (c) Emotional state of the user during the interaction with the robot according to the commonly accepted six basic emotions (happiness, sadness, surprise, anger, disgust, and fear) [42]. Due to their association with facial expressions, decoding of them can be expected to be reliable.

(2) Acoustic information: Spoken comments and utterances by users during the interaction with the robot were protocolled.

All observation protocols were digitalized. The collected text material served as the basis for content analysis. Room was also given for categories to emerge inductively from the collected material itself.

Strand C: Questionnaires
At the end of the deployment phase, all employees received a link to the online questionnaire via e-mail (items are shown in "Appendix 1"). Participants were asked about their computer experience, general attitudes towards the deployment of robots at a care site, use and ease of use of the robot tasks and user experience, considerations about perceived safety and a final open question about requirements and potential tasks that the robot could accomplish in future years.

A total of 70 (51 females, 19 males) questionnaires were returned. However, the number of completed items differed across respondents. We still chose to use all 70 for our analysis. The respective number of answers for each discussed item will be given in the results section.

Descriptive analyses were applied using SPSS. Due to the lack of normal distribution in the data (tested via Kolmogorov-Smirnov) nonparametric tests were calculated to find differences between age, groups or sex. However, differences were not statistically significant; hence only descriptive analyses are reported here.

Point of Interface
Data were separately analyzed for each strand and results were drawn together for meta-inferences [31,43–45]. Although handling each data-strand equivalently in respect

of weighting, it was found that the category-system derived from interview analyses provided a detailed and informative frame for meta-inferences. Findings from questionnaires and observations provided additional information and perspectives.

4 Results

During the trial, the robot covered 27.94 km. Autonomy was measured in terms of the percentage of time spent on active, autonomous behavior in a day across system lifetime (i.e. navigation, greeting tasks, autonomous docking and undocking etc.).

This low number can be explained by the fact that the robot was, due to the exploratory nature of this first deployment, only operating during office hours on week days (i.e. between 8AM and 5PM). For the autonomy numbers, also the pilot-testing phase before official start of the deployment was included resulting in 20 days and 19 h of cumulative system lifetime. Autonomous operation (without system failures etc.) in total reached 48 h 53 min and 17 s. This leads to an autonomy value of 38.80% in the available working time. This was then measured out of the cumulative system lifetime (which included time the robot was not allowed to operate autonomously), resulting in an autonomy value of 9.6%.

As could be expected of the first run of a robot in such a real-world scenario, technical problems occurred. Main issues that had to be solved related to navigation in the busy corridors and reliable scheduling at the beginning of the trial. Therefore autonomy time was partly restricted, which also influenced the availability of the robot's tasks.

4.1 Usability

Descriptive analyses showed that 24 of 65 (37%) employees did go through the info on the robots touchscreen (App. 1, Item 13). Corresponding to these findings, only three out of ten interviewees did use the robot. *Interview analyses* revealed reasons why people did not use the robot. One interview partner stated that he was very critical of technical devises such as robots and therefore had tried to avoid the robot. One employee mentioned that he did not know the robot could be used; another did not try to use it because it offered no games. Two others feared to damage the robot when doing something wrong. Two employees did not give any reason for not using the robot.

Quantitative data indicate that certain fears could be the reason for not using the robot. When looking at the data of non-users, 13 of 30 employees (11 missing answers) feared to make mistakes when using the robot (=43%). In the group of robot users, only three out of 24 (13%) indicated such fears (App. 1, Item 9). Within the group of non-users, 12 out of 30 (9 missing answers) feared to damage the robot when using it, whereas only three out of 24 (13%) of the robot users indicated that fear (App. 1, Item 10).

Observations showed that residents, employees and visitors alike were interested in the robot and its functionalities. Stopping next to or in front of the robot, they listened to the voice output, clicked through the menu and read contents themselves or aloud for others. 79% of the 24 employees who used the robot stated that they were able to use the robot without explanation by others (App. 1, Item 8) and 68% stated that it was easy to gather information on the screen (App.1, Item 5). 18 user considered the menu design appropriate (App. 1, Item 14) and the menu comprehensible (App. 1., Item 15). But it was also *observable* that especially older adults had difficulties with the rather small fonts on the screen. They often had to lean forward when using the robot or were squeezing their eyes together when trying to read the contents. They also struggled with the faint voice output, listened hard and held their heads close to the robot.

Asked in the *online questionnaire* if employees of the care-hospital considered the deployment of robots at a care site generally useful, ten out of 68 respondents (15%) chose "does apply" and 35 (50%) "does rather apply". 18 employees (26%) stated it "rather does not apply" and six (9%) "does not apply", (*Mean* = 2.63, *SD* = 0.94), (App. 1, Item1), (Fig. 3).

4.2 Social Acceptance

In the *questionnaire data* 35 out of 66 employees answering the question (53%) would (rather) like to and 31 (47%) would (rather) not like to share their workplace with a robot (Fig. 4) (*Mean* = 2.4, *SD* = 1.22.), (App. 1, Item 2). *Observations*

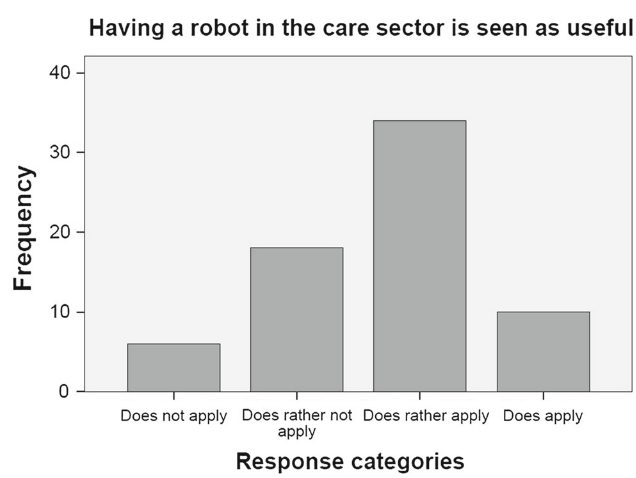

Fig. 3 Care staff's general perception of the usefulness of deploying robots in the care sector. The frequency depicts absolute numbers of responses per answer option on the four-point Likert-Scale (does not apply—does apply)

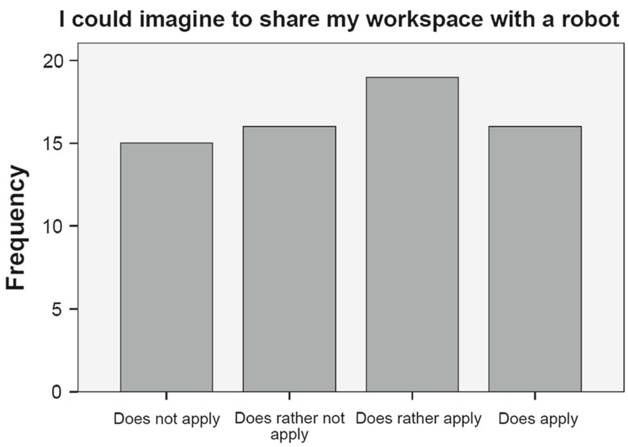

Fig. 4 This graph shows the attitudes of care staff about sharing their work environment with a robotic agent. The frequency depicts absolute numbers of responses per answer option on the four-point Likert-Scale (does not apply—does apply)

showed that the robot, although not yet offering any work-supporting tasks, was positively perceived from people at the care site. Employees, visitors and users were seen greeting the robot, saying their goodbyes to it or waving at it when passing by. Many users also introduced themselves to the robot, asked it for its name or tried to begin a conversation.

Interview analyses, however, revealed controversial attitudes towards the robot deployment at the care facility: first, the presence of a robot at a care site led to irritation (mentioned in 4 interviews) and there was fear that the robot could take away workplaces and successively replace care staff (mentioned by 3 interview partners). A similar attitude was also perceptible during *observations*: a group of elderly persons was sitting with visitors in the lobby area and claimed that there was already too much technology dominating their everyday lives and that this development was not desirable. Older adults/visitors also assumed that the robot would, in the long run, replace care staff. This was not seen as a desirable development. Interviewees rather hoped that humans were going to take care of them in the future and not robots (addressed in 7 interviews).

This attitude was shared by *interviewees* who also emphasized that robots could never replace the specific human abilities and qualities in care. That is, humans provide a specific way of reacting, of interacting and communicating. They can react sensitively to a specific situation in a precise moment. Interviewees expressed their opinion that this flexibility and care could not be provided by a programmed machine.

Contrary to these findings, *interview analyses* showed that interviewees also considered the robot as a source of support for care staff and that the deployment of a robot would also create new workplaces (5 interviewees). Due to their programming and therefore precise working manner robots could compensate human mistakes, complement and improve human abilities or probably even surpass them. Robots could conduct everyday tasks that may tire human staff. One interviewee emphasized the potential economic advantage of robots, since they can work all around the clock, have low ongoing costs and could be more profitable than human staff.

Finally, participants' impressions about the recent development in robotics could be identified in the *interviews*. On one hand, robotic devices were seen as a useful innovation increasing economic profitability and possibly exceeding human abilities (5 interviewees). On the other hand, technical developments in the field of robotics were seen as an unstoppable development that was certainly going to enter the care sector (2 interviewees). Participants regarded this as a development that employees cannot change, and that they have to adapt to, in order to keep up with the spirit of the times.

In terms of helping the robot when he was stuck (reciprocity) six interview partners experienced situations where the robot called for help. Two mentioned that they felt sorry for the robot. Further *interview analyses* showed that interview partners dealt differently with such situations:

(1) Helping the robot (2 persons).
(2) Not helping but getting somebody else to help the robot (4 persons).

As a reason for not helping, interviewees mentioned that they did not know what to do or that they were afraid of damaging the robot.

4.3 User Experience

Both*interview analysis* and *observations* showed that employees, residents and visitors were curious about the robot. People were looking at the robot, and some employees even wanted pictures to be taken together with the robot. With its blue, blinking eyes, its blue headlight and the "science fiction-like" appearance, the robot was perceived as a positive diversion and something new and fascinating within the daily routines of the site. It was described as "nice", "likeable", "funny", "witty", "amusing", "cool", "inspiring" and "exciting". The robot's presence elicited a positive atmosphere and made employees smile. This could also be witnessed in the *observations*, where users were frequently seen laughing when interacting with the robot.

4.3.1 Communication Modalities

83% (n = 36) of the employees considered the robots voice as appropriate, although *interview analysis* showed that the voice was perceived too artificial (App. 1, Item 7). Regarding the volume of the robot's voice output, 74% (n = 24) of the employees who used a functionality of the robot felt that the volume was appropriate in the *quantitative survey*. Including all employees who answered that question (users and bystanders) 87% (n = 38) were satisfied with the volume (App. 1, Item 6).

Interviewees were disappointed by the touch-screen being the only means of interacting with the robot. They rather would have liked to have interactive language communication with the robot (2 participants). This was also *observable* in the field, when people tried to start a conversation with the robot and became frustrated after several failed attempts of receiving answers from the robot. Users were observed saying: "Look, it does not talk to me!", "I told him something, but he does not say anything!" or "I talked so often to you, but you don't give me any answers!"

Over time, users became bored by the invariant programme and functionalities of the robot. The general interest in the robot remained, as users still approached the robot but left after they saw that the robot still offered the already familiar contents. One user stated: "It always tells the same!" Other comments were: "Oh, I already know that quote!", and "We already know that, you have to tell something new". Some *interview partners* stated that they were annoyed by the robot's voice output and by the fact that it always repeated the same sentences and contents with a very artificial voice. One explicitly wished for a more natural voice of the robot, probably even with local dialect.

4.3.2 Technical Problems and Perception of Security

During the *interviews*, employees addressed technical problems and malfunctions of the robot (8 interviewees). Interview partners expressed their disappointment in regard to the lack of interactivity, the slow reaction times and little autonomy of the robot as well as the navigation problems and missing artificial intelligence. It also became apparent that users were frustrated or lost interest, if the robot did not work properly.

In regard of safety, our *quantitative analysis* revealed that 63% (n = 56) of the employees felt safe when encountering the robot in the corridors of the care site (App. 1, Item 12). When asked if they considered it easy to move past the robot 87% (n = 56) of the employees agreed to it being easy (App. 1, Item 4). When asked if employees considered situations in which the robot had to move out of their way to be either difficult or easy, 60% (n = 54) rated such situations as "easy" and 40% (n = 54) considered them "difficult" (App. 1, Item 3).

Interview analyses pointed out reasons why the robot's behaviour might not have been predictable enough: interviewees were for instance uncertain if the robot was able to detect people/obstacles, and if it would move out of the way. Sudden or unexpected appearances of the robot seemed to frighten people at the care site. A similar pattern emerged in the quantitative data: 25 out of 45 employees (56%) did not consider the robot's behaviour predictable (App. 1, Item 11).

5 Discussion

With this study we hope to contribute to the assessment of social acceptance and experiences towards a long-term autonomous robot that was deployed for the first time at a care-hospital for older adults with severe dementia or multimorbidity in the course of the four-year research project STRANDS. These findings should first help to develop the robot and its tasks for its following deployments and to shed light on how people in a care facility perceive such a device in a real-world context, rather than in an artificial lab or living-lab situation. If such technical aids should be deployed in the care sector in the years to come, such findings are important to build the basis for future developments. Furthermore, it is also important to involve several professional groups that can be found in the care sector, and not just care staff by itself. There are many other staff groups involved and robots could be of assistance in many potential areas in the future [24]. Thus we want to discuss the findings of this study in the subsequent section.

5.1 Usability

It was found that employees, visitors as well as residents were interested in the robot and tried to interact with it. Yet the analysis also showed that about two thirds of employees did not go through the information on the touch screen. Reasons for that were either the lack of information about the offered functionalities on the screen or anxiety of the potential users to break something or to do something wrong. It was furthermore found that older adults had problems using the robot due to small icons and fonts on the display and the low voice output, which did not meet requirements brought on by age-related impairments. In contrast, employees considered the menu structure and design as comprehensive and easy to handle.

Our consolidated findings show that users of different age groups are interested in the robot but that the user-menu for an autonomous robot needs to be self-explanatory enough, so that interested persons can anticipate what (tasks) they can expect of the robot. This constitutes a specific challenge at this care-hospital due to the high degree of dementia or multimorbidity. Additionally, visual content and acoustic output has to be visible and loud enough to be well perceived by all potential user groups. Making such outputs adaptive to the specific needs of certain users could also be of advantage

[7,14]. Furthermore contents should be designed inclusively, following a barrier-free design.

Overall, the STRANDS robot was not perceived to be very useful during its first deployment. This can be understood because the robot did not offer specific tasks that would ease the working routines of employees at the care site. This goes in line with arguments from [10,18,46,47], who claim that a robot's tasks, ist functionality and usability are a crucial factor influencing its acceptance. This will change in future years of the project, when tasks will be developed according to requirements on site in an iterative process and in cooperation with employees from the care site.

5.2 Social Acceptance

In line with findings from Hudson et al. [48] we found an ambivalent attitude towards the robot. On one hand, the STRANDS-robot was socially accepted by staff and residents, as they paid attention to it during their working routines, showed interest or spoke to it. Also its potential utility in further years of the project was acknowledged, and economic advantages of the deployment of a robot were pointed out. Positive attitudes towards robots were also found in other studies like [15].

On the other hand, half of the employees who completed the questionnaire stated that they would not want to share their workplace with a robotic aid. A possible reason for this attitude could be the fear that the deployment of a robot at a care site could successively take away jobs and thus threaten jobs. Additionally, interview participants as well as observed residents and visitors claimed that a robotic aid could and should never take over care tasks. These attitudes are backed up by other studies showing that people wish robots to perform rather repetitive, tedious or demanding chores instead of any care or relation specific tasks [3,7,49,50].

Finally, there was a general feeling among some interviewees seeing the introduction of robots in the care sector as an inevitable development. A similar feeling towards robotic aids was also reported by Wu et al. [11], who found out that older adults perceived robots as a 'necessary evil' they would accept, if there was no other choice left.

Based on these findings, it becomes clear that the care sector is a very sensitive area where interpersonal devotion is a crucial attribute. This should be kept in mind when developing and introducing robotic aids to the care sector in future. According to our findings, older adults and care staff would appreciate if robotic aids were generally not involved directly in their care. They should also not threaten jobs of human staff. Robots therefore are rather seen undertaking tasks that are either physically demanding for care staff (e.g. lifting patients; transporting objects) or that would give staff more time to engage in care and social contact for their clients.

5.3 User Experience

Human–robot interaction was mostly accompanied by positive moods and emotions. Interest and positive emotion, however, turned into disinterest and disappointment due to occurring malfunctions and to the unchanging program/output of the robot.

Employees and older adults were disappointed that the robot was not able to engage in a real dialogue and that its voice output was rather limited. This corresponds to findings from [3,9,18] that a more socially communicative robot is preferred by older people. It follows that for future trials, vocal output needs to be implemented carefully. Utterances of the robot have to meet its actual ability to understand and process spoken contents. The repetitive vocal outputs of the robot also annoyed some employees. Others disliked the artificial sound of the voice. These findings are comparable to [6,51]. In this regard, a recorded human voice might help making users feel more comfortable in the presence of the robot.

Users sometimes had difficulties anticipating and recognizing the robot's behavior. They were not able to tell if it would evade during encounter or when the robot changed its behavior switching from one task to another. It thus seems necessary that robots are equipped with certain cues to enhance predictability of its behavior. A study conducted by May et al. [52], for example, demonstrated that flashing lights mounted on a robot or a robot that moves its head in the direction of its motion could be of help.

6 Limitations

One point that has to be stressed is that the robot offered only limited functions during its first deployment of the project. This was on one hand due to the fact that we wanted to carefully introduce such a technical aid at a site with very vulnerable end users, and on the other hand because this trial served as a first introduction of the robot. For future requirement analyses we considered it necessary that the end-users had already seen the robot and thus would be better able to think about useful tasks [24]. Nonetheless, the robot's presence fostered different impressions, feelings or attitudes. For future research it would be interesting to see how people in the care sector perceive and accept a robot that can offer more care specific tasks.

During the trial some navigation problems occurred, perturbing the robot's autonomy. This probably biased the user's perception of the robot. For further trials, it has to be taken care that navigation issues are solved so that the users can evaluate a robustly working robot.

Due to the exploratory field-trial nature of the study, a balanced sample could not be used for observations or the questionnaire survey. Instead, what is represented here is an incidental sample. For the interviews, a selection of different professions working at the care site was selected.

7 Conclusion

This study contributes to the new field of research about first impressions, experiences and social acceptance of a long-term autonomous robot at a care-hospital for older adults with severe dementia or multi-morbidity and different professionals at the care facility.

Findings show that the deployment of such a robot creates ambivalent feelings and responses. On one hand, people are curious, engaging with the robot and enjoying its presence. On the other hand, the introduction of a robotic aid in such a sensitive area as a care institution is also accompanied by fears and refusal. Bearing this in mind, one has to pay attention to carefully introduce such devices and to develop devices that rather clearly assist human staff than take over tasks that would as a consequence threaten human work-spaces or lead to a depersonalization of the care actions per se.

It was also found that when introducing an autonomous robot, it is especially important to have a self-explanatory way of offering functionalities, so that older users or handicapped users can access them without help. Enhancing the predictability of the robot's behavior is also a crucial aspect when designing robots, enabling users and bystanders to easily anticipate what the robot will be doing next.

Finally, to keep up the users' interest, especially over a longer period of time, various contents have to be offered that should be presented in an unobtrusive manner.

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Compliance with Ethical Standards

Conflict of interest No conflict of interest declared.

Ethical Standards The study received ethical approval from the ethics board at the care facility "Haus der Barmherzeigkeit", Vienna, Austria. This board consists of different professionals from the care context.

Appendix 1

Items of Online Survey

See Table 1.

Table 1 Items used in the online survey and answer categories of the 5-point Likert Scale

Item	Answer categories
1. I think the deployment of a robot in a care environment is generally useful	From 1 ("does apply") to 5 ("does not apply")
2. I can imagine having a robot in my department/ at my workplace	From 1 ("does apply") to 5 ("does not apply")
3. How difficult did you find the situation of the robot trying to avoid you in the hallway?	From 1 ("very difficult") to 5 ("very easy")
4. How difficult did you find the situation of trying to walk past the robot?	From 1 ("very difficult") to 5 ("very easy")
5. How difficult did you find trying to access information on the robot's screen?	From 1 ("very difficult") to 5 ("very easy")
6. What do you think about the volume of the robot's voice?	Appropriate; inappropriate
7. What do you think about the robot's voice?	Appropriate; inappropriate
8. I can operate the robot, even if there is nobody to explain what I should do	From 1 ("I do not agree at all") to 5 ("I totally agree")
9. I hesitate to use the robot, because I am afraid of making mistakes	From 1 ("I do not agree at all") to 5 ("I totally agree")
10. I am afraid to use the robot, because I could break something	From 1 ("I do not agree at all") to 5 ("I totally agree")
11. The robot's behavior is predictable	From 1 ("I do not agree at all") to 5 ("I totally agree")
12. I feel save if the robot approaches me in the hallway	From 1 ("I do not agree at all") to 5 ("I totally agree")
13. Did you use the robot's functions?	No functions used; retrieved information;
14. What do you think of the robot's user menu?	The design is inappropriate; the design is appropriate
15. Was the user menu comprehensible for you when using the robot?	Not comprehensible; comprehensible

Appendix 2

Guideline for the staff interviews

See Table 2.

Table 2 Interview guideline for post-trial staff interviews according to the factors of the USUS-framework

Usability
Effectiveness
In how far did the robot influence your daily routine?
Could you interact with the robot if you wanted to?
If you wanted to use the robot, could you use it without problems? Give us one example!
If it didn't work, which problems did you have?
Which changes and improvements in the robot would you suggest?
Predictability
Do you think that the robot has adequately reacted to the commands of the involved persons? Why?
Social acceptance
Do you miss the robot now it's gone? Why don't you miss it? Why do you miss it?
Are you looking forward to seeing/using the robot again in Y2? Why? Why not?
User experience
Emotion
What were your expectations of the robot when it got here?
How did you feel about it?
What do you think of the robot now? Why?
What did other people tell you about their experiences with the robot?
Human oriented perception
Would you consider the behavior of the robot as social? Why/why not?
Feeling of security
How did it feel when the robot was approaching you in the hallway?
Future perspectives
How could life change if robots are integrated into a care facility?

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