Lessons Learned from the Deployment of a Long-term Autonomous Robot as Companion in Physical Therapy for Older Adults with Dementia

A Mixed Methods Study

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Abstract— **The eldercare sector is a promising deployment area for robotics where robots can support staff and help to bridge the predicted staff-shortage. A requirement analysis showed that one field of robot-deployment could be supporting physical therapy of older adults with advanced dementia. To explore this possibility, a long-term autonomous robot was deployed as a walking group assistant at a care site for the first time. The robot accompanied two weekly walking groups for a month, offering visual and acoustic stimulation. Therapists' experience, the robot's influence on the dynamic of the group and the therapists' estimation of the robot's utility were assessed by a mixed methods design consisting of observations, interviews and rating scales. Findings suggest that a robot has the potential to enhance motivation, group coherence and also mood within the walking group. Furthermore, older adults show curiosity and openness towards the robot. However, robustness and reliability of the system must be high, otherwise technical problems quickly turn the robot from a useful assistant into a source of additional workload and exhaustion for therapists.**

Keywords— ***long-term autonomous robot; real-world deployment; physical therapy; companion; dementia; user requirements; care.***

I. Introduction

Age related diseases like dementia are increasing in Western society, leading to social, health and political challenges [1]. The DSM-5 [2] uses dementia as an umbrella term for disorders due to subtypes like Alzheimer's, vascular disease or also Parkinson's, to name only the most common ones. Dementia is marked by cognitive decline, sometimes accompanied by behavioral disorders, often progressing and leading to complete dependence on caregivers in all activities of daily life. Alzheimer's disease, the most common form, is informed by a steadily progressive decline in memory and learning. Likewise, the ICD-10 classifies dementia as a syndrome in the wake of a usually chronic or advancing disease, characterized by the impairment of "memory, thinking, orientation, comprehension, learning capacity, language and judgment" [3]. Usually, this also involves changes in emotional control and social behavior. Some forms of dementia also include motoric restlessness and agitation.

In therapy, apart from medication, cognitive stimulation and physical activities like walking have been identified to improve behavior and physical condition of dementia patients in long-term care, and can also reduce symptoms of depression [4, 5].

To support the care sector in different fields authors claim that robot technology could be a purposeful means [6, 7, 8, 9, 10, 11, 12, 13]. In this context, it is important that technical developments meet the applicatory needs of end users. Any development process should therefore be led by careful analyses of user requirements [6, 9, 14, 15, 16, 17]. As was shown by [18] in a requirement analysis workshop with staff in an institution for elder care, walking groups that are offered as physical therapy for older adults with dementia could be one possible area of deployment for a long-term autonomous robot. Participating physical therapists suggested that a robot could accompany their walking groups and offer acoustic and visual stimuli during the walk as well as during resting periods in between. Especially wandering and agitated patients could be accommodated with the use of technology in this setting [4].

These findings constituted the basis for the implementation of a unique robotic walking-group companion. While not claiming that a robot could provide a fully established form of therapy, elements used in reminiscence therapy, such as sounds to evoke past experiences [19], could be offered as stimuli, in order to increase social interaction and emotional well-being of patients.

For this novel implementation in robotics and in physical therapy, our research questions focus on the influence of the robot and its perception by therapists:

1. How do physical therapists experience the robotic-companion during the walking groups?

2. How does the robot influence the dynamics of the therapy group?
3. How do therapists perceive the utility of such a robot-task?

Findings from this exploratory trial should further feed into recommendations for future deployments of such robots in the context of a physical therapy walking group for older adults with dementia.

II. Setting and Materials

A. Real-world deployment at a care site

The robot was deployed for the second time (as part of a four-year project) at the "Haus der Barmherzigkeit", an elder care facility in Austria, where it served as a companion for the walking groups in physical therapy. The care-hospital provides long-term care for 350 older adults with advanced dementia, severe multimorbidity or multiple sclerosis. 465 employees are working at the institution.

B. Walking groups as physical therapy

Residents with progressed dementia receive different therapeutic interventions at the care site. One intervention is the walking group in physical therapy. The goal of this intervention is to obtain the mobility of the residents, to provide them with diversion in their daily routines and to engage them in an activity with other residents. Two consecutive groups of about four to five residents (in total 10 residents) aged 74-95 years meet twice per week in the afternoon to walk a tour on the ground floor of the care-facility. Both are gender-mixed groups, with the first group comprising slower and the second faster walkers. Four therapists (three women, one man, age: 26-33 years) lead the groups. In teams of two, they are responsible for guiding the walking groups one afternoon of the week (Monday group and Thursday group), see table 1.

Tab.1 Overview Walking-Group Participants

	Monday	**Thursday**
Group 1 14:00-14:45	Therapists 1, 2 Participants: A, B, C, D, E Observer X	Therapists: 3, 4 Participants: A, B, C, D, E Observer Y
Group 2 14:45-15:30	Therapists 1, 2 Participants F, G, H, I Observer X	Therapists: 3, 4 Participants: F, G, H, I, J Observer Y

Every Monday and Thursday, the first walking group gathers at 2pm in front of a therapy room on the ground floor. While waiting for all participants to arrive, therapists sometimes engage participants in activities like singing, playing with balls or balloons or talking. The group then walks through the ground floor level of the building. If the weather is nice they also go outside. To give exhausted participants a break, the group stops at resting points, where they can sit down for a while. While walking, therapists try to animate and involve the patients by singing traditional hiking-songs, talking about pictures in the corridors or current happenings. After 45 minutes the group returns to the starting point and the participants of the second group arrive.

C. A robot as a walking group companion – the idea

The major challenges for therapists are to motivate participants for the walking tour, to keep them together as a group due to motivational and conditional issues, to keep agitated/wandering persons within the group and to establish a positive group atmosphere (mood).

To tackle these challenges of walking group therapy, the robot should fulfill the following functions:
- accompanying the walking group
- serving as a source of motivation
- focusing the group
- supporting social interaction within the group by providing something therapists and residents can talk about during the sessions
- providing an acoustic stimulus with playing musical background for singing during the walking periods or playing specific natural sounds in predefined areas of the building that refer to the surroundings (e.g. playing the sound of cow bells in a corridor with paintings showing cows in a field)
- entertainment and activation for the participants during resting periods (i.e. music and a picture gallery).

A specific walking-group software was developed providing these task-elements and an interface for human-robot interaction during the walking-group sessions to enable therapists to easily make use of the robot.

D. Robot and general system set-up

Fig. 1 Scitos robotic platform

For the deployment, a non-holonomic SCITOS G5 mobile robot with a human-robot interaction super structure was used (Figure 1). It is 1.72m tall, has a diameter of ca. 61cm, and is equipped with a SICK s300 laser range finder for navigation, a Kinect like sensor mounted on a pan-tilt unit for people perception, a touch screen on its back and an actuated pair of eyes as a focal point for human interaction. During the walking group, the robot was navigating autonomously using a combination of a Dynamic Window Approach local planner [20] for obstacle avoidance and a Dijkstra based global planner provided by the robot operating system (ROS) navigation stack.[1] On top of this, a high-level topological representation as described in [21] was used, defining not only the resting areas mentioned above but also every other action executed during the walking group at waypoints. The robot's maximum speed during deployment was 0.55m/s, adjusted to

[1] http://wiki.ros.org/navigation

the speed of the quick walkers. To prevent the robot going too far ahead of the slow walking group, certain waypoints were installed where the robot waited for the group to catch up.

E. Walking Group State Machine

For the reliable identification of the therapist and to distinguish them from patients and visitors, we used a version of the WhyCon circular marker tracking system [22]. Therapists accompanying the group had to wear a lanyard with an A6 "control card" showing one of the markers attached to it. Besides identification, this control card was a means of communicating with the robot even from a distance of up to 5m. Whenever the therapists held the card upside down towards the robot's camera during the tour, the robot stopped and the state-machine went into "Control Panel"-state. An administration interface was displayed that enabled staff to start or stop the companion tasks, set the volume for the music and other sound effects of the robot, switch from playing of music to pre-defined nature sounds while the robot was driving, abort the tour, select a specific resting area to go to, or send the robot to the next resting area on the usual route.

The walking group routine was implemented as a finite state machine which can be seen in figure 2 showing the states and their transitions. The stick-figure symbolizes that human interaction is required to transition from this state to the next. The start and end state of each walking group was "Entertain".

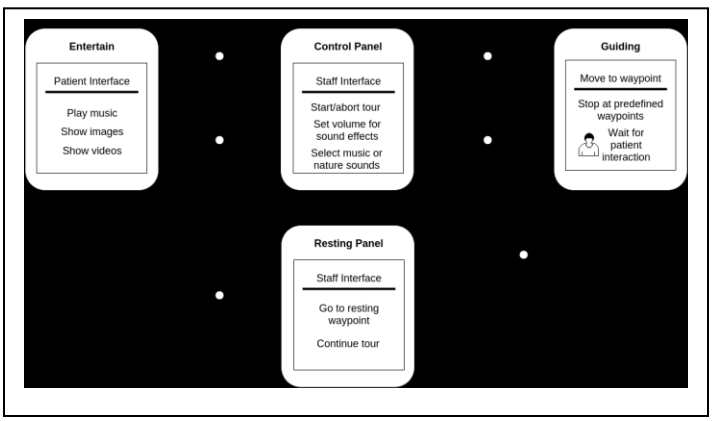

Fig. 2 State machine for the walking group real-life scenario

Before the start of every walking group, the robot was waiting at a fixed waypoint showing an entertainment interface. Staff and patients could choose from either playing music (traditional German hiking songs) or watching pictures of animals used in therapy. This entertainment interface was designed to be as simple as possible and thus only consisted of two layers: the selection menu showing three large buttons for "music" and "pictures" and the actual entertainment window, which showed three buttons for "music" using common symbols from cassette players for "play", "forwards", and "backwards". "Pictures" were presented as an auto-loop through a gallery. With content contributions by the therapists, the robot offered a selection of five songs and eight natural sounds. The gallery featured 20 images. These data files were exchangeable via a back-end especially designed for this deployment.

When started by a therapist, the robot navigated ahead of the group to the next resting area using the described navigation approach. The robot's camera was turned backwards to allow for the tracking of the therapists' control cards. While moving towards the resting area, the robot would cross several intermediate waypoints, some of which were defined as stopping points (one stopping point between each two resting areas) where the robot waited for the group to catch up. To determine if the group was close, the control card was used to calculate the distance to the closest therapist. If this distance was below a certain threshold, the robot displayed a large continue button that could either be pressed by the therapist or a patient. This interactive feature not only encouraged the older adults to interact with the robot under the guidance of the therapist, but also allowed to control the robot's distance to the group and prevented passersby from interacting during a walking session.

During navigation and the entertainment phase, the robot played the same music, trying to stimulate the patients to sing and dance along. If the music was switched off in the administration interface, the robot played pre-defined nature sounds when passing certain waypoints fitting the surroundings (e.g. the sound of cowbells in an area where pictures of cows in a field are hanging on the walls). Whenever an interaction was required, the robot used acoustic feedback via jingles to confirm that a button had been pressed or that it stopped to wait for the group.

Before arriving at a resting area, a waypoint was defined where the robot sought confirmation if the group liked to rest or continue to the next area. This feature was motivated by the fact that some groups need more rests than others. If a rest was triggered, the robot positioned itself close to chairs to allow patients to interact with it while resting.

During each walking group session, the robot was remotely monitored by a technical expert. The navigation, however, was completely autonomous, and interactions between the patients and staff were not guided by an experimenter.

III. METHODS

To evaluate the companion service of the robot during the physical therapy sessions, qualitative and quantitative data were collected using *observations, rating scales, and interviews*. This resulted in a concurrent mixed methods multistrand research design [23]. The application of different methods of data collection is highly recommended in the field of studying HRI [24, 25], as it enables to gain a broader insight into the field of research [23, 26, 27, 28]. Data were collected and analyzed separately for each strand. After analysis the data were brought merged for a meta-inference [23, 29, 30, 31]. The single strands of data collection will be explicated in the subsequent sections.

A. Data collection[2]

To trace back the robot's impact on the walking group, data from periods without and from periods with the robot companion were compared. Thus all strands of data collection started two weeks prior (i.e. pre-assessment) to the deployment, continued throughout, and ended one week after the deployment (i.e. post-assessment).

1) Observations

Every walking group session was accompanied by a member of the research team ("Observer X" on Monday and "Observer Y" on Thursday), who observed proceedings and interactions and protocolled the happenings. No additional video recordings were taken for ethical and data protection reasons. Please note that most of the participants with dementia have official guardians and cannot give reliable consent themselves. For the observation protocol, the routes, occurring errors of the robot, group dynamics and cohesion, communication between therapists and participants, mood and motivation were noted.

Observation was furthermore used to examine the reaction of older adults with dementia to the robot. Due to their severe state of dementia, they were not able to fill out rating scales or provide reliable information during interviews.

2) Rating Scales

After every walking session therapists and the observer filled out a visual analogue scale (VAS). This form of rating scale is an established tool for measuring subjective attitudes and feelings [32]. The scales spanned 10cm, ranging from a negative pole (0) to a positive pole (10). Respondents specified their level of agreement by indicating a position along the continuous line of 10cm between the two respective end-points. Ratings were then measured and transferred into the according percentage of the rating (1cm = 10%). After each session, therapists and the observer rated their subjective impression on atmosphere/mood of the group (poles: aggrieved-cheerful), motivation of participants (demotivated-very motivated), group cohesion (loose-strong), and amount of communication with the participants (sparse-intensive). In the sessions with the robot, five additional questions were presented: To which extent was the robot topic of conversation? Could they involve the robot in the session or was the robot annoying (never-all the time)? And the general perception of robot companion (not good-very good) and perceived utility (not at all-very much).

Data were analyzed using SPSS 22. For changes over time, Friedman tests were applied, and Wilcoxon matched pair tests for session comparisons. Statistical analysis was limited when calculating changes over time for ratings on a daily basis. Due to the small sample size (n=3 raters per group, i.e. two therapists and one member of the research team) Wilcoxon tests were not applicable and just Friedman test results were obtained.

Significance level was set to p=0.1 due to the exploratory nature of this study. No interrater-reliability was calculated and no blinding occurred, because the study did not aim to find out if different raters (therapists) would rate a situation objectively and similarly but focused on the therapists' subjective perceptions of the robot's influence over time.

3) Interviews

After the post-robot session, each therapist team took part in a group discussion. The basis of the discussion was a questionnaire guideline with 15 open ended questions[2] about their experience with the robot during the physical therapy. The discussions were sound recorded and transcribed. The transcribed texts were analyzed using the f4-analysis software following the analysis procedure of [33, 34].

IV. RESULTS

Findings from all three strands of data collection will be presented to answer the leading research questions.

A. Experience of therapists

1) General attitude towards the robot: The interview analysis revealed that all four therapists had a positive attitude towards the robotic companion prior and at the beginning of the trials. They thought the robot to be "funny", "cool" and "exciting". Therapists mentioned that the robot also had a positive charisma for older adults and that most participants reacted positively to its presence. It was observable that especially the music created a very engaging atmosphere, with therapists and residents singing along, laughing, clapping their hands or swaying to the rhythm of the music. All four therapists appreciated the entertainment function of the robot during resting situations with its music and the picture galleries.

2) Human Robot Interaction:

a) Therapists: Three therapists considered the handling of the robot easy. One mentioned that she had difficulties to control the robot in the beginning and therefore did not always activate all its functions during the resting periods. Therapists also appreciated that the robot recognized them as reference persons. The only aspect that was tedious for them was to always show the card to adjust the music volume. One therapist stated that she found it tedious that the robot stopped every couple of meters, which made it necessary to press the continue-button again and again.

b) Older adults with dementia: Most of the older adults did not start interaction on their own. Only a few went to the robot's screen and pressed on it randomly. Therapists explained that older adults are not familiar with using touch screens, and thus they either press too hard or they press and do not let go again. Therapists claimed that older residents with dementia would not be able to manage the menu on their own. In order to facilitate a meaningful interaction, the therapists had to give instructions. Thus interaction between

[2] Please find material of data collection provided under this link: https://lcas.lincoln.ac.uk/owncloud/index.php/s/taqrUQBiW3SUxh6

patients and the robot very much depended on how much therapists engaged and encouraged the residents. Personalizing the robot and calling it by a name made this easier for the therapists. During resting situations therapists engaged the older adults to start and run the picture gallery.

3) How therapists made use of the robot: Interviews and observations showed that therapists engaged the participants in using the robot (e.g. pressing the 'continue' or 'resting' button, going through the picture gallery). Both sources of data indicate that the participants who actually interacted with the robot liked the interaction. Yet, as was observable, the two therapist-teams made use of the robot slightly differently: the Thursday therapists activated the music already during waiting situations, singing or dancing to the robot's music. Also during the walks they made use of the music stimuli. During rests they encouraged older adults to look at the picture gallery and sing to the songs played by the robot. The Monday therapists did not activate the robot during the waiting phase before walking. During walking they rather played natural sounds than hiking songs, but played songs sometimes during resting or looked at the picture gallery.

4) Problems and difficulties during the trial: Since this was the first trial in which a long-term autonomous robot was deployed in such a real-world scenario, technical difficulties occurred. Sometimes the robot lost navigation, especially when obstacles (e.g. beds or wheelchairs in the corridors) blocked its way. In that case, the robot stopped, ran recovery and used time for new path planning. Other problems occurred due to a bad Wi-Fi connection within the building so that the picture and music galleries were not always accessible during the resting periods. Sometimes the robot did not respond immediately to the therapists' control-card. Observation protocols showed that the failure intensity differed between the Monday and Thursday group. For the Thursday group the robot worked well during the first session. However in the successive sessions, technical problems became more frequent (i.e. navigation problems or WiFi problems) and even severe during the last session. In contrast, the Monday group was faced with severe navigation problems at the beginning, which slightly improved for the subsequent sessions.

5) Therapists' perception of navigation failures: Therapists were not satisfied with the navigation behavior of the robot. One thought it was strange that the robot sometimes drove in certain curvy lines and circles during its recovery attempts although it would have had enough space to follow a straight line. One therapist claimed that she could not understand why the robot was not able to learn that ways are blocked at given times and how it could navigate around possible obstacles. All four therapists reacted very sensitive to navigation failures and mentioned that these failures threaten to overshadow positive aspects of the robot's walking-group service.

a) Therapists' perception of other technical failures: All four therapists stated that handling the robot in case of technical problems was an excessive demand. One of them mentioned that they have to do "100,000 other things" during the walking sessions, such as looking after or caring for participants. Thus, situations where technical problems occurred were perceived as very tedious or annoying. The impact of technical failures was also reflected in the therapists' "annoyance" ratings, which significantly increased for the Thursday group facing a well working robot at the beginning but then increasing problems over the subsequent sessions ($p=0.05$). Thus ratings of Thursday therapists for utility decreased over the course of the robot's deployment ($p=0.05$).

b) Therapists' comments on the robot's behavior: Three negatively perceived aspects during the procedure of the walking sessions were addressed. All of those can be referred to as a lack of flexibility in the system. One therapist team claimed that the robot was not flexible enough. They had to adjust to the tour of the robot, to its speed and to the running order of its songs. Hence, the therapists could act less spontaneously in the organization of the walking group sessions. This was also observable, as the tours differed from time to time in the pre- and post-robot phase, with tours also taking place outside the building. During the robot sessions, the tours always had to follow the same route of the robot inside the facility. Another lack of flexibility identified by therapists regarded the robot's speed. The condition of the participants varied, even within the same group (slower and faster walker), so that the robot was perceived too rigid in its velocity. Thirdly, not all of the residents could be engaged with the robot at once. During resting periods, for example, the robot stopped on a predefined spot and could not be flexibly sent to different resting persons. Thus just one or two residents, who had to approach the robot, could interact with it simultaneously.

c) Other difficulties during the walking sessions: As the conditions of older adults with dementia can vary from day to day, walking group procedures and dynamics can also vary. Besides that, health conditions of participants can set limits to the proceedings of the walking group. Especially Monday groups faced many incidents with participants getting sick, feeling dizzy, and having respiratory problems or difficulties with eye sight. In their second robot session, one of the participants got lost, so that the session had to be stopped.

B. The robot's influence on group dynamics

The interview analysis showed that therapists perceived the robot as a useful tool for entertaining walking group participants, if it functioned reliably. Both therapy teams stated that certain residents profited from the presence of the robot. Especially one very restless participant, who hardly stayed with the group, was very interested in the robot and reckoned it as a point of reference during walking. Another participant had difficulties to communicate and connect with the group because of only speaking her foreign mother tongue. She benefited from the robot's presence and its music offer which allowed her to increase the degree of her social interaction. It was furthermore noted that other participants were also very curious about the robot, looking at it, talking about it, asking questions about it or trying to press buttons on the screen. Four participants did not seem to be directly influenced. They were just watching but did not try to interact.

Rating data for the Thursday group showed that therapists involved the robot more during its first deployment, and significantly less afterwards (p=0.05). Furthermore, significant differences in group coherence, (p=0.048), motivation (p=0.021), and for atmosphere (p=0.055) were found for the Thursday group when comparing the walking group sessions (Figure 3). Due to the small sample size, no post-hoc comparisons between pairs of sessions could be analyzed, but medians show highest ratings for all three differing variables, i.e. coherence, motivation, and atmosphere, in the session where the robot was deployed for the first time (i.e. session 3 in Fig. 3). The robot worked well on that occasion, as opposed to the sharp decline thereafter (session 4 and 5 in Fig. 3) with increasing technical problems.

The pattern of the Monday group looks different: ratings for group coherence (p=0.05), positive group atmosphere (p=0.05), group communication (p=0.05), as well as ratings about how much therapists talked to the participants (p=0.074) seemed to increase in the course of the sessions with the highest difference between session 2 (pre-assessment without the robot) and session 7 (post-assessment without the robot). For the sessions with the robot (i.e. session 3 to 6 in Fig.4) the first one with intense technical problems had the lowest ratings, while the other 3 sessions in which the system worked slightly better show also slightly better ratings (although with some variance).

C. *Therapists' feedback on the utility of the robotic walking group service*

Therapists differentiated between the utility in terms of *supporting their work* with the patients and the utility in terms of *entertainment*. In regards to the first aspect, all four therapists stated that for real demanding tasks the robot's utility was very low. Problems mentioned in this regard were, for example, supporting participants (as a kind of walking aid) or bringing water when they get dizzy. Furthermore the perceived utility of the robot was quickly limited when technical problems occurred. In such cases, the robot was perceived as "another dementia patient" therapists had to look after. This resulted in over exhaustion of the therapists because looking after the participants is already very demanding. Nonetheless, therapists perceived the entertainment function of the robot as a useful tool, which allowed them to hand over some of their own entertainment activities to the robot, thus feeling relieved in this regard.

V. Discussion

This study aimed at evaluating a new deployment area for long-term autonomous robots in elder care. For this real-world trial, a robot was deployed for the first time as a companion for physical therapy walking groups of older adults with advanced dementia. The leading questions of research addressed the therapists' experience with such a robotic companion, how the presence of the robot influenced the dynamics of the therapy group and how therapists perceived the utility of this robot task. To answer these questions a mixed methods study design was chosen. Three strands of data were collected: observations, interviews and ratings.

Findings indicate that older adults with severe dementia

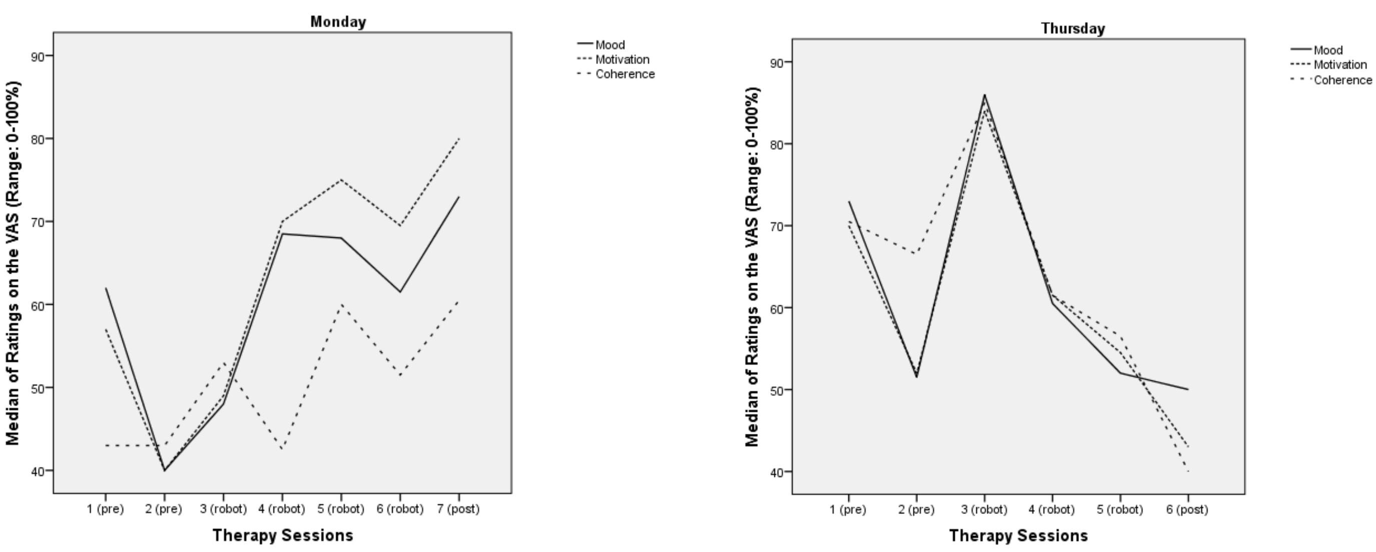

Fig.3 The graphs depict the medians of subjective ratings of therapists and observers across slow and fast patient groups for overall atmosphere/mood (0=aggrieved, 100=cheerful), motivation (0=demotivated, 100=very motivated), and group coherence (0=loose, 100=strong) over the course of the sessions. Therapist team "Monday" (seven sessions) and "Thursday" (six sessions) were analyzed and visualized separately because of differences in robot performance leading to different ratings.

had a neutral and positive attitude towards the robot and that therapists had a positive attitude towards the robot, in particular before and at the beginning of the trial. Therapists considered the robotic walking group companion useful in terms of passing their entertainment endeavors partly onto the robot. To make use of the robot, patients suffering from dementia need encouragement and guidance. The acoustic stimulation during the walking sessions had a motivating effect on some of the participants by animating the patients to sing, dance and sway. However, there were also some participants who did not actively engage with the robot.

Our findings furthermore elucidate the close link of user experience and proper, robust functioning. In the Thursday group, which was confronted with increasing malfunctions over sessions, therapists perceived the robot as more annoying and less useful in sessions where more errors occurred. Their ratings for group motivation and group coherence decreased over the sessions, probably due to the malfunctioning of the robot. Malfunctions of the robot quickly constituted an excessive additional demand for therapists who primarily have to take care for the dementia participants. Thus, differences in the results for the Monday and Thursday groups can be explained by the Monday groups having started off with more errors and experiencing a system becoming slightly more stable over time, whereas the Thursday group experienced a very stable system in the beginning and ended with a higher error rate. The high ratings in the post-robot session in the Monday group could either be a result of the therapists' relief that the robot was no longer present or due to the exceptional lack of any incidents with participants (e.g. sickness, participants going astray).

Requirements and areas of improvement addressed by the therapists concern higher flexibility of the system: routes, music offer and the possibility to freely send it to different locations, e.g. during resting times so that more participants could make use of the robot. Furthermore, a more flexible speed adjustment would be required to meet the varying needs of this specific end-user group.

Some recommendations for future implementation of such a robotic companion can be derived from our findings:

1) Stable navigation and functioning: to ensure a positive perception of the robot, and thus higher utility, it is most important that its navigation and path finding function work reliably. Errors in this domain irritate end users and clearly disturb the therapy session and work of therapists, which in turn impacts the perceived utility of the robot's task.

2) Flexible route planning: to allow spontaneous actions during the walking group sessions and introduce variation, the robot should be able to adapt its route according to the therapists' plans.

3) Flexible behavior: end users should be able to send the robot to different places, e.g. to stop in front of different users during resting situations and not just navigate between pre-defined waypoints. That way, the robot could be used more flexibly and also be engaged for more spontaneous requirements.

4) Flexible speed adjustment: as the condition and physical state of older adults with dementia can vary from time to time, it would be necessary for the robot to adjust its speed accordingly. This would make it possible to have the robot really going *with* the group instead of being ahead of everyone.

5) Consider such services for single patient sessions: mood and physical shape of older adults with dementia can vary from session to session. Thus, a robotic walking group companion for single-client therapy sessions in which the therapist is able to adjust the robots behaviour to the individual needs and is thus even better supported by the robot, would probably provide an alternative with high utility.

VI. Limitations

Limitations of the study concern the small sample size of only 4 therapists (two per group), which reduces the meaningfulness of the statistical analysis. We are aware of the fact that significant results should be interpreted with caution and cannot be generalized. Such shortcomings, however, were made up for as good as possible by using different data sources within a mixed methods design. Technical failures during the single walking sessions, as described, certainly also strongly influenced the therapists' experiences.

Nonetheless, the approach of our study and the data gained from it serve to highlight possibilities, as well as limitations of deploying a robot in a real world context like this therapeutic walking group. In addition to that, they point to new areas and improvements for investigation in future work.

VII. Conclusion

In summary, this study showed that there might be potential in deploying a robot for therapeutic walking groups with older adults suffering from dementia. Robustness and reliability of basic functionalities like navigation and path planning are important. Moreover, it is also crucial to develop flexible robotic systems that can adapt to the varying demands of end users occurring in a real-world scenario. If the system fulfills these requirements, a robotic companion could be especially useful for providing entertaining stimuli, as a point for orientation focusing participants' attention, and as a positive influence on group coherence and, as tendencies show, also atmosphere within the group.

Acknowledgments

The authors wish to thank the therapists and older adults for their participation, as well as Markus Weninger for his support in data collection. Furthermore, we would like to thank members of staff for their interviews and participation in our workshop, and the STRANDS project partners for contributions. The research leading to these results has received funding from the European Community's Seventh

Framework Programme under grant agreement No. 600623, STRANDS. (http://strands.acin.tuwien.ac.at/).

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