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Robotic Assistance in Nursing Care: Survey on Challenges and Scenarios

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Abstract—Robotic assistance in nursing care is an increasingly important area of research and development. Facing a shortage of labor and an increasing number of people in need of care, the German Nursing Care Innovation Center (Pflegeinnovationszentrum, PIZ) aims to address these challenges from the side of technology. Little is known about nurses experiences with existing robotic assistance systems. Especially nurses perspectives on starting points for the development of robotic solutions, that target recurring burdensome tasks in everyday nursing care, are of interest. This paper presents findings focusing on robotics resulting from an explanatory mixed-methods study on nurses experiences with and their expectations for innovative technologies in nursing care in stationary and ambulant care facilities and hospitals in Germany. Based on the findings, eight scenarios for robotic assistance are identified based on the real needs of practitioners. An initial system addressing a single use-case is described to show perspectives for the use of robots in nursing care.

Keywords—Robotics and automation, engineering management, engineering in medicine and biology, medical services, public healthcare.

I. Introduction

ensuring nursing care is one of the biggest humanitarian challenges of the future. The use of innovative technology is a promising way to counteract the already prevailing shortage of nursing staff and increase of patients requiring care, which incorporates innovative approaches grounded in robotics and human-technology interaction. In recent years, many innovative technological developments have been promoted in the care context. Their integration into everyday nursing practice has so far only been very selective.

A participative design process is absolutely necessary for the nursing care domain [1]. Otherwise, caregivers and patients often reject the implementation of innovations in their everyday life. At the same time, the technical qualifications of nursing care practitioners have to be elevated to put innovative technologies to good use [2]. The benefits and challenges of new solutions in the field of human-robot interaction in nursing care have so far been studied on a case-by-case basis only.

Systematic research approaches are needed to adequately include formal and informal caregivers, persons in need of care, and the conditions of use – but also ethical and legal issues – when developing new solutions and implementing them in nursing practice. Context-specific conditions in different supply settings have to be considered. This is the research and development focus of the project PIZ (*Pflegeinnovationszentrum*, Innovation Center of nursing care), funded by the German Federal Ministry of Education and Research (BMBF). The goal of PIZis to analyze needs for innovative technology in nursing care practice and facilitate the transfer of new technological solutions into practice while incorporating considerations on ethics and responsibility in the entire research process. Within this scope, PIZevaluates available solutions and performs research and development for new nursing care technology. To aid transfer into practice, PIZalso develops qualification programs and outreach to practitioners. PIZis funded within the ”Bringing Technology to the Person” initiative [3], which focuses on integrated technology development with priority on use-cases and users. The technology being developed is intended to support and relieve the nursing staff as visualized in Fig. 1.

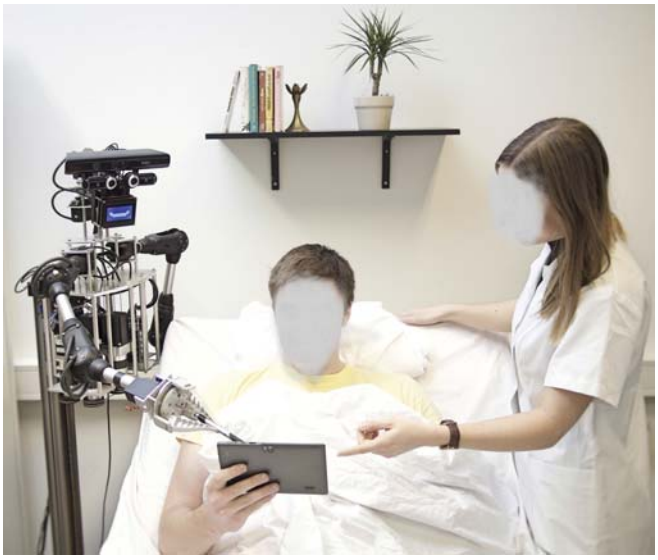


Fig. 1 An ideal scenario: Robots cooperate with the care professional and patient in an intuitive way. This is the vision of the robotics efforts of the German federal nursing care innovation center

PIZfollows a rigorous participative design and development methodology. As a first step towards useful and accepted robotic assistance systems, promising scenarios for robotic assistance were to be identified. This paper presents the initial findings focused on the robotics technology of a large explanatory mixed-methods study (n=1335) among care professionals in Germany.

Specifically, the paper contributes:

- Qualitative evidence of sentiments and requirements from

nursing practitioners.
- Eight scenarios for robotic assistance in nursing, identified through a qualitative analysis of the said the large study.

II. Related Work

Related work can be grouped roughly into two categories. The first addresses acceptability and usability issues in nursing care. The second focuses on specific robotic solutions to individual care activities.

Even though robotic systems belong to the most frequently researched technology categories in the context of nursing care, nurses experience with and perspective on robotic assistance has been mainly addressed by prior research by assessing technology commitment, technology acceptance or usability aspects [4]. Few authors address an analysis of tasks applicable to robotic assistance systems in nursing care. Some of them consider only general requirements on the robotic system [5]. Chen and Kemp [6] investigate the question of which activities are often performed by caregivers and how much they enjoy these activities. Nejat *et al.* [7] survey the use of assistive robots in health care, as well as their strengths and limitations. Hülsken-Giesler and Daxberger [8] describe requirements and evaluation criteria for nursing care robotics from a perspective of nursing care science.

Others investigate the possible applications of mobile autonomous service robots for specific care activities. Here, the focus is less on requirements and needs, but more on system evaluation. Dubowsky *et al.* [9] focuses on mobility assistance with a semi-automated walker, including multiple sensors for navigation and health assessment. Park *et al.* [10] develop a mobile robot which is to perform entertainment functions for elderly people. The Care-o-Bot platform [11], [12] aims at a variety of tasks, starting from fetch-and-carry to entertainment. This platform has been experimentally evaluated for several tasks, some of these in the field. Chen and Kemp [6] investigate physical interaction between a nursing care robot and professional nurses. A participative design process of a teleoperated assistance robot for the elderly is described by Michaud *et al.* [13]. Recently, the research topic of social robotics for care applications has gained more popularity [14]. Especially the mass-produced social robot Pepper is used for research regarding human-robot interaction, e.g. for the social interaction with dementia patients [15].

One particularly important field of assistance in nursing care is physical relief. This topic plays a major role when it comes to the early retirement of nurses due to health issues, aggravating the care crisis [16]. Previous work was able to show that the physical stress on the lumbar spine of nurses is often exceeding the limit while carrying out nursing activities [17]. One exemplary robotic system for physical support is the RoBear companion [18]. This robotic companion resembles an automated patient lifter and can help during the transfer process of patients from bed to chair or from bed to bed or vice versa.

Despite sizeable previous work as described above, to our knowledge, no rigorous open-ended investigation and identification of specific scenarios for robotic assistance involving nursing care practitioners seem to be reported in the literature.

III. Explanatory Mixed-Methods Study

An explanatory sequential mixed-methods design was used to explore nurses experiences with innovative technologies in everyday practice. By combining quantitative and qualitative methods of data collection and analysis, this allows for a complex approach to and a deepened understanding of the research topic [19]. Initial literature reviews to categorize and differentiate technology categories (results are published elsewhere [4]) and on national prior surveys on nurses' experiences as well as interviews with experts from nursing science and practice guided the development and pretest of an online survey.

The final survey items included 21 polar and 10 open questions which addressed experiences with and rating of technologies that have been used by the participants in everyday nursing practice, barriers and facilitators for technology use in practice, the need for technology use in nursing practice, and recurring burdensome nursing tasks (regardless of whether a technological solution is already known or seems likely). Questions on socio-demographic and professional characteristics (such as duration of practice in nursing and vocational position) as well as a short-scale on technology commitment [20] were also included. Invitation to participate was sent by e-mail to 19000 directors of nursing in stationary and ambulatory long-term care facilities and hospitals throughout Germany.

Descriptive results of the online survey were used in semi-structured focus group discussions with 14 nurses and nursing executives to facilitate discussion about experiences and prospective use-scenarios for innovative technologies. Participants of the focus group discussions initially took part in the online survey and agreed to further participate in the study. The focus group discussions followed a pre-developed proceeding: After an introduction to the study, participants were confronted with results from the online survey (one-page handouts and presentation slides) from which discussion on the topics perspectives on future use, technological assistance in everyday nursing practice, disuse of technology and effects on nursing practice was guided by two members of the research team. Opening questions on the topics were phrased in a standardized manner throughout the groups with the addition of further pre-defined questions according to the dynamic of the discussions. Hereby, participants commentaries could be taken up by the moderators and explored in depth. One member of the research team chaired the discussion with a second person writing minutes on the discussion process. Those minutes, together with digital recordings of the discussions as well as metaplan cards with highlighted aspects of the discussion were included in the data analysis.

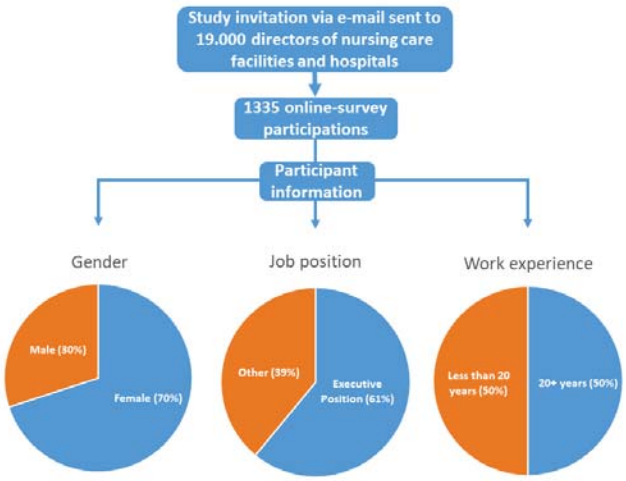


Fig. 2 Visualization of the number sent invitations, the actual number of survey participations and selected participant information

Quantitative data from the online survey were analyzed descriptively by using R version 3.6.1. The qualitative data were analyzed using MAXQDA 2018. Furthermore, the qualitative data from the focus group discussions and the online survey was deductively structured in categories following the lead questions of the respective data collection. Data on the online survey was further summarized and structured inductively. Data from the focus group discussions were structured using the method of key statements which were addressed repeatedly by the participants [21].

This study received approval by the ethics committee of the German Society for Nursing Science (DGP).

IV. Nurses' Experiences with and Perspectives for Robotic Assistance

1335 persons participated in the online survey from March to May 2019 (see Fig. 2). Depending on the given answers and filter options, the number of the reported sample size for single items may vary. About a third of participants answered items on socio-demographic characteristics. Of those, the majority is female (70 %), and 61 % work in an executive position such as director of nursing (DoN). 50 % are working in ambulatory care, have been working in nursing practice for more than 20 years, and are between 45 and 54 years of age and participated out of all federal states of Germany.

94,8 % (n=1018) reported practical experiences with innovative technologies. 7 % of 1074 persons who reported experiences with specific technology categories have been working with robotic technologies in nursing. Regarding types of robotic assistance, experiences mainly encompassed emotional and communication robots (both 29.9 %), followed by service robots (13.8 %). Experiences with other robotic systems, such as robots for transportation or wearable robotics were scarcely reported.

Focusing on perspective use of robotic assistance in nursing practice, 5,9 % (n=49) of 825 open answers of the online-survey contained specific mentions of robots and applications for robotic assistance of which 48 were eligible for analysis. 13 answers were unspecific and expressed the need for robotic assistance without describing scenarios. 12 answers described scenarios on a more generalized level, such as robots for support of nursing tasks in everyday practice, robots for social engagement and activities or robots, that take care of housekeeping activities. 23 answers described specific scenarios for robotic assistance. The following scenarios were repeatedly highlighted by the participants:

- games, engagement, and activities (cognitive stimulation and communication),
- offering and handing over of food and drinks, assistance with eating and drinking,
- support of functional mobility (Turning and positioning of a person in the bed, positioning from bed to (wheel)chair, to stand, to walk, transportation of persons),
- washing and bathing a person,
- making the bed,
- measuring vital signs including documentation and sharing information with nurses
- tracking persons and
- supply with and disposal of materials (laundry, stock material, litter, and waste).

The focus group discussions took place at three study sites in Bremen, Berlin, and Munich in May and June 2019 with 14 participants from seven federal states whose socio-demographic and professional characteristics matched those of the participants of the online survey. Robotic assistance was addressed specifically regarding support physically burdensome tasks:

> "What would really be helpful for nurses is robotics in regard to exoskeletons [], how can we achieve to go easy on nurses' resources? [] it is helpful to have something that enhances my muscular strength."
> [Head-Nurse, hospital setting, translated from German]

But participants also voiced critical considerations on robotic assistance in nursing practice more prominently than respective thoughts on other technologies:

> "Robotic assistance itself is expedient. But not robotics as in fully-automated but as in complementary."
> [Head-Nurse, hospital setting, translated from German]

The need for relief of the strain of burdensome physical tasks was repeatedly emphasized in the qualitative sections of the online survey and the focus groups as well.

V. Identified Scenarios

In the following, the identified scenarios where robotic assistance was seen as beneficial are explained in more detail.

The scenario *games, engagement, and activities* involves the engagement of the patient to maintain the cognitive ability and stimulate communication. This makes it easier for caregivers

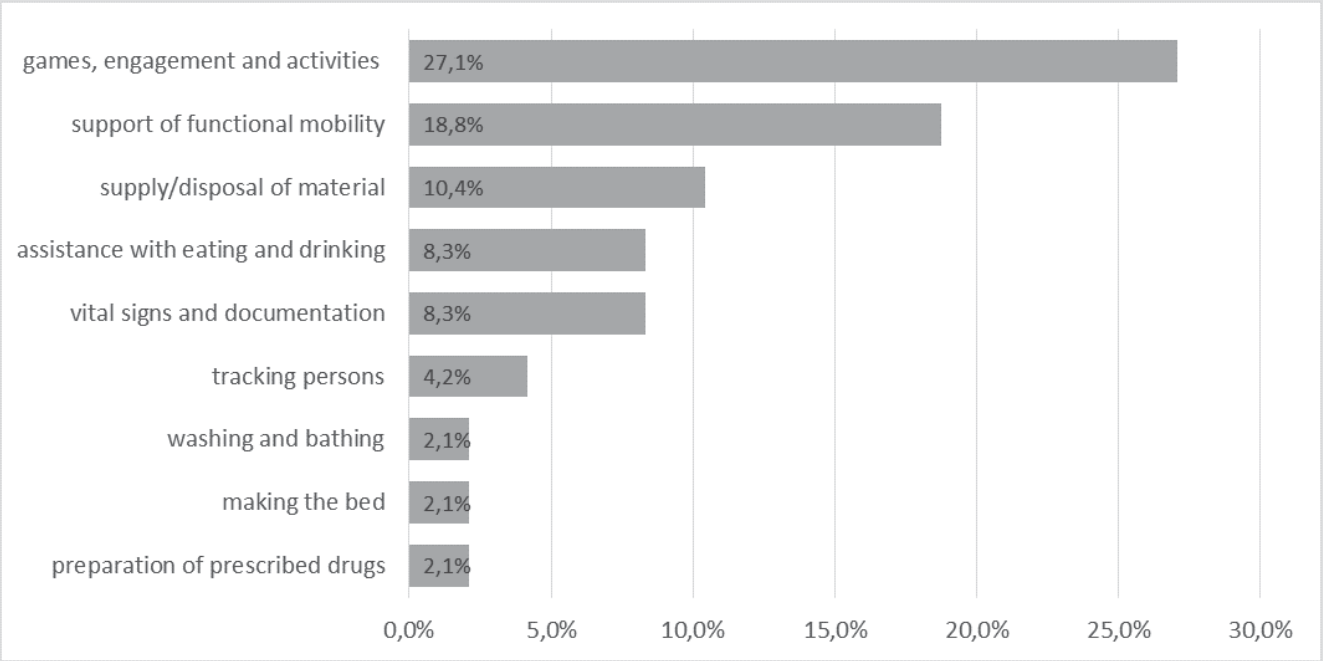


Fig. 3 Proportion to all coded segments for robotic assistance (n=48)

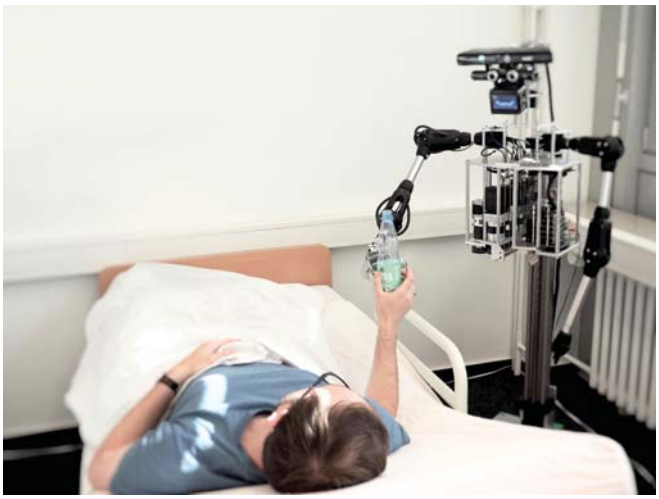


Fig. 4 Example scenario of a robot serving water

to establish a relationship with the patient and facilitates the understanding of the patient's statements and needs. Another goal is to counteract increasing frailty by the motivation to perform physical activities.

The scenario *Offering and handing over of food and drinks, assistance with eating and drinking* enables the patient to be served a glass or bottle of water or some food autonomously, as shown as an example in Fig. 4. The drink may be stored on the bedside table, for example, but not within reach of the patient. Another important function here may be to remind the patient to drink, e.g. for patients with dementia. This often happens because bedridden patients have limited mobility. Also, the process of reaching for food should be supported. This can be important in cases of limited mobility or tremor.

The scenario *Support of functional mobility* resembles one of the key issues in nursing and thus has to be dealt with more thoroughly. As it was already stated in previous research work by Glaser and Höge [16], physical overload in everyday life during nursing activities leads to early retirement. Moreover, previous work by Jger *et al.* [17] has shown that the forces acting on the lumbar spine during the main activities of the nurse in bed exceed the permitted limits for healthy and ergonomic work. For this reason, robotic approaches to aid in lowering physical stress limits are urgently needed. While the automation of all activities within this broad field is an extremely complex undertaking, individual activities can first be automated to support the nurse. One important use-case of this scenario is turning the patient and securing on the side where he or she was placed by the nurse. This is done frequently by the caregivers to perform cleaning tasks, reapply bandages, or change bedsheets. Usually, a second nurse or positioning aids are required for this activity, but often it is hard to find someone to fill this support role even in a hospital. This use-case seems to be the most promising to tackle first, as it has a large potential impact on both care efficiency and physical relief for the caregiver.

The scenario *Washing and bathing a person* is performed depending on the patient's mobility in bed or bathroom. Depending on the patient's mobility and activity, the assistance of a second person may be necessary in both cases. The scenario consists of hair and body washing as well as intimate care. These can get an additional degree of complexity from the patient's wounds or pain.

The scenario *Making the bed* is very different depending

on the mobility of the patient. For a bedridden patient, this includes the user scenario *Support of functional mobility* completely included. The patient is placed in one half of the bed while the other is moved into a new position. Then the side is changed. With mobile patients, this patient leaves the bed first. Both variants are physically very stressful, see Friday et al. [22]. Here also a problem of the care hits on the desire of the care forces to hand over this work to a robot.

In addition to monitoring vital data with a patient monitor, the scenario *Measuring vital signs including documentation and sharing information with nurses* also includes the additional measurements required, such as temperature, blood gas, or other blood values. Frequently, all data still has to be manually transferred to the patient file. Another aspect of this user scenario is the compact transfer of the development of the values and particular anomalies during the shift of a nurse to the transferee. The transfer represents a risk for the receipt of the most important information and thus for the optimal care of the patient.

The scenario *tracking persons* means that the robotic system should always know where the patient is. This is particularly necessary for people with a tendency to run away. These mostly disoriented and needy persons must otherwise be tracked and retrieved by nursing staff. As a result, they lose time for other important tasks.

From the scenario *Supply with and disposal of materials*, nursing staff expects their material trolley to be constantly filled automatically with all the necessary utensils and its waste bin to be emptied automatically. Also, there should always be a trolley near the nurse when she needs it. Missing materials can lead to long interruptions in patient care, as extra journeys to the camp are required.

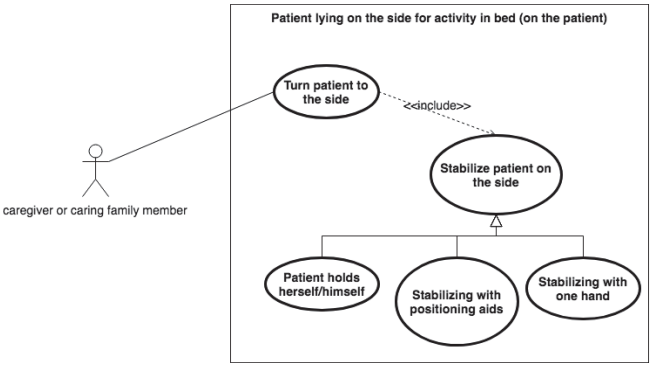
VI. Exemplary Use-Case Analysis

As an example of further use-case analysis, we focus on the scenario *Support of functional mobility*. In particular, the task *Turning and positioning of a person in the bed* seems to be the most promising to tackle first, as it has a large potential impact on both care efficiency and physical relief for the caregiver. This task would be performed several times a day by the system since a large number of nursing activities are supported by it. A more thorough use-case analysis of all identified activities will be the subject of future work.

One important aspect of this activity is securing the patient lying on the side. This is done frequently by the caregivers to perform cleaning tasks, reapply bandages, or change bedsheets. This use-case is dubbed *Patient lying on the side for activity in bed (on the patient)*.

First, the user scenario is considered, as shown in Fig. 5. The current regular procedure of the activity is as follows [23]:

1) Patient turns to the side or is turned by the nurse to the side
2) Patient stays on the side or is secured by a nurse or positioning aids on the side
3) Nursing staff carries out the task



(a)

(b)

Fig. 5 (a) Example use-case diagram for *Patient lying on the side for activity in bed (on the patient)*. (b) First demonstrator for this use-case in the Living Lab IDEAAL for home care at OFFIS

This use-case as depicted in Fig. 5 offers the main assistance potential in the step *Stabilize patient on the side*. The patient can not usually hold him/herself on the side without help, thus either external positioning aids or manual stabilization by the caregiver is necessary. Positioning aids, such as shaped cushions, usually impair the task which made the repositioning of the patient necessary. Finally, manual stabilization at the very least costs a hand that would be useful in the final task and is usually quite strenuous.

This scenario requires a robotic assistance system that can exert enough force to stabilize the patient. A simple start

command by the caregiver or an action recognition system could trigger the start of the assistance task. The assistance system must be able to recognize the patient's posture, identify a suitable stabilizing grasp, and perform the stabilization.

Assistance must be provided quickly from the moment the caregiver requests assistance or such intent is recognized. Responses by care professionals indicate that the caregiver must not get the feeling that he or she has to wait for the system. It is important for the patient that the stabilizing grasp of the assistance system is no more unpleasant than it would be by a human being.

Fig. 5 shows an early prototype assistance system for this use-case on the right.

VII. Conclusion

Nursing care is a prime application of close human-robot collaboration, which will become very important as demand increases. Acceptance by the care professionals and patients is key, so the respective groups need to be involved in designing corresponding robotic assistance systems.

This paper presented findings from an explanatory mixed-methods study on nurses' experiences and perspectives on innovative technologies and robotic assistance in nursing practice. These scenarios identified in this study serve as a reference for further research and development efforts.

It is evident that awareness of possible robotic assistance is not widespread in the nursing community. Only 7% of respondents declared experience with robots in their nursing practice. We see a large potential in awareness-raising and outreach activities to increase this number.

VIII. Future work

In future work, we will evaluate the study further and analyze the user scenarios in detail. Also, we will identify robotic solutions and develop prototypes to investigate their feasibility. In particular, the support of functional mobility will become one of our focal points.

Acknowledgments

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