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Exploring needs and challenges for AI in nursing care – results of an explorative sequential mixed methods study

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Abstract

Background and aim While artificial intelligence (AI) is being adapted for various life domains and applications related to medicine and healthcare, the use of AI in nursing practice is still scarce. The German Ministry for Education and Research funded a study in order to explore needs, application scenarios, requirements, facilitators and barriers for research and development projects in the context of AI in nursing care.

Method A sequential explorative mixed methods study including a stakeholder and expert workshop ($N=21$), expert interviews ($N=14$), an online survey ($N=53$) and a Datathon ($N=80$) was conducted with an emphasis on qualitative data.

Results Needs and application scenarios encompassed the micro- and meso-level of care and derived from typical phenomena inherent to nursing care as well as from skill- and staff mix and consequences arising from staff shortages, from the extend of informal care and an associated need for information and education of informal caregivers and nursing assistants. Requirements for and characteristics of successful research and development projects included regulatory, processual, technological, ethical and legal aspects and supportive eco-systems.

Conclusion A key element in the design of research projects remains participatory and demand-driven development that aims to bring AI solutions out of the lab and into practice. However, influencing factors remain that are outside the sphere of influence of individual projects, in particular the creation of resilient legal foundations for data use and the use of AI in practice, standardization of data structures and the establishment of infrastructures for data exchange across institutions and projects.

Keywords Machine learning, Nursing care, Hybrid systems, Expert systems

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Background

While artificial intelligence (AI) is being adapted for various life domains and applications related to medicine and healthcare [1–3], the use of AI in nursing practice is still scarce [4]. In this context, AI can be defined as algorithms enabling learning from data sets to achieve intelligent, goal-oriented action [5]. The potential for AI applications in nursing care, which might use prominent types of AI approaches such as machine learning (ML) or expert or hybrid systems, has been shown and discussed previously [4, 6–9]. For example, numerous studies report on data-based pattern identification through ML as a means of data analysis by algorithms [10] for automated planning and scheduling of nurse rotations or image and signal processing to detect falls or changes in activity or mobility patterns of patients [4]. Expert systems can mimic the reasoning of a human expert, who would solve a complex problem, by applying predefined if–then rules drawing on a specific knowledge base [11] and a rule-based reasoning engine [10]. Expert systems are utilized to support clinical decision-making and case-based reasoning [12, 13]. By integrating ML with expert systems, hybrid systems combine different AI capabilities [14–16] but are considerably less often developed for application in nursing care than ML based applications or expert systems [4].

Frequently reported application scenarios for AI in nursing care include hospital and intensive care settings, such as reducing (false) alarm rates, diagnosing early deterioration or sepsis or predicting complications [17–20], where a sufficient amount of electronic medical, nursing, or health record data as well as real-time sensor data on vital parameters are available [4]. AI applications to support independent living at home that mostly utilize sensor data on movement and other activities obtained from smart home environments or wearables are also developed fairly often [4]. Even though some AI solutions have been developed for the long-term and home care sector as well as for the application in educational settings, the latter settings can be considered less frequently addressed by research and development (R&D) [4, 21]. Despite a growing literature base on proof-of-concept or case studies, little evidence on sustainable implementation of AI in nursing care and long-term effects for nurses, informal caregivers, patients or organizations have been reported [4, 21, 22].

R&D projects in the field of AI and nursing care are facing multiple obstacles inherent to technology development and implementation in health care [23]. Those include different or low degrees of digitization of care facilities, especially in settings outside of hospitals which is not only accompanied by a lack of data but also by a lack of respective infrastructures. In settings where either

only limited data is available or recorded, AI-related skill gaps in the field of data engineering and data analytics can also impede an effective development of AI applications [24]. Factors influencing the success of R&D generally described as crucial for technology development and implementation in health and nursing care, such as acceptance by staff and patients, implied changes in staff roles, practices and identities or an organizations' capacity to innovate [25] also have to be considered by researchers. And even though AI R&D for nursing care basically refers to general AI R&D and respective initiatives in medicine, nursing care-specific adaptations that take into account core nursing values [6] and theoretical nursing models might be necessary. Considering the fact that a considerable amount of research on AI in nursing does not involve nurses or nursing scientists in the development process [21, 22], the demand for participatory research that includes relevant stakeholders as early as the topic identification and focus setting phase to achieve a more user-centered development that addresses issues concerning the clinical reality of nurses [22] increases. As of today, stakeholders' perspectives on AI R&D for nursing care have rarely been systematically described. Knowledge of the needs for and challenges of AI R&D for nursing care contributes to planning and conducting successful research projects that aim to achieve real-world impact.

Against this background, the German Ministry for Education and Research (BMBF) launched a national funding program for research on repositories and AI applications for nursing care.¹ In preparation for the call for applications, the BMBF initiated a study to include published empirical evidence and expertise from relevant stakeholders to inform and specify requirements for eligible grant applications and to identify determinants of successful R&D. This paper summarizes findings from said study that have been obtained by implementing an explorative sequential mixed methods design in order to explore needs, application scenarios, requirements, facilitators and barriers for R&D in the context of AI in nursing care.

Figure 1 depicts the process and phases of the study that consisted of a rapid review, an online stakeholder and expert workshop, expert interviews, an online survey and a datathon. We report on the results of the online workshop, the expert interviews, and the online survey, which addressed the following overarching research questions:

¹ Starting in 2022 the German Ministry for Education and Research will provide research grants for innovative AI R&D that aims to support nurses and informal caregivers and to improve self-determination and quality of life of care recipients.

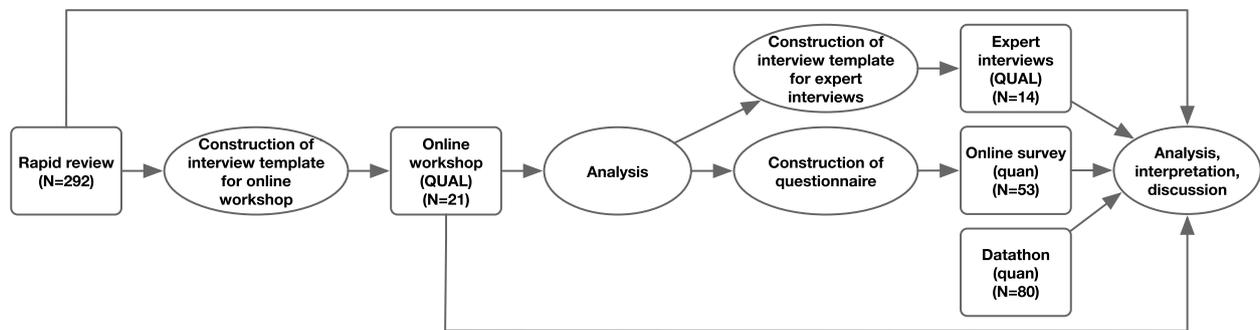


Fig. 1 Model of the study process and relation of study phases of data collection and analysis

- (i) What needs and scenarios for AI applications in nursing care do the stakeholders identify?
- (ii) How do the stakeholders prioritize and rate needs and application scenarios?
- (iii) What are requirements for and characteristics of successful research projects addressing AI and nursing care?

Methods

Study design, operationalization of AI in nursing care and reporting

A sequential explorative mixed methods study was conducted from April 2020 to November 2020 with an emphasis on qualitative data. Mixed methods designs involve the collection and analysis of both qualitative (QUAL) and quantitative (quan) data and integrating it in the design analysis by merging, connecting or embedding the data in order to achieve a more complete understanding of the research topic [26]. The sequential explorative approach allows for gathering insights on the research topic based on qualitative data in a smaller sample of individuals and then using the findings from the qualitative data in a quantitative phase to generalize or prioritize results [26]. Figure 1 shows the sequence and interaction of the strands of data collection and analysis of the study. To address the research questions, the findings of a rapid review [4] informed the construction of an interview guideline and schedule for the online workshop. Based on the results of the online workshop a questionnaire for the online survey was developed. Alongside observations of an additional datathon, results from the online workshop, expert interviews and online survey led to answering the research questions and discussion of results against the literature base identified by the rapid review. Methods for the online workshop, expert interviews and online survey are briefly summarized below. A detailed description of the methods is entailed in Additional file 1: Appendix 1.

We operationalized the subject area of nursing care by considering characteristics of the person involved in nursing care activities, the person receiving nursing care and the setting of care delivery. Figure 2 shows the matrix used for the operationalization of the subject area nursing care. Nursing care activities on the micro-level of care delivery include a person in need of care according to Book XI of the German Social Code [27] or care delivered by a certified nurse (field A to C). It further allows for including care tasks and activities arising from delegation from doctors as well as of care provided by informal caregivers. However, this does not take into account areas of activity that, for example, prevent or delay the need for care by means of privately procured assistive technologies, i.e., in which neither a formal status of care-dependency exists nor care professionals are usually involved (field D). For this reason, operationalization indicated by field A to C was used for the literature review. In the subsequent data collection, participants were informed that relevant aspects can also arise from field D. We also included the meso-level of nursing care, which comprises the level of institutions, providers and organizations, as well as the macro-level, which comprises the overall planning and organization of the health care system.

The reporting follows the guidelines provided by the consolidated criteria for reporting qualitative research (COREQ) [28] and criteria on mixed methods reporting [29].

Execution of the sequential approach

The online workshop lasted four hours and aimed at exploring and identifying relevant topics of AI in nursing care. Perspectives of relevant stakeholders were collected in moderated discussion rounds on the topics "Needs for artificial intelligence", "Promising application areas and focal points for research and development" and "Conditions for success of research projects". Stakeholders were selected by the study team in agreement with the BMBF

Person in need of care according to Book XI of the German social code?

		yes	no
Registered nurse delivering care?	yes	A e.g. home care, nursing home, residential care daycare	B e.g. hospital, nursing education, consultation
	no	C e.g. informal caregiving	D e.g. prevention, out-of pocket acquisition of assistive technologies

Fig. 2 Matrix for the operationalization of the subject area nursing care

and included nurses, directors of nursing and management from hospitals, nursing homes and home care services, informal caregivers, and scientists with a background in nursing, nursing education, computer science and AI research or ethics. Further, digitization officers or people with a working background in digitization in nursing care or in processing and analyzing routine data in nursing care were invited. Additional file 2: Appendix 2 contains the interview guideline of the workshop and Additional file 1: Appendix 1 provides information on detailed methods of the online workshop.

Data analysis followed the approach of content structuring content analysis [30] and was carried out deductively by structuring and summarizing participants' digitally recorded and manually mapped statements along with the guiding questions. Thematic areas and anchor quotes were transcribed for the main categories as well as subcategories.

The expert interviews aimed to include a nursing science perspective and to classify specific aspects, such as the operationalization of nursing-specific knowledge. In addition, the perspective of informatics on nursing as an object of AI R&D should be deepened and significant ethical and legal aspects should be given space during the 2-h long interviews which were conducted online. Additional file 3: Appendix 3 contains the interview guidelines for the expert interviews and Additional file 1: Appendix 1 provides more information on the methods used for the expert interviews. Participants were selected by the

study team in agreement with the BMBF. The invited 34 individuals included experts in the focus area of nursing and health science, informatics, R&D, and ethics and law. Data analysis followed the procedure of a structuring qualitative content analysis [31] and entailed the conversion of handwritten minutes into a digital documentation of the conversation which was then compared to digital recordings of the interviews. Text passages and anchor quotations were transcribed and transferred into a synthesis.

The online survey aimed at prioritizing and evaluating the findings generated in the online workshop. Participants of the online workshop as well as individuals who were invited to participate in the online workshop but could not attend or who were requested for expert interviews ($n=77$) were invited to take part. In addition, the network of the study team and the BMBF was used to invite further participants. Survey items were derived from the results of the online workshop and focused on topics that had been referred to as a need and a promising starting point for AI development and application as well as potential benefits of an AI application for nurses, people in need of care, or informal caregivers or the technical feasibility of specific AI applications. In addition, an assessment of the individual topics' ranking within the framework of research funding was also requested. Participants rated single topics on a scale from 1 (lowest priority for research funding) to 10 (highest priority for research funding) and on a 4-point Likert scale for

general potential for realization (very low, rather low, rather high, very high potential for realization). Technical feasibility and expected benefit of AI solutions for selected topics were rated on a scale from 0 (no expected benefit / not feasible) to 10 (very high expected benefit / very feasible). Participants were also asked to name the setting most likely to benefit from each selected application scenarios and to prioritize application scenarios that have been referred to less often in the online workshop. Further, socio-demographic data of the respondents were collected, which included information on their participation in the online workshop, their main professional activities, the sponsorship or provider of their professional institutions and whether they had previous experience in research projects on AI in nursing care. Data collection was carried out using the online tool EFS Survey. Data analysis was carried out descriptively along the research questions and, if necessary, differentiated according to relevant characteristics, using the software R version 4.0.0 [32]. Only the responses of persons who completed the questionnaire and answered at least one question were included in the analysis.

A datathon was hosted to gain insight on data quality and the potential for AI in nursing care. We do not report on specific results of the datathon but outline the rough procedure for the sake of completeness of all steps of data collection in the underlying research project. In teams of 9 to 13 people, 80 participants from the fields of business, nursing, informatics and data science, design, communication, innovation and marketing worked on challenges in the topic areas fair use and allocation of nursing staff and resources, use of multivariate sensor data from a clinical geriatric unit with an affiliated nursing laboratory, better information and advice for caregivers and care by relatives, and guideline-based care and quality indicators (fall prevention). Participants were asked to take part in a short online survey after completing the datathon to provide feedback on the format of the event as well as on future needs for collaboration and networking.

Synthesis of quantitative and qualitative results and researchers' background

Mixing of data and results during the phases of data collection entailed the inclusion of qualitative and quantitative results from the rapid review into the development of the interview guideline and input presentation of the online workshop. Findings from the literature and the online workshop also informed the development of the interview guidelines for the expert interviews while the online survey aimed at rating and prioritizing results from the online workshop from the perspective of the stakeholders. Results for the qualitative and the quantitative strand of this study are reported complementarily

in relation to the research questions given above. As the online workshop, expert interviews and online survey were conducted in German, results were initially compiled in German and then translated to English for publication. The authors primarily responsible for data collection and analysis (KS, DD) both hold a nursing degree and have been working in different clinical settings for acute in- and outpatient care. They have conducted prior research on use and implementation of digital technologies in nursing [33–35] and have gained expertise in quantitative and qualitative research methods over several years.

Ethical aspects and consent

Participation was voluntary; the selected experts were considered a non-vulnerable population in the study context and participation wasn't classified as of particular risk. After receiving written information on the study including statements on data protection and concordance with the European General Data Protection Regulation, all participants provided written consent to participation, to pseudonymised analysis of the data and to publication of anonymized results. Due to the short duration of the study, no additional ethics approval was obtained, as available hearing dates didn't correspond with the timeframe of the study. Phrasing and content used in the written information and informed consent statements had previously been used in multiple studies of the research group after prior receiving approval by ethics committees. Participants of the online workshop received a lump sum reimbursement of 100 €, which they had not been informed about before.

Results

21 of 58 invited experts took part in the online workshop, 53 experts completed the online survey and the perspectives of 14 experts were included in the interviews. Table 1 shows the number of participants per stakeholder group for the online workshop and expert interviews. Most participants of the online survey ($n=28$, 52.8%) belonged to a nursing care related area of expertise such as nursing practice, management or education. 16 participants (34.0%) reported belonging to another area of expertise. The majority of participants of the online survey ($n=39$, 73.6%) had not previously taken part in the online workshop and 25 participants (47.2%) reported experience in research projects on AI in nursing practice.

Needs and application scenarios for AI in nursing care

Participants of the online workshop predominantly brought up need and application scenarios for AI targeting the micro level of nursing care. Recurring considerations entailed specific actions and decisions to

Table 1 Number of participants of the online workshop and expert interview per stakeholder group

Status group	Number of participants	
	Online workshop	Expert interviews
Management/DoN ^a /Provider of Home Care	2	
Management/DoN/Provider of Nursing Home Care	1	
Management/DoN/Provider of Daycare	1	
Management/DoN/Provider of Hospital Care	2	
Informal Caregiver	2	
Digitization Officer/ Digitization in Nursing Care	3	
Registered Nurse ^b	1	
Nursing education and Nursing science	4	5
AI research and development	5	6
Ethics and Legal research	–	3
Total	21	14

^a) DoN = Director of Nursing. ^b) Five nurses predominantly working in direct patient care were invited to the workshop of which one participated. The overall sample contains more than one registered nurse as individuals in the groups Management/DoN/Provider and Nursing education and Nursing science also held a nursing degree

be executed by nurses during the care process, such as assessment of care needs, selection of suitable and effective interventions, and monitoring and evaluation of health status and outcomes. Informal caregivers emphasized needs and application scenarios in counselling, quality of life and experience and prevention of stressors. Participants from care organizations expressed the need for intelligent staff mix models. Further, application scenarios for planning of care services and route planning in home care were highlighted. Table 2 lists topics that were highlighted as needs as well as promising application scenarios for AI in nursing care and anchor-citations.

Some of the nursing scientists taking part in the expert interviews regarded AI as more suitable to support decisions of low complexity in care. They rated the nature of the overall nursing process as too complex and multidimensional to be managed by AI. However, the potential of AI to compile and provide information and thus ultimately initiate a decision was repeatedly emphasized. The use of AI in home care to support independent living for people in need of care and to detect risks or emergency situations was also mentioned. Staff shortages in long-term care and hospital settings and the respective challenges arising from a more heterogeneous staff and skill mix were named as reasons for needs. The transfer of clinical guidelines into AI applications for monitoring care provision and outcomes could support staff and skill mix as well as interdisciplinary and intersectoral collaboration. In this context, a high potential for the use of AI was described by linking different data sources while

taking into account the expertise of the professional groups involved in healthcare.

“How can we support the different competencies that we have in nursing, that we have in the qualification mix, how can we support the qualification mix, so to speak, with assistive technologies in order to provide the right information at the right time in the right place?” (Nursing Scientist)

Experts from AI R&D rated the daily interactions occurring in nursing care with a few restrictions as too complex to be supported by an omni-purpose AI. However, they pointed out that complexity must be considered depending on the respective situation and the specific research question. For the detection of situations in which no model or theory is yet available, for example in the case of multimorbidity, they named deep-learning systems as suitable for generating knowledge and understanding the complexity of these situations and, in the course of this, for developing rule-based systems based on this knowledge. Further, the amount of data available influences the degree of complexity and ultimately the methodological decision for or against the use of ML.

“These deep learning systems [...], you can use them as tools to try to understand complex issues for which you don't yet have a model, for which you don't yet have a theory. [...] This could be something like these multimorbidity situations. Complex situations where you have to make decisions under complex circumstances that can be very different. [...]” (AI research and development)

Table 2 Needs and promising application scenarios for AI in nursing practice emphasized during the online workshop

Need and promising application scenario	Anchor-citation
Care needs assessment and risk assessment	"The fact that I continuously use a certain system that records my everyday life, that then registers when there are deviations from this everyday life. Or when I think of movement sensors in the apartment, when the system suddenly notices that I get up more often at night to go to the toilet than I used to, that the system then realizes that this could be a sign of incontinence or a disturbed day-night rhythm [...]" [Management/DoN/Provider of Home Care]
Care planning in complex care situations	"That AI simply supports me in finding adequate interventions, especially for very complex care cases or very multimorbid people. There are also interactions sometimes [...]" [Management/DoN/Provider of Hospital Care] "Assessment or nursing assessment and transfer into nursing care planning. Where [...] individual complex situations [...] are covered. Not just pure if-then functions." [Management/DoN/Provider of Hospital Care]
Evidence-based decision support	"Keyword evidence-based decision support [...]. I want to emphasize this again because it is something very concrete that could be implemented directly. The databases are there, the preparation of the data, the knowledge access, that is missing at this point. Quick decision-making tools to really do better." [Nursing Education and Science] "The most ideal [...] would of course be an AI on site at the bedside. That I can also use exactly this knowledge on site. [...] The variant I would have a voice control and interact verbally with the AI." [Management/DoN/Provider of Hospital Care]
Medication management	"The [...] medication management. How much are people taking of what, are they actually doing it, what is being taken [...] that would be a nice topic for automation." [AI research and development]
Physical and cognitive activation	"Activation. Both physical and cognitive I can imagine very well. [Example Tovertafel]. It would be great to have such tools also generated at home and also everything that has to do with training at home, with solidification of skills or improvements." [Informal Caregiver]
Route planning	"That both traffic reports, the supply wishes of the customers, the available employees and their qualifications, etc. are all taken into account and that a finished tour is proposed [...]. I think this is very important to support the care managers [...] and [...] to free up more time for other activities. [...] If you do more research in that area and develop that further, I think that can be a very useful support." [Management/DoN/Provider of Home Care]
Nurse rostering, staff mix	"How do we get service planning on the one hand and the planning of concrete nursing care with staff deployment – and not so much with the question of how many personnel are to be deployed, because there are corresponding [legal] specifications – but with the question of how this is to be distributed qualitatively and quantitatively. [...] In a correlation of content, between the staff deployment, with all its facets, qualification and such things, and the concrete activities. So also, for example, such a question: Doesn't the care of Mrs. Klarenbach in a cognitively restricted scenario actually have to be allowed to last longer than, so to speak, usually?" [AI research and development]
Counselling of informal care givers and patients	"I can think of care counselling, which would also be suitable, at least initially, for AI use. [...] AI could first provide support upstream to give orientation and sounding out and then guide you directly to the help that you need and that will then help you further." [Management/DoN/Provider of Home Care]
Quality of life and stressors of informal caregivers	"Also, to collect specific needs of the relatives. What are the needs of those standing at the bedside? To call up and recognize the quality of life and well-being based on certain parameters, whether it's through digitalized image processing or observation modules [...] also for people with cognitive impairments." [Informal Caregiver]
Education, mediation of knowledge and competencies (nurses, other health professionals, informal care givers)	"For example, how to qualify nursing assistants to take on more tasks at a distance, even if they don't have the expertise. Here, AI could provide support, for example, with the help of [smart glasses] that then impart knowledge, transmit what the nursing assistant sees and can also evaluate it directly and then give her a recommendation for action. If the nursing assistant looks at a wound, that the AI can then convert what it sees and say I now recommend this and that care." [Management/DoN/Provider of Home Care] "The concrete ideas [...] I can think of are education and communication. [...] Also information sharing. What is where? That's what's wrong in some cases, that people on the ground don't know who is where, who can provide what support. Education [...] I could very well imagine that there are certain care topics that perhaps generate automatically, so that [caregiving relatives notice] oh there's a problem right now. [...] big issues, what about even if... for example, food refusal, for example, pain conditions." [Informal Caregiver]

DoN Director of Nursing

Experts from AI R&D commented on what they considered to be important conditions or information needed for needs-driven development of AI applications.

They pointed out specific challenges, for instance when patients may behave differently because of unconsidered medication effects or participate less frequently in

Table 3 Ranking of topics for research funding (rank 1 (highest) to rank 10 (lowest)), online survey

Topic	Mean rank	Median rank
Care needs assessment and risk assessment	3.60	3
Evidence-based decision support (e.g., selection of interventions, consultation of other health professionals)	4.26	4
Care planning in complex care situations	4.28	4
Nurse rostering, staff mix	4.42	4
Education, mediation of knowledge and competencies	5.34	5
Route planning (in home care and inpatient care)	5.51	7
Medication management	5.57	6
Counselling of informal care givers and patients	5.79	6
Physical and cognitive activation	6.25	7
Quality of life and stressors of informal caregivers	6.26	7

research than would be necessary for an algorithm to be trained. In order to avoid mis- or underrepresentation of individual socio-demographic characteristics in the data, they pointed out the need to include as heterogeneous groups of people as possible to obtain a suitable data base. In this context, they also mentioned data protection as a hurdle that would come into play in particular if individual care situations were to be mapped. Further, a lack of standardized comparable data for nursing care complicates the further development of learning systems.

Experts from ethics and legal research pointed towards general challenges associated with the automation of decisions. For example, the process of automation through the use of AI creates dangers, regardless of the type of AI system. For example, discrimination would not be recognized, the technology would be considered neutral, and responsibility would be handed over to technology. This way of dealing with technology favors intransparency, people are deprived of the possibility to object, and the evaluation of complex amounts of data may pave the way for new kinds of abuse of data or information. These dangers may be particularly pronounced in nursing, but they do not represent nursing-specific characteristics. Depending on the context in which an AI system is used in nursing and the degree of human involvement, different risks arise and different solutions are needed to guarantee an ethical use of AI. If humans represent an intermediate instance in the system or if the system is in direct contact with the person in need of care and interacts with them, a differentiated discussion and decision on the ethical design is required in each case. Depending on the application situation, a human intermediary between the AI system and the action becomes more important, as does the qualification of the nursing staff, who represent such an intermediary.

"I think what's important here is that the risks are different depending on whether it's a system where

a human being acts as an intermediary. So, if it's a system that, for example, makes a prediction or a diagnosis that is then used by a nurse, a caregiver, a doctor, then it's a different situation than a system that interacts directly with the person concerned. And the approaches we need to guarantee ethical use are different depending on whether there is a human intermediary or whether it is a system that is in direct contact with the people concerned. In any case, a differentiated discussion is needed regarding the ethical design, because topics such as traceability, complaints, and responsibility must be organized and implemented in a completely different way in these two cases." [Ethics and legal research]

Priorities and rating of scenarios

Participants of the online survey were also asked to rank the ten needs and application scenarios derived from the online workshop, as they thought they should be prioritized in research funding. Table 3 shows the results of said ranking with rank 1 representing the highest priority and rank 10 representing the lowest priority. The topic of care needs assessment and risk assessment was ranked particularly high, with a median rank of 3 and an average rank of 3.6. The topics evidence-based decision support, care planning in complex care situations and nurse rostering were rated in the median 4th place while physical and cognitive activation and the quality of life and stressor of informal caregivers were ranked at the bottom of the list.

Participants were asked to evaluate hypothetical AI systems (without further specification of the system design) for the ten needs and application scenarios with regard to expected benefit for nursing professionals and nursing assistants, for care patients, for informal caregivers and the technical feasibility at the time of the study. For Fig. 3, the three assessments of the expected benefits

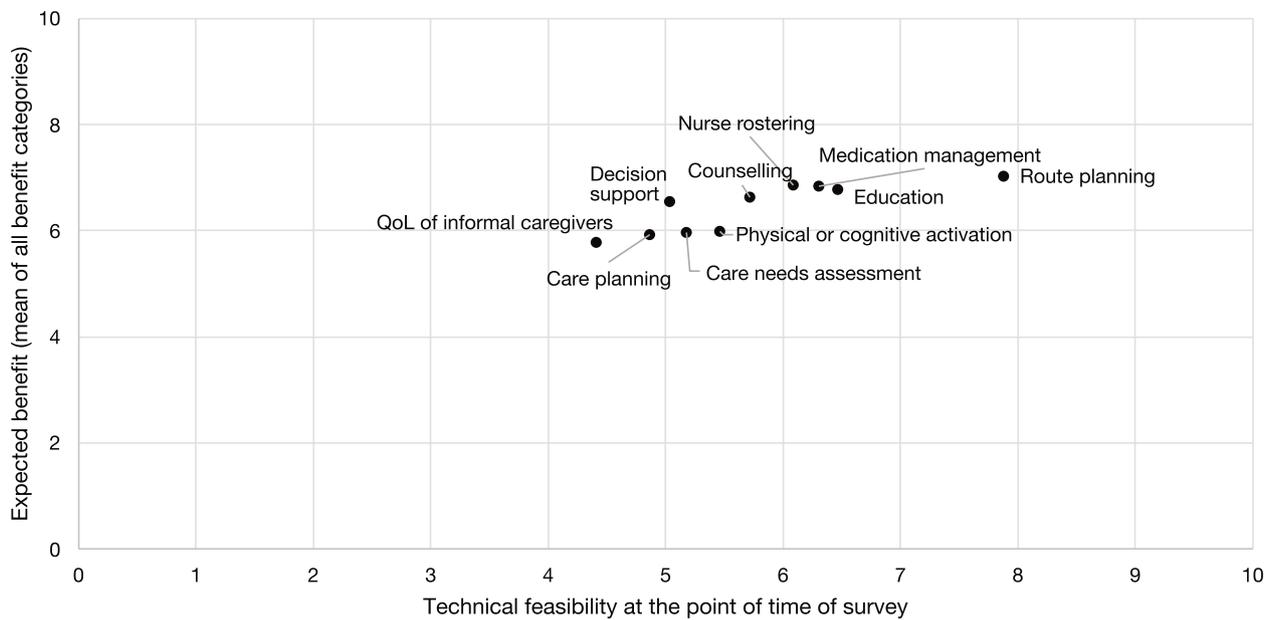


Fig. 3 Evaluation of expected benefits and technical feasibility of AI solutions for identified needs and application areas. Rating on a scale of 1 (no benefit, impossible feasibility) to 10 (very high benefit)

Table 4 Particularly relevant nursing settings for key applications of AI: Proportion of people who find the respective setting relevant for the focus of application (multiple answers possible)

Key applications	Setting					
	All	Home care	Informal care giving	Inpatient long-term care	Daycare	No answer
Education, mediation of knowledge and competencies	69.81%	5.66%	16.98%	7.55%	5.66%	1.89%
Medication management	64.15%	18.87%	9.43%	22.64%	5.66%	1.89%
Care needs assessment and risk assessment	62.26%	26.42%	7.55%	26.42%	13.21%	1.89%
Physical and cognitive activation	49.06%	7.55%	18.87%	16.98%	16.98%	11.32%
Evidence-based decision support	47.17%	16.98%	18.87%	13.21%	3.77%	3.77%
Counselling	45.28%	15.09%	37.74%	7.55%	7.55%	3.77%
Care planning in complex care situations	45.28%	28.30%	11.32%	37.74%	20.75%	3.77%
Nurse rostering, staff mix	30.19%	52.83%	1.89%	50.94%	35.85%	0.00%
Quality of life and stressors of informal caregivers	18.87%	18.87%	69.81%	0.00%	15.09%	5.66%
Route planning	9.43%	81.13%	0.00%	16.98%	18.87%	1.89%

were combined into a mean value and plotted against the assessment of technical feasibility. Participants expected AI systems to have a medium to high benefit in all ten needs and application scenarios, as well as medium to good feasibility. Route planning can be considered the application scenario with the highest average benefit and at the same time the best technical feasibility. AI Systems aiming at the quality of life of informal caregivers received the lowest ratings in both aspects.

Participants were asked to indicate for each application scenario whether AI systems were relevant for one or

more settings or equally relevant for all settings (Table 4). AI solutions for the application scenarios of medication management, care needs assessment and risk assessment and education and mediation of knowledge and competencies were considered relevant for all settings by the majority of respondents. Solutions related to counselling, care planning in complex care situations, physical and cognitive activation, and evidence-based decision support were also named as relevant for all settings by a large proportion of participants, but also received differentiated assessments. For example, solutions for care

AI Research and Development for Nursing Care

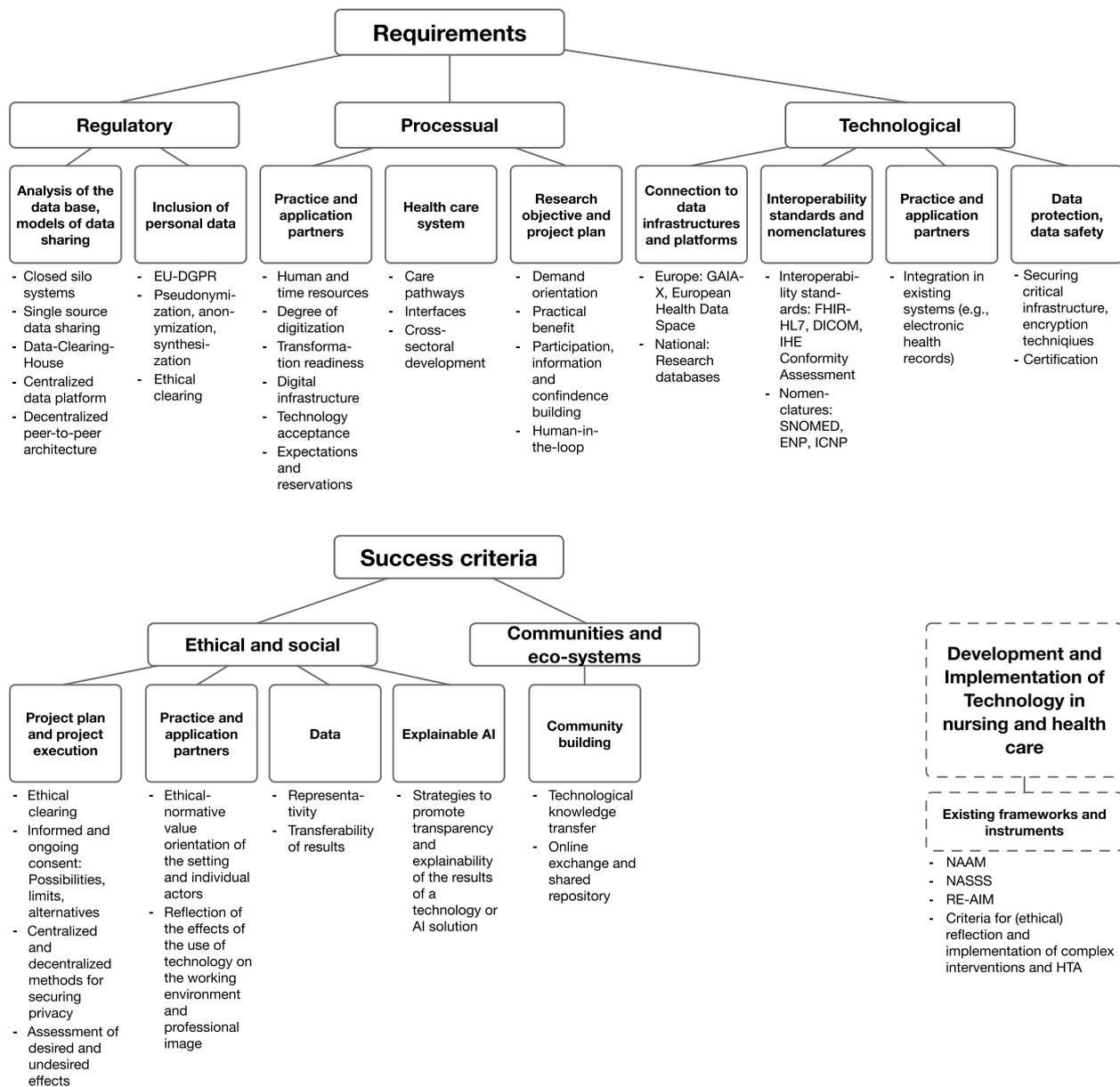


Fig. 4 Requirements and success criteria for AI research and development in nursing care

planning in complex care situations are primarily named as relevant in settings with the participation of professional caregivers, while for counselling, a particular relevance in home care by relatives is emphasized.

Requirements and characteristics of successful research projects

Figure 4 shows the categories that summarize requirements and characteristics of successful research projects

from the perspective of the stakeholders included in the study. Next to regulatory, processual and technological requirements, success criteria include ethical and legal aspects and supportive communities and eco-systems as well as the inclusion or reflection of existing frameworks and instruments for the development and implementation of technologies and interventions in nursing and health care, such as the NASSS [23] or RE-AIM [36, 37] framework.

Regulatory requirements were concerned with the analysis of the data and models of data sharing in compliance with data protection regulations. As R&D projects often include personal data for which informed consent is mandatory, possibilities to guarantee a fundamental use of the data should already be assessed during the planning phase of a project. This includes the consideration of technical measures to comply with data protection (e.g., anonymization, pseudonymization, or synthetization) and particular challenges arising when applying ML components that learn from personal data, such as clarification on how to proceed when data subjects withdraw consent to data processing. The experts additionally recommended to always consult an ethics committee and obtain an ethical clearance if this is not already mandatory by other regulations. If applicable, the study should then be registered in a study registry.

Processual and translational requirements comprise of aspects concerning project planning, execution and management. While R&D projects were considered as mostly being driven by AI researchers, the role of application partners and care facilities was of high relevance. If the application or evaluation of an AI solution is to be tested in practice, care facilities or institutions should be planned as permanent consortium members. The inclusion of several nursing homes or home care services, for which personnel resources to accompany the project should be available, was deemed as desirable to prevent the threat of temporary delays or failure of the project implementation due to shortcomings and staff shortages. Close involvement of the application partners from the very beginning of the project planning supports a needs- or practice-driven approach to R&D that focuses on the needs of the target group and the expected benefits for nursing practice. Further, the involvement of nursing scientists could – next to providing scientific support – also act as a mediator between nursing practice and developers. Choosing and rigorously implementing a participatory design approach supports to focus on specific care scenarios, the emergence and significance of available data, the definition of expected benefits and target groups and the incorporation of underlying conditions and mechanisms of the health care system, for which usual care pathways and interfaces to other institutions and sectors should also be taken into account.

While requirements for the technical infrastructure and the discussion of technical implementation details are part of every R&D project, the experts pointed out that specifications should be made in advance and the existing infrastructure in participating care facilities should be evaluated during the projects' planning phase. If data from electronic nursing or health records or other documentation systems are to be used, the

existing structure of the data, their continuity, quantity, and quality must be taken into account. Classification systems such as the European Nursing Care Pathways (ENP), the International Classification of Nursing Practice (ICNP) or the Systematized Nomenclature of Medicine (SNOMED), with structured data on nursing and medical diagnoses and measures, offer significantly simpler evaluation options than freetext documentation, but have so far found only limited use in R&D projects. The implementation of standards, especially in the area of interoperability, was considered to be very important for successful product development in the long term. The use of open protocols and data exchange formats enables integration into existing or future infrastructures. This is particularly relevant in regard to the frequently formulated requirement of cross-sector data exchange; a lack of integration of stand-alone solutions into existing systems within the care facility was perceived as disadvantageous and can thus represent an obstacle to market introduction. In this context, the technical aspects of data protection and data security should also be addressed as early as the planning phase of R&D projects.

Considering social and ethical aspects, the experts pointed out, that, next to incorporating lessons-learned from previous projects to identify ethical and social challenges that might affect a new project, research activities supporting the identification of ethical or social questions that arise among the actors within the research field involved and addresses them with regard to technology development and use, should be incorporated in the project. Recurring ethical issues concerned undesirable effects, such as the creation of new inequalities through new technologies in care and the representativeness of the persons with whom a new technology is tested and of the data from which an AI system learns. While the dimensions of gender and skin color in particular are prominently discussed in general AI research here, nursing-specific dimensions are largely unknown to date. For nurses, the comprehensibility and explainability of AI was highlighted as particularly important in decision support. The concept of human-in-the-loop as the involvement of humans in the decision-making and implementation process of algorithmic decisions and ultimately their option not to implement or act on the suggestion of an AI system, was considered essential for nursing.

In addition to project-specific considerations, structures for the transfer of knowledge and the networking of actors and projects in the thematic field should be created. By implementing communities and eco-systems that go beyond the boundaries of individual projects, translation and dissemination of practical findings that may contribute to nursing education and the scientific community could be supported. If open-source program

code is made available in online communities, existing programs or elements of them can not only be used by other developers but can also be extended or improved by them as part of their work. By using internationally recognized software libraries and programming languages, developers may prevent the development of niche solutions. As civil society initiatives also call for the fundamental disclosure of program code from publicly funded projects, a care specific platform would not only promote interoperability and provide targeted solutions for recurring problems but could also support public involvement and transparency.

Discussion

To our knowledge, this is the first study to explore application scenarios and challenges for AI and AI R&D in nursing care from a multifaceted perspective.

Needs, application scenarios and priorities described and rated by the stakeholders

The stated needs and application scenarios mainly encompassed the micro- and meso-level of care activities and derived from typical phenomena and problems inherent to nursing care as well as from skill- and staff mix and consequences arising from staff shortages, from the extend of informal care and an associated need for information and education of informal caregivers and nursing assistants.

The areas of application discussed, as well as the needs named, coincide in part with the issues and conceptualizations already taken up by R&D in recent years [4, 6], with both the literature and the participants' contributions primarily addressing the micro- and meso-level of care. AI solutions at the macro- or population-level, such as for regional care or case management and planning, are not at the forefront of the discussion. Even though the latter might pose an additional starting point for R&D, a needs- and demand-driven development of AI solutions, primarily based on the needs and issues expressed by stakeholders on the micro- and meso-level, with a view to success factors for future sustainability of technologies in nursing care seems to be of higher priority.

While findings and R&D on application scenarios targeting nursing-relevant phenomena and problems such as prevention of pressure ulcers or falls already exist [38–47], a lot of nursing-related health problems that are addressed by international nursing guidelines and expert standards, such as management of nutrition or pain and specific nursing assessments to identify risks and care needs seem to have hardly been taken up by R&D so far. It is striking that while expert systems for nursing care are already being reported in the literature to some extent [4], they did not play a prominent role in the

online workshop or the expert interviews. This might be due to a lack of a sufficient knowledge base on detailed guidelines that would be needed to develop expert or even hybrid systems.

As some experts pointed out, in a first step, ML could be utilized to generate knowledge needed for the development of expert systems. While needs for supportive, preventive and educative interventions for informal caregivers and for the relieve of caregiver burden on professional caregivers were emphasized during the online workshop and the expert interviews, these groups of people have not yet been given increased attention by R&D [4]. In contrast to application settings widely utilized for the development of AI solutions for nursing care in the literature, such as acute and intensive hospital care or independent living of the elderly [17, 20, 48, 49], no specific setting was prioritized during the stakeholder-process. Stakeholders rather expressed ideas for setting-overarching applications.

In summary, the topics identified in the online workshop and confirmed in the online survey offer various starting points for R&D. Between the application focus areas rated in the online survey, a rather low variance in terms of expected benefits, feasibility and the proposed prioritization in research funding was revealed. Instead, the results indicate that the actual design of AI systems and the underlying R&D projects play an important role.

Requirements for and characteristics of successful R&D projects

Requirements and characteristics expressed by the stakeholders included regulatory, processual, technological, ethical, and legal aspects and supportive eco-systems. While some requirements and characteristics were less AI-specific, but rather related to already known success factors for the application and implementation of technology in nursing or health care described in the literature [23], some AI-specific aspects were highlighted or can be found within more generalized topics. For instance, while compliance with the data protection regulations is mandatory for any research project, the chosen model of data sharing may be of particular importance in this context when conducting AI R&D. Considerations can range from siloed systems, which make data sharing significantly more difficult, to centralized data platforms or decentralized architectures (e.g., training AI models using federated learning) for data sharing.

A recurring theme for processual requirements was the early and ongoing inclusion of care facilities and nursing practice as project partners to support demand-driven and participatory R&D with a high expected clinical benefit. As a high level of participation and involvement of nurses as co-creators poses particular management

challenges and is likely to increase the level of project uncertainty [50], project coordination within care facilities or in the consortium is seen as the task of a dedicated functional unit. If technology implementation is part of a R&D project, resources for the associated changes in work processes and organizational structures of care facilities must also be available. Faced with persistent staff shortages, research tasks often take a back seat to care tasks in day-to-day work and the filling of positions in project management also competes with unfilled positions in direct care. Since the facilities' options for shaping this are limited, R&D projects in nursing care do not realize their full potential under the given conditions of nursing staff shortages throughout German health and nursing care. This might also affect R&D projects outside of Germany as staff shortages have been reported throughout the EU [51]. Here, the integration of explicitly remunerated persons as transformation and innovation agents should be considered, who are available as permanent contact persons for R&D to support a two-way transfer of research into health care practice. While this can be achieved within single projects by temporary funding, examples of ongoing structural collaborations to provide infrastructures that promote scientific research in long-term care in co-creation with end-users and stakeholders [52] show new possibilities for participation that have not yet been established to a larger extent.

Other recurring topics included structure, continuity, quantity and quality of data and respective access to data. While classification systems such as ENP, ICNP or SNOMED offer structured data and much simpler evaluation options than free-text documentation, they have so far only been implemented to a limited extent in Germany. Further, an international perspective on classification shows the need for a more comprehensive rollout of these coding schemes to achieve a coherent language in the field of nursing – a demand that has been emphasized in professional discussions for decades, but whose comprehensive implementation is still in need of improvement (c.f. [53]). Depending on the information system and the internal data processing, it can be helpful to use automated procedures to monitor but also to improve data quality [54]. Especially in the extraction of standardized codes, new AI procedures could prove their worth in the medical sector [55].

Similar methods can significantly accelerate the improvement of data quality in the care sector but require data availability and clarification of regulatory issues. For example, free-text fields often need to be pseudonymized at considerable expense. Scalable automated procedures have recently become available for this purpose as well [56], but their use must be legally secured. The implementation of interoperability standards is also considered

to be very important for successful product development in the long term. This is particularly relevant with regard to the frequently formulated requirement of cross-sectoral data exchange. For data exchange in the care sector, technical interoperability standards such as FHIR-HL7 or the IHE Conformance Statement can be used, which also contribute to networking in the healthcare sector beyond the project period and purpose.

Moreover, addressing the technical aspects of data privacy and data security in the planning phase of R&D projects seems important. This may include standards such as ISO 27001 or ISO 13606, the basic IT Protection compendium of the German Federal Office for Information Security, data processing requirements imposed by the General Data Protection Regulation (GDPR) of the European Union, encryption methods, and also procedures such as anomaly detection [57] or differential privacy [58]. Conditions for a needs-driven development expressed by experts from AI R&D referred to available feedback on outcomes of processes for learning loops and access to a bias-free database. Similar attempts towards fairness evaluation with the help of dedicated calibrated data sets exists in the AI research community (e.g., <https://github.com/zykls/folktables> and <https://arxiv.org/abs/2108.04884>). However, in the field of nursing care such data sets are not yet established.

Next to including insights and principles derived from previous research on ethical use of AI in nursing and health care [59], the experts voiced the need for the identification and treatment of ethical or social questions that arise among the actors within the research field involved. This is of particular importance as, for example, evidence on the design of intelligent assistive technologies for dementia suggests that the absence of explicit ethical considerations might be a co-determinant of current structural limitations in the translation of technologies from designing labs to bedside [60]. The use of an ethical evaluation tool, such as the model for the ethical evaluation of socio-technical arrangements (MEESTAR) [61] supports a structured dialogue on a socio-technical scenario in order to analyze its use, identify moral problems, and find adequate solutions [62]. The experts pointed out the importance of the explainability of AI and the individuals' option to actively decide against an algorithm-based impetus for action for nurses and patients alike. While a societal approach to educating and training people on the use of AI in general that is already being executed in various countries [63] contributes to the public knowledge on AI, R&D projects can incorporate the development of suitable approaches for AI in nursing care in the co-creation process from an early project phase onwards.

With regard to the need for establishing supportive communities and eco-systems to support knowledge

transfer and networking, R&D projects can actively contribute by utilizing established online-communities such as GitHub (<https://github.com/>) or by initiating topic-specific public platforms such as StackOverflow (<https://stackoverflow.com/>). Particularly due to the multi-layered and often interdisciplinary issues such a platform should not only be aimed at developers but should be suitable for explaining issues from the perspective of the various disciplines involved and for collecting knowledge on AI in nursing care in a freely available way.

Limitations

Limitations of the results primarily arise from the selected method and expert sample. The exploratory character of the study combined with a short duration of the project resulted in data collection that could not and was not supposed to reach data saturation. As published evidence from comparable studies is missing, confirmatory analyses of our results in larger and more diverse samples including perspectives from different countries are needed to confirm or contrast our results. Especially regarding specific application scenarios and single use cases for AI solutions we assume that not all ideas could have been uncovered. We also have to assume that not all fields of expertise were present in the study participants. As the number of experts in AI with a specific focus on nursing care in Germany is limited, all authors of the multidisciplinary team engaged their network to include as many experts as possible.

Even though participants of the online workshop received the visual documentation of the workshop and all participants who provided contact data later received the German language results of the underlying research project, no communicative validation of the transcripts or results with the participants was conducted. Further, the underlying subjective definition of AI needs to be kept in mind when looking at the results. Even though the decision to allow for a subjective definition, on the one hand, promotes heterogeneity of ideas, it may, on the other hand, contribute to the underrepresentation of topics as participants were given a general introduction to AI, ML, expert and hybrid systems but were not asked to think of application scenarios for ML, expert or hybrid systems separately. The underlying operationalization of nursing care was chosen to be broad as well and made known to all participants. Recent research activities surrounding the NUPHAC-EU framework for nurses' role in interprofessional pharmaceutical care highlights the challenge of developing and systematizing a uniform understanding of nursing tasks and activities [64]. However, in Germany nursing care is mostly understood in conjunction with benefits according to Books V and XI of the German Social Code and thus narrower than the

operationalization proposed in this study. Therefore, results may exhibit a stronger focus on activities of nursing care either taking places in institutions of health and long-term care or with the involvement of nurses.

The world café format chosen as a method for the online workshop aims at the focused use of dialogue to foster productive relationships, collaborative learning, and collective insight [65]. Due to the thematic closeness of the selected discussion topics and the interactive manner of the methods, participants might not have repeatedly stated topics important to them, which might also have led to an underrepresentation of topics within the overall discussion in this phase of the study. Therefore, we entailed an online survey which helped prioritizing the previously identified topics. It needs to be noted that we did not use a survey instrument that had been tested for its content validity and psychometric properties. The sample of participants of the online survey was rather small. A confirmation of the needs and topic areas in a bigger sample would underline the importance of certain topics, even though the topics derived from this study are in line with needs for overall technological support expressed by nurses in Germany in previous research [34].

Conclusion

This study identified various starting points for R&D on AI in nursing care and highlights requirements and success criteria of R&D from a multidisciplinary perspective of experts. A key element in the design of research projects remains participatory and demand-driven development, which should ideally aim to bring AI solutions out of the lab and into practice. In addition, awareness of the importance of good data for well-functioning AI solutions should also be raised. A lack of high-quality data for nursing care poses an important barrier towards the development of AI solutions. The quality has to be ensured throughout all phases of collection, storage and (pre)processing of data for AI solutions.

In addition, regulations and standards must be advanced to facilitate the development of AI solutions in nursing care. In particular, resilient legal foundations for data use and the use of AI in practice, standardization of data structures and infrastructures for data exchange across institutions and projects have to be established. The responsibility for this lies with political decision-makers and administrative bodies. For Germany, these would include the contractual parties for quality assurance and reporting in long-term care according to § 113 of the SGB XI and the Federal Joint Committee as the highest decision-making body of the joint self-government of physicians, dentists, hospitals, and health insurance funds. For this

purpose, they can draw on existing experiences and knowledge from past research projects, existing expert groups and (inter)national initiatives. Research should promote further development of appropriate structures and frameworks.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s44247-023-00015-2>.

Additional file 1: Appendix 1. Detailed Methods.

Additional file 2: Appendix 2. Interview guideline online workshop.

Additional file 3: Appendix 3. Interview guideline expert interviews.

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Authors' contributions

KS and DD conceptualized the study, handled recruitment and organized and conducted the online workshop. They developed the interview guidelines and conducted and analyzed the expert interviews. They also developed the items for the online survey and analyzed the data. DF, FB and MS, each conducted a focus group during the online workshop, wrote minutes and discussed and validated the synthesis of results generated by KS and DD. Together with KWO, they also advised the interview guidelines and items of the online survey and discussed the results with KS and DD. KWO, DF and FB conceived the superordinate research project and applied for funding. All authors worked on developing the guiding research questions of the study and commented on and approved the final manuscript.

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Availability of data and materials

German language results have been published publicly in the "Concept for Embedding AI Systems in Nursing Care" and are available at <http://dx.doi.org/10.26092/elib/496>. Anonymized transcripts of the expert interviews and visual documentation of the online workshop (both in German) can be made available on request via the authors. Code availability: Not applicable.

Declarations

Ethics approval and consent to participate

Informed consent was obtained from all participants involved in the study. All methods were carried out in accordance with relevant guidelines and regulations. The selected experts were considered a non-vulnerable population in the study context and participation was not classified as of particular risk. According to the "Guideline of the Ethics Committee for the Application of §§ 1 and 3 of the Ethics Procedural Rules of the University of Bremen", the Ethics Committee of the University of Bremen is responsible for research projects in which there is a risk of impairment of physical or psychological integrity or a violation of community goods. In addition, according to German law ethical approval is only necessary for studies of interventional nature regarding medicinal products (medicinal products act, AMG) or medical devices (medical devices act, MPG). As this study wasn't of interventional nature and due to the short duration of the study, no additional ethics approval was obtained, as available hearing dates did not correspond with the timeframe of the study. After receiving written information on the study including statements on data protection and concordance with the European General Data Protection Regulation (GDPR), participants of the expert interviews, online workshop and

online survey provided written informed consent to participation, to analysis of the data obtained and to publication of anonymized results. Phrasing and content used in the written information and informed consent statements had previously been used in multiple studies of the research group after prior receiving approval by ethics committees, including the ethics committee of the German Society for Nursing Science.

Consent for publication

Not applicable.

Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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