Prerequisites and Pathways for the Human-Centered Design of AI-Assisted Work Systems in Healthcare

Zur Erlangung des akademischen Grades einer
DOKTORIN DER PHILOSOPHIE (Dr. phil.)

von der KIT-Fakultät für Geistes- und Sozialwissenschaften des
Karlsruher Instituts für Technologie (KIT)
angenommene

DISSERTATION

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Tag der mündlichen Prüfung: 17.03.2026

With the exception of the articles "Auswirkungen von KI auf die Arbeit in der Pflege" (Appendix D), originally published in *ASU – Zeitschrift für medizinische Prävention*, 60(4), pp. 21–55, © Gentner Verlag GmbH & Co, and "An Integrative and Transdisciplinary Approach for a Human-Centered Design of AI-Based Work Systems" (Section 4.2) (both reproduced with the permission of the respective publishers; further reproduction or redistribution is not permitted), this document is licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) license: https://creativecommons.org/licenses/by/4.0/deed.en

Kurzfassung

Die vorliegende Dissertation untersucht Voraussetzungen und Ansatzpunkte für die menschengerechte Gestaltung KI-gestützter Arbeitssysteme, die im Gesundheitswesen zum Einsatz kommen. Der Einsatz solcher Technologien birgt das Potenzial, zur Entlastung beizutragen, ist jedoch auch mit Risiken wie Kompetenzverlusten oder einer Entpersonalisierung der Patient:innenversorgung verbunden. Angesichts der zunehmenden Integration von KI-Systemen auch in besonders sensiblen Bereichen der Gesundheitsversorgung ist ein wirksames Risikomanagement unerlässlich. Bestehende Governance-Ansätze für die Entwicklung von KI-Technologien formulieren normative – insbesondere ethische – Anforderungen jedoch meist auf einer kontextunabhängigen Ebene. Dadurch bleiben sie unverbunden mit den spezifischen Bedürfnissen derjenigen, die mit den Systemen interagieren. Zudem fehlen bislang geeignete Ansätze, um solche Anforderungen wirksam in Risikoanalyse- und Compliance-Prozesse zu integrieren. Die Dissertation basiert auf vier Artikeln und leistet einen Beitrag zur Operationalisierung sowie zur nachhaltigen Verankerung normativer Gestaltungsanforderungen entlang des gesamten Lebenszyklus von KI-Systemen. *Paper 1*, „Digital technologies in nursing: An umbrella review", bietet zunächst eine Übersicht über die Forschungslandschaft zu digitalen (einschließlich KI-gestützter) Pflegetechnologien und unterstreicht die Notwendigkeit einer nutzerzentrierten Technologiegestaltung. *Paper 2*, „An integrative and transdisciplinary approach for a human-centered design of AI-based work systems", identifiziert zentrale Voraussetzungen für die Entwicklung von Risikomanagementprozessen, die eine effektive Ausrichtung von KI-Systemen an normativen Standards ermöglichen. *Paper 3*, „A context-specific analysis of ethical principles relevant for AI-assisted decision-making in health care", präsentiert die Ergebnisse einer Interviewstudie zur Spezifizierung ethischer Gestaltungsanforderungen aus Sicht direkter Stakeholder. *Paper 4*, „AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design", dokumentiert einen partizipativen Technikfolgenabschätzungsprozess, in dessen Rahmen kontextsensitive Risikomanagementstrategien und -instrumente entwickelt wurden. Diese fokussieren insbesondere auf Mechanismen, die Auswirkungen auf die Interessen relevanter Stakeholder erfassen und eine kontinuierliche Ausrichtung an normativen Anforderungen ermöglichen. Insgesamt unterstreicht die Dissertation die Notwendigkeit, top-down-orientierte Governance-Ansätze durch kontextsensitive, iterative und partizipative Entwicklungsprozesse zu ergänzen – um sicherzustellen, dass KI-Technologien sowohl das Wohlbefinden der im Gesundheitswesen tätigen Erwerbstätigen als auch eine patientenorientierte Versorgung unterstützen.

Abstract

This doctoral thesis investigates prerequisites and pathways for the human-centered design of AI-assisted work systems in healthcare. While AI technologies offer the potential to alleviate systemic pressures within the healthcare sector, their integration into practice also has been linked to potential adverse consequences, including professional deskilling and the depersonalization of caregiver-patient relationships. In light of the increasing spread of AI systems in high-stakes sociotechnical healthcare environments, the use of effective risk management strategies is imperative. However, existing risk-governance frameworks generally delineate proposed design criteria – especially ethical criteria – at a context-independent level, potentially leaving them only weakly connected to the situated needs of those who interact with the AI systems; moreover, these frameworks lack means of facilitating their sustainable integration into risk assessment and compliance processes. Through four peer-reviewed research papers, this thesis contributes to the operationalization and sustainable integration of normative design criteria in the AI development lifecycle. *Paper 1*, "Digital technologies in nursing: An umbrella review," synthesizes the extant research landscape on digital nursing technologies, underscoring the importance of user-centered technology design. *Paper 2*, "An integrative and transdisciplinary approach for a human-centered design of AI-based work systems," identifies key prerequisites for the development of risk management processes that enable the alignment of AI systems with normative standards. *Paper 3*, "A context-specific analysis of ethical principles relevant for AI-assisted decision-making in health care," presents the findings of a bottom-up case study on healthcare stakeholders' context-sensitive specifications of proposed ethical design criteria. *Paper 4*, "AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design," documents a participatory technology assessment process in which strategies and instruments for the human-centered development and implementation of AI-assisted healthcare technologies were developed. These focus particularly on mechanisms that capture the impacts of AI systems on stakeholders' needs and practices and support ongoing alignment with normative requirements. In essence, the thesis underscores the need to transition from top-down governance approaches to context-sensitive, iterative, and participatory technology development processes to ensure that AI technologies in healthcare settings foster both patient-centered care and the well-being of healthcare professionals.

Acknowledgements

I wish to express my sincere gratitude to all those who have supported me throughout the development and completion of this dissertation.

Foremost, I am indebted to my supervisors, Armin Grunwald and Martin Schütte, for their openness to my research interests and their consistent and reliable support throughout this work. I am also especially grateful to Linda Nierling, my mentor at KIT, for her guidance during this journey and for the sustained and enriching scholarly exchange.

My heartfelt appreciation further extends to Ulrike Rösler, my research group leader during my time at the BAuA, for exemplifying engaged research in the field of work and organizational studies and for her encouragement and constructive feedback at every stage of this project. I am equally thankful to my colleagues Marlen Melzer and Johannes Wendsche for their collegial support, the cordial work atmosphere, and the inspiring scientific exchange. My sincere appreciation also extends to Anne Wöhrmann, whose consistent intellectual engagement was a valuable and greatly appreciated source of support.

Finally, I would like to express my gratitude to all co-authors who contributed to this dissertation. Collaborating with them on the associated publications was not only intellectually enriching but also, in many respects, a significant source of joy and motivation.

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List of Abbreviation

AI	Artificial Intelligence
HCD	Human-Centered Design
ML	Machine Learning
OSH	Occupational Safety and Health
TA	Technology Assessment

Research Papers Submitted as Part of this Dissertation

I have independently made substantial and significant contributions to all of the research papers listed below*, including in the three papers published with co-authors (cf. Section 7 of Appendix 5b of the Doctoral Regulations of the Karlsruhe Institute of Technology (KIT) for the KIT Faculty of Humanities and Social Sciences, for the attainment of the Doctor of Philosophy degree (Dr. phil.), dated October 4, 2016):

Paper 1: **Schlicht, L.**, Wendsche, J., Melzer, M., Tschetsche, L, & Rösler, U. (2025). Digital technologies in nursing: An umbrella review. *International Journal of Nursing Studies*, *161*. https://doi.org/10.1016/j.ijnurstu.2024.104950

Paper 2: **Schlicht, L.**, Melzer, M., Rösler, U., Voß, S., & Vock, S. (2021). An integrative and transdisciplinary approach for a human-centered design of AI-based work systems. *Proceedings of the ASME 2021 International Mechanical Engineering Congress and Exposition. Volume 13: Safety Engineering, Risk, and Reliability Analysis*. The American Society of Mechanical Engineers. https://doi.org/10.1115/imece2021-71261

Paper 3: **Schlicht, L.**, & Räker, M. (2024). A context-specific analysis of ethical principles relevant for AI-assisted decision-making in health care. *AI & Ethics*, *4*, 1251–1263. https://doi.org/10.1007/s43681-023-00324-2

Paper 4: **Schlicht, L.** (under review). AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design. Faculty of Humanities and Social Sciences, Karlsruhe Institute of Technology.

*For an overview of all publications, refer to Appendix E.

Table 1 provides an overview of my contributions to each research paper, categorized by key elements of the development process.

Table 1

Overview of contributions to the research papers

Research paper	Conceptualization and design	Data collection and analysis	Manuscript writing	Estimated contribution
Paper 1	Joint	Joint	Joint	70%
Paper 2	Joint	n/a	Joint	55%
Paper 3	Independent	Joint	Independent	85%
Paper 4	Independent	n/a	Independent	100%

"The danger of future automation is less the much-deplored mechanization and artificialization of natural life than that, its artificiality notwithstanding, all human productivity would be sucked into an enormously intensified life process and would follow automatically, without pain or effort, its ever-recurrent cycle." (Hannah Arendt, 1958, p. 132)

1 Introduction

Technological innovation has been a persistent catalyst for transformation in healthcare practices, yielding notable improvements in both the efficiency and quality of provided care. However, novel technologies have also frequently given rise to unanticipated challenges. For instance, while the adoption of computerized physician order entry systems enhances the traceability of prescriptions, the integration of repetitive alerts, such as those flagging potentially harmful medication interactions, has been shown to disrupt clinical workflows, leading to alert fatigue and reduced adherence (Khajouei & Jaspers, 2010). Similarly, the widespread integration of electronic health records in the 1990s strengthened information continuity but has also been linked to technostress and a reduction in time dedicated to direct patient interaction, partially due to the need to manage system malfunctions (Kelley et al., 2011; Provenzano et al., 2024).

In recent years, *artificial intelligence* (AI)[1] has emerged as a key driver of digital transformation across various healthcare domains. The advent of machine learning techniques, in conjunction with the proliferation of digital health data, has led to the rapid advancement of AI in the sector, including in the form of predictive analytics, decision support, and diagnostics (Bohr & Memarzadeh, 2020). The importance of digital transformation in healthcare is widely recognized – not only as a means of increasing efficiency but also supporting more responsive and personalized models of care. However, the integration of AI systems has also given rise to a wide array of serious concerns, many of which stem from their mounting capacity to assist with tasks that have traditionally been dependent on human cognitive functions (Parker & Grote, 2022), which is driving the redistribution of decision-making authority, a potential erosion of the relational and moral dimensions of care, and shifts in professional healthcare roles.

There is a growing recognition of the importance of the human-centered design of AI-assisted work systems in healthcare, particularly when it comes to these systems' alignment with local workflows, professional practices, and the sociotechnical contexts in

[1] While there is currently no universally accepted definition of AI technologies, a commonly recognized feature is their ability to generate outputs, such as predictions, recommendations, or decisions, that may influence both physical and digital environments. This includes the capacity to derive models or algorithms from data using techniques like machine learning or logic-based methods. Moreover, AI technologies operate based on predefined objectives and may evolve autonomously, adapting and learning from their environment (EU, 2024; OECD, 2019b).

which they are embedded. However, strategic support for the sustainable integration and operationalization of normative design criteria for AI technologies in healthcare settings remains conspicuously absent. Against this backdrop, this dissertation contributes to ongoing efforts to advance the integration of such design criteria into the development of AI systems. The focal point of this inquiry lies in a transition from conventional top-down governance approaches to context-sensitive, iterative and participatory technology development processes that prioritize the situated experiences and ethical considerations of stakeholders within the healthcare sector.

1.1 The Janus-Faced Nature of AI Within the Healthcare Sector

To the best of this dissertation's knowledge, there is currently no reliable data available on the uptake of AI technology in the healthcare sector. Nevertheless, there is no question that a multitude of AI-based applications have already been integrated into healthcare systems or are currently under development (de Nigris et al, 2020; Preti et al., 2024). This trend is accompanied by a hope that AI may help to alleviate systemic pressures and support an increasingly strained workforce. According to the 2021 European Working Conditions Telephone Survey, 49% of healthcare workers in the European Union (EU) experienced a high level of job strain in 2021 – well above the average rate of 34% across all sectors (Eurofound, 2024).[2] Physicians and nurses in particular described intense working conditions, characterized by high work speeds and substantial emotional demands. Furthermore, nurses reported health and safety risks at the highest rate (69%), once again well beyond the EU cross-sector average of 34% (EC, 2023). These burdens are further compounded by persistent workforce shortages and the rising demand for healthcare services, driven by aging populations alongside overall population growth (OECD, 2020; WHO, 2022).

In response to these challenges, AI tools offer the potential to alleviate systemic pressures within the healthcare sector – for example, by streamlining workflows,

[2] Note: These data were collected during the COVID-19 pandemic; thus, it may be assumed that the reported level of strain was at least partially moderated by pandemic-related factors. Furthermore, the lack of data regarding the use of AI systems hinders quantification of the systems' association with (prior) occupational strain during the survey period.

enhancing clinical decision-making, automating routine tasks, and enabling more personalized approaches to patient care (Sharma et al., 2022; Yakusheva et al., 2025). In addition, these tools may also improve the working conditions of healthcare providers. By assisting with repetitive or cognitively demanding tasks, they may, for instance, mitigate mental workloads and decision fatigue, and, in turn, lead to lower stress levels and higher job satisfaction (Boone et al., 2024; Martinez-Ortigosa, 2023).

However, the integration of such technologies has been linked to potential adverse consequences, including professional deskilling and the depersonalization of caregiver-patient relationships (Rubeis, 2020; Thompson et al., 2023). Increased reliance on machine-generated recommendations may lead to the increased prominence of technology-driven interactions (Boone et al., 2024; Mittelstadt & Floridi, 2016) and a corresponding increase in *objectifying work* that privileges tightly scripted procedures (Grote, 1997). Furthermore, overreliance on AI tools has the potential to compromise healthcare professionals' capacity to discern and respond expeditiously to critical situations, thereby engendering tensions between human intuition and AI-driven decision-making (Secinaro et al., 2021). Such dynamics could ultimately undermine perceptions of clinicians' autonomy and contribute to a disconnect between them and their patients – both an emotional disconnect and a practical one, with patient records and care decisions overseen by an AI tool.[3]

Healthcare professionals constitute the backbone of a human-centered healthcare system. Their capacity to deliver high-quality care is inextricably linked to their health and safety (Lenaerts et al., 2024). Therefore, even from a purely pragmatic perspective, it is imperative to carefully evaluate the interactions between emerging AI systems and the work-related characteristics of healthcare professionals. Current AI systems are primarily designed to inform and assist clinicians rather than to automate their tasks. Nevertheless, the shifting distribution of tasks between humans and machines demands a heightened focus on the dialogical-interactive elements of patient care as well as the interests of the human "work object", i.e., the patients and clients (Archibald & Barnard, 2018; Morley et al., 2020). Given the often-vulnerable circumstances of those receiving care, effective

[3] Furthermore, job demands related to interactions with patients and their relatives alongside the emotional demands inherent in such interactions have been identified as key determinants of healthcare professionals' well-being (Cavanagh et al., 2020; Eurofound, 2024; Marzocchi et al., 2024).

communication on and advocacy for patients' rights and needs are fundamental tenets of professional health care practice. Neglecting the relational dimensions of healthcare, especially in the sociotechnical design of AI systems with a direct impact on human-to-human interactions, risks eroding the holistic approach that is essential to ethically aligned healthcare delivery (Rogers et al., 2021; Rubeis, 2020).

1.2 Aim and Scope of the Dissertation

In order to ensure that the introduction of AI systems in the healthcare sector indeed supports employees and to avoid unintentionally inflicting harm on patients, there is a need for effective strategies and instruments that facilitate the context-sensitive operationalization of *ethical design criteria* (e.g., respect for autonomy, justice) and the sustainable integration of normative design criteria more broadly – encompassing *established criteria for human-centered work design*, such as work-integrated learning and holistic work design – throughout the development and implementation of AI technologies. In recent years, a considerable number of guidelines have been developed to support the design of socially beneficial AI systems (Corrêa et al., 2023; Fjeld, 2020; Jobin et al., 2019). In addition, various regulatory frameworks, such as the EU's *Artificial Intelligence Act* (Regulation (EU) 2024/1689) (AI Act), have established a legal foundation for governance. However, these frameworks generally delineate proposed design criteria – particularly ethical ones – at a context-independent level and lack means of facilitating the sustainable integration of these criteria into risk assessment and compliance processes (Morley et al., 2023; Sanderson et al., 2023). This finding extends to publications that are designed to offer healthcare-specific guidance (Goirand et al., 2021; Lukkien et al., 2023). While the context-independent formulation of relevant design criteria may certainly be useful in raising awareness of their importance, their translation into design processes that account for the situated needs of those interacting with the systems usually requires further conceptual specification. Furthermore, to effectively inform AI applications' risk management processes – especially in complex sociotechnical domains like healthcare – there is a need to develop measures that can facilitate the integration of normative requirements in a sufficiently precise and verifiable manner throughout the technologies' lifecycles (Sanderson et al., 2023).

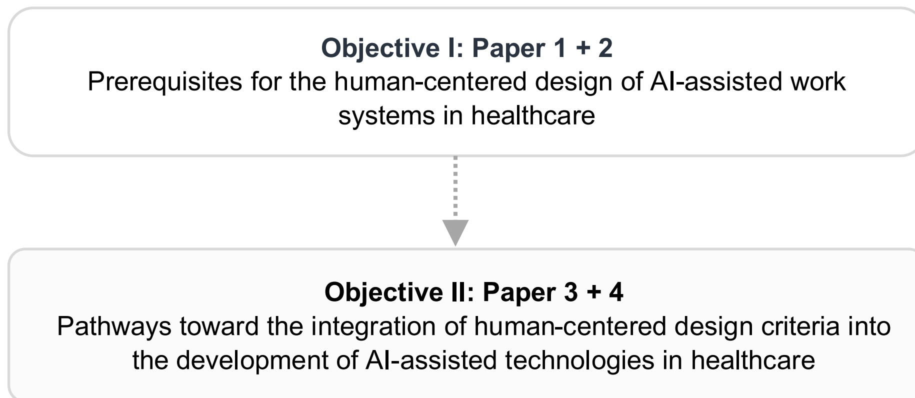
This dissertation contributes to ongoing efforts to incorporate normative design criteria into the development of AI-assisted healthcare systems through two distinct research objectives. *First*, as a foundational step, it aims to determine which specific prerequisites exist for the development of measures for the human-centered design of AI-assisted work systems in the healthcare sector (*Objective I*). This includes an analysis of the extent to which AI-assisted systems impact occupational safety- and health-related factors as well as ethical factors, which serves to identify factors that require particular attention when developing measures to ensure human-centered technology design in the healthcare sector. Beyond this analysis, the dissertation identifies critical, yet unresolved prerequisites for the development of effective risk management processes aimed at aligning AI systems with normative standards. *Second*, it proposes exemplary pathways (i.e., strategies and instruments) toward the effective integration of normative design requirements throughout AI tools' lifecycles (*Objective II*). This includes the context-sensitive specification of proposed ethical design criteria, and strategies to facilitate the *continuous* alignment of AI-assisted work systems in healthcare with normative requirements. Overall, drawing on analytical perspectives common in the field of *technology assessment*,[4] this thesis shifts the focus from the prevailing top-down governance approaches to ones that integrate the context-sensitive work-related and ethical concerns of stakeholders within the healthcare sector into technology design.

The four research papers incorporated into this dissertation are structured in line with the two research objectives, as shown in **Figure 1**: Papers 1 (see **Section 4.1**) and 2 (see **Section 4.2**) address *Objective I*, while papers 3 (see **Section 4.3**) and 4 (see **Section 4.4**) address *Objective II*.

[4] TA is an interdisciplinary field of problem-oriented research that aims to systematically evaluate and manage the unintended consequences of technological innovations, particularly those related to human decisions and actions, with the ultimate goal being to align technological progress with ethical and societal values (Grunwald, 2019, 2022, 2024).

Figure 1

Overview of research objectives and linked papers



To define the scope of AI technologies under consideration, this thesis focuses on AI systems that assist with *person-related tasks* in healthcare, i.e., those that involve direct engagement with patients (Böhle & Weihrich, 2020). Such tasks constitute a core component of most healthcare professions and are crucial for ensuring patient-centered care. The AI systems used for such tasks are predominantly information and communication technologies (e.g., pain assessment systems, decision support systems) that aid clinicians in evaluating and responding to patients' physical or psychological states by analyzing a wide array of data inputs (Yelne et al., 2023). These technologies have the capacity to significantly affect the dialogical dimensions of care delivery, including communication, shared decision-making, and the interpretation of individual patient needs. Accordingly, they also have the capacity to alter the clinician-patient relationship and influence healthcare professionals' moral decision-making processes (Li et al., 2023; Morley et al., 2020). Consequently, especially from an ethical perspective, their development and implementation warrant careful deliberation (Badawy et al., 2024).

Furthermore, this dissertation places emphasis on technologies designed for implementation in the field of *nursing care*. While most studies on the use of AI in healthcare focus on technologies geared towards physicians, nurses make up approximately 59% of the global healthcare workforce (WHO, 2020) and are increasingly recognized as key users of digital healthcare technologies (Rouleau, 2017; WHO, 2019). Furthermore, nurses frequently assume responsibility for individuals with limited decision-making capacity, which often requires them to make complex decisions that take

into account multiple perspectives and the unique needs of individual patients (Rainer, 2018; Suhonen, 2018). While the risk of overlooking the interests of care recipients within care processes exists independently of AI, it can be assumed that such risks may be exacerbated by the introduction of AI systems – especially those that influence or mediate human-to-human interactions.

Finally, the criteria that were investigated in the publications that contributed to this thesis fall into two interrelated yet distinct categories: *ethical criteria*, which primarily pertain to healthcare professionals' moral responsibility for the well-being of patients, and *criteria for human-centered work design*, which address employees' work characteristics and health. The ethical criteria under consideration are based on the widely recognized framework developed by Beauchamp and Childress (2019). In conjunction with the criterion of explainability, which was also considered in this thesis, these criteria form the basis of the design requirements set out in the High-Level Expert Group on AI's (AI HLEG's) "Ethics Guidelines for Trustworthy AI" (AI HLEG, 2019), which are referenced in the AI Act – the first comprehensive legal framework for regulating AI in the European Union (European Parliament & Council of the European Union, 2024) – as a foundation for the ethical design of AI systems.[5] Regarding the criteria for human-centered work design, this dissertation draws on internationally established concepts that promote personality development, health maintenance, and employee performance (e.g., ISO, 2016, 2019b, 2024; Ulich, 2011). Both sets of criteria are collectively referred to as human-centered design (HCD) criteria throughout this dissertation.[6] A comprehensive overview of all considered criteria is available in Appendix A.

The remainder of this dissertation is organized as follows. **Section 2** delineates the research landscape relevant to this dissertation's objectives. More specifically, **Section 2.1** identifies fundamental prerequisites for the human-centered design of AI-assisted work systems in healthcare and delineates the dissertation's corresponding contribution, while **Section 2.2** explores the need for measures that facilitate the effective integration of normative design requirements into the development of such AI technologies and, once

[5] In addition, a mapping review conducted by Floridi et al. (2018) on the key ethical guidelines for AI found that many AI initiatives incorporate claims that correspond to this framework.

[6] Note that the proposed range of normative criteria for the design of AI-assisted technologies is vast. Rudschies et al. (2020) identified 49 distinct criteria across 40 publications. This dissertation does not seek to address the entire spectrum of these normative considerations; rather, it focuses on a select subset of widely recognized criteria.

more, delineates the contributions of this thesis. **Section 3** presents the detailed research questions. **Section 4** comprises the four research papers that make up this work's core contributions. Finally, **Section 5** provides a synopsis and discussion of the dissertation's key findings.

2 Background

2.1 Prerequisites for the Human-Centered Design of AI-Assisted Work Systems in Healthcare

2.1.1 Synthesizing Evidence on AI Systems' Impact on Nursing Practice and Ethically Relevant Care Outcomes

AI-assisted systems in the healthcare sector encompass a wide array of applications. Diagnostic algorithms support clinicians in interpreting medical images, such as X-rays and MRIs, to detect anomalies (Khalifa & Albadawy, 2024). AI has also emerged as a pivotal element in the development of customized treatment plans through the integration of patients' data and medical histories (Alowais et al., 2023). In surgical settings, robotic systems and continuous monitoring technologies are increasingly incorporated into standard clinical workflows (Al Kuwaiti et al., 2023; Sharma et al., 2022). Moreover, health management systems such as data-driven triage systems, which gained traction during the COVID-19 pandemic, have been adopted to manage overcrowded emergency departments and streamline patient prioritization (Garrido et al., 2024). More recently, generative AI tools based on large language models (e.g., GPT-4, Gemini) have been developed to support administrative tasks and patient communication (Abridge, 2025; Tortus, 2025).

While most AI applications in healthcare have been developed for the medical field, there has been a steady rise in research and practical efforts aimed at applying such technologies in nursing as well (Buchanan et al., 2020; Ruksakulpiwat et al., 2024; von Gerich et al., 2021). The use of AI systems holds considerable promise for enhancing nurses' care delivery across multiple domains. For instance, they can aid in the monitoring of patient activity and health, enhance care coordination and communication, and provide decision-making support (Seibert et al., 2021). Emerging evidence suggests that such systems can have positive impacts on nurses' job characteristics, including reduced workload and improved workflow efficiency, particularly in emergency settings (Park et al., 2025). Nevertheless, studies also indicate that they may have adverse effects, such as the undermining of clinicians' decision-making competencies (Benzinger et al., 2023). Furthermore, many of these technologies possess the capacity to influence interactions

between nurses and patients in ways that may potentially disrupt or reconfigure “traditional cultures of caring ethics” (Ramvi et al., 2023, p. 1124). In particular, there is a risks of shifting power dynamics and altered conditions for empathic engagement with recipients of care.

The sustainable integration of HCD criteria into technology design – an endeavor aimed at mitigating the risks posed by technology to healthcare professionals and patients – necessitates an early recognition of such consequences that may arise from the use of AI systems in healthcare. However, at the time of the writing of this dissertation, there had yet to be a comprehensive overview of the systems’ effects. More specifically, no systematic review had yet examined how *various* digital technologies (including AI-assisted systems) affect work-related and organizational factors in nursing care, or how they are related to ethically relevant outcomes for people receiving care.

Several umbrella reviews have examined digital nursing technologies, but these have largely focused on individual technologies such as telehealth applications (Zhang et al., 2023). Given the large number of studies and reviews on the matter, a comprehensive overview that maps and synthesizes findings from multiple systematic reviews is vital to generate a full picture of AI-assisted systems’ influence on these factors and to determine aspects that require particular attention when developing measures to ensure human-centered technology design in the healthcare sector. Against this backdrop, this thesis provides a systematic review (“Digital technologies in nursing: An umbrella review”) of the research landscape on digital healthcare technologies as a foundational step alongside a special analysis of AI-assisted technologies (see **Section 4.1**). This includes an assessment of current research gaps as well as an examination of the influence of moderating organizational preconditions.

2.1.2 Identification of Unresolved Prerequisites for the Integration of HCD Criteria into Risk Management Processes

In light of the advanced capabilities of AI systems and their potentially significant effects on healthcare personnels’ work characteristics and health, it is imperative to consider established *criteria for human-centered work design* – such as work-integrated learning and holistic work design, as outlined in regulatory standards (e.g., ISO, 2016, 2019b, 2024) – alongside technical design criteria (e.g., transparency, functional safety)

from the outset of a technology's development. However, while technical design criteria are routinely considered throughout the development process, criteria for human-centered work design remain largely neglected (Kahlert & Grote, 2024). This is the case despite the fact that there has been a strong focus on *prospective work design* (Corbett, 1985) in the fields of work and organizational psychology for decades (Parker & Grote, 2022; Waterson et al., 2015). Furthermore, risk assessment methods focused on criteria for human-centered work design are, at present, largely confined to applications in established work systems rather than being integrated across systems' entire lifecycles (e.g., Müller et al., 2018). Consequently, related risks are often identified only during or after the implementation of a technical system in the workplace, rendering subsequent adjustments complex and resource-intensive (cf. *Collingridge dilemma*; Collingridge, 1980).

Moreover, as tasks related to clinician-patient interactions are transferred to AI systems, there is an unprecedented potential to influence the moral agency of healthcare professionals. Consequently, also *ethical considerations* play a pivotal role in ensuring human-centered work design (Grote, 2023; Schlicht et al., 2021). Especially in the context of systems designed to assist with tasks that necessitate an evaluation of the unique situation of the person in need of care, it is generally agreed that ethical criteria – such as respect for autonomy and justice – should be considered from the outset of the design process to ensure that AI integration does not give way to care recipients' needs being neglected.[7] However, to date, these criteria haven not been systematically considered in technology development.

This thesis identifies two critical yet unresolved prerequisites for developing effective risk management processes aimed at aligning AI-assisted work systems in healthcare with such normative standards. A fundamental requirement is the *conceptual specification* of ethical criteria related to the moral agency of healthcare personnel. As criteria like *respect for autonomy* are interpreted and conceptualized differently by different people and societies (Zwart, 2015), "armchair" approaches pose the risk that criteria – especially if applied in a template-like manner across different application domains – fail to account for the needs and interests of the people actually interacting with the systems, ultimately rendering them ineffective or even potentially harmful (Tsamados

[7] Note that this assertion presupposes that ethical criteria or derived requirements can be codified into software components (cf. *computational ethics*; Poszler et al., 2024; Segun, 2021).

et al., 2021; Webb et al., 2019). Consequently, there is a broad consensus that ethical criteria, especially when applied to the development of technologies used in socially sensitive fields like healthcare, must be specified for context-sensitive requirements (Grote, 2023; Mittelstadt, 2019). To achieve such "normative-descriptive alignment," these criteria must be informed by what moral philosophy refers to as *thick concepts* (Richardson, 2018) – i.e., concepts that combine descriptive elements, such as the individual needs and abilities of the people affected by the application, and evaluative elements such as right or wrong – which may be considered ethically salient within the particularities of technology usage (Goirand, 2021; Mittelstadt, 2019). These concepts facilitate the specification of normative criteria within a contextual scope, thereby offering a complementary approach to top-down governance mechanisms (e.g., ethical frameworks, regulatory standards, organizational policies) from a bottom-up perspective (Nierling & Maia, 2020; Resseguier & Rodrigues, 2021).

To ensure that ethical criteria are recognized as morally significant by those interacting with the systems and that they are sensitive to their individual interests, the specification of the criteria is ideally achieved through case studies involving domain-specific stakeholders (Grobe, 2021; WHO, 2021). This has the potential to not only facilitate their alignment with the overarching requirements of the healthcare sector but also enable differentiation within it. For instance, it can facilitate an assessment of whether the criterion of *respect for autonomy* necessitates distinct conceptual specifications in short-term care settings (e.g., hospitals) and long-term care settings (e.g., nursing homes).[8] However, existing guidelines and frameworks predominantly employ a context-independent approach, lacking guidance tailored to sectors like healthcare and its many unique settings (Goirand et al., 2021). Moreover, empirical research involving healthcare stakeholders remains limited, leaving their perspectives on the requirements for context-specific specifications of ethical criteria largely unexplored (Mittelstadt, 2019; Prem, 2023).

[8] In long-term care settings, where residents commonly experience cognitive impairments, autonomy may often best be preserved through shared decision-making processes that emphasize empowerment and a holistic assessment of individuals' needs and motives. In contrast, in short-term care settings, the realization of autonomy may need to be linked more strongly to a reduction in information asymmetry through patient education, thereby avoiding paternalistic practices that undermine patients' ability to make informed independent decisions.

A second challenge hampering the sustainable alignment of AI-assisted work systems in the healthcare sector with such normative requirements – including ethical criteria and criteria for human-centered work design – arises from the *adaptive nature* of many AI systems. While the risks associated with technological systems are inherently shaped by the sociotechnical environments in which they operate (Orwat et al., 2024), AI algorithms are distinct in that they may evolve over time in response to dynamic data environments and patterns of user engagement. As a result, it is particularly challenging – if not entirely unfeasible – to identify all risks associated with their deployment *a priori* during the design phase. The associated challenge of integrating HCD criteria into adaptive technologies and systems in a way that effectively addresses their dynamic and context-specific risks shall become evident in the following (fictitious yet plausible) scenario:

A university hospital has implemented an AI-assisted documentation system that integrates speech recognition and clinical decision support to reduce the administrative burden on the hospital staff, thereby enabling them to dedicate more time to direct patient care. The system allows staff members to dictate patient-related data, which is subsequently transcribed, analyzed, and utilized to generate personalized treatment recommendations. In their efforts to incorporate the design criterion of work-integrated learning, developers have integrated explanatory feedback, which is displayed whenever deviations from professional guidelines occur. Initially, the system is perceived as a valuable aid, as it alleviates administrative burden and provides a sense of security. However, over time, it begins to flag deviations from standardized care recommendations with greater frequency, having learned that issuing such warnings leads to greater adherence in future use cases, particularly when feedback is framed more strictly. Consequently, caregivers' responsiveness to individual patients' needs declines, as decision-making shifts from relational care to protocol adherence. Additionally, nurses are confronted with a growing loss of job autonomy and an escalating sense of moral distress, which culminates in heightened psychological strain and diminished job satisfaction.

Prevailing engineering and risk management methodologies generally lack mechanisms for the *continuous* mitigation of such emerging risks. In other words, they do not facilitate iterative information exchange and refinement processes between operators and system designers, or they do so only to a limited extent (Siedel et al., 2021).

Consequently, they are presently ill-equipped to address the challenges posed by adaptive AI systems in healthcare settings. In response, there is a growing consensus regarding the need to enhance existing risk assessment and mitigation methodologies through iterative mechanisms that facilitate the continuous monitoring, assessment, and mitigation of risks (European Parliament & Council of the European Union, 2024; OECD, 2023; Poszler et al., 2024; WHO, 2023). However, there is still a need to identify suitable strategies and instruments capable of supporting such continuous system refinement throughout the AI lifecycle.

This dissertation engages with both of these unresolved challenges – the specification of ethical criteria and the need for continuous design and risk management methodologies – by situating them within the framework of *technology assessment* (TA). TA offers a well-established repertoire of socio-epistemic practices that support the development of approaches to aligning technology design processes with normative requirements (Grunwald, 2019, 2024). Through anticipatory and participatory methods (e.g., scenario analysis, stakeholder engagement, impact assessments), TA facilitates the systematic examination of emerging technologies within their sociotechnical contexts and enables the early identification of potentially critical impacts. Moreover, it has also been shown to be effective in informing prospective risk governance processes, as evidenced in the domains of nuclear energy and gene editing (e.g., CRISPR/Cas9) (IAEA, 2013; Siemaszko et al., 2020).

As a preliminary step, this dissertation examines the delineated unresolved prerequisites for integrating HCD criteria into risk management processes through a discussion paper, "An integrative and transdisciplinary approach for a human-centered design of AI-based work systems" (**Section 4.2**). This paper provides the conceptual underpinnings for the subsequent development of exemplary pathways toward the effective integration of these criteria, encompassing the context-sensitive specification of ethical design criteria and strategies to facilitate the continuous alignment of AI-assisted work systems in healthcare with normative requirements.

2.2 Pathways Toward the Integration of HCD Criteria into the Development of AI-Assisted Healthcare Technologies

2.2.1 Context-Sensitive Specifications of Proposed Ethical Design Criteria

Occupational safety and health measures are guided by the overarching goal of ensuring that tasks are free from physical harm and adverse psychosocial factors, but still manageable, supportive of personal development, and conducive to social sustainability. This goal extends to the selection and implementation of work equipment (WHO & Burton, 2010). According to the *European Framework Directive 89/391/EEC* on occupational safety and health, enacted in 1993, employers across the EU are legally obligated to assess and mitigate risks to employees' health and safety arising from the design and use of work equipment (European Council, 1989).[9] Accordingly, in Germany, for example, §3 of the Operational Safety Ordinance stipulates that employers must conduct hazard assessments prior to procuring work equipment and do so in a manner that considers interactions with job demands and organizational structures.

The advent of AI-assisted technologies introduces a qualitatively novel challenge for the promotion of decent work, as they have the potential to impact employees' moral agency and disrupt the relational and moral dimensions of professional practices to an extent that appears to exceed what has previously been observed in relation to conventional work equipment. However, such ethical concerns are not systematically addressed by existing occupational safety frameworks and related risk management tools. In response, a substantial corpus of publications has emerged in recent years aiming to provide normative guidance for the socially responsible development of AI-assisted systems (Corrêa et al., 2023; Fjeld, 2020; Jobin et al., 2019). These works come from a variety of sources and reflect a wide range of regulatory approaches. National frameworks, including Germany's "Standardization Roadmap of Artificial Intelligence" (DIN & DKE, 2022) and France's AI strategy (Ministère de l'Économie, 2021), delineate country-specific

[9] Note that, to maintain a focused scope, this dissertation primarily focuses on European regulations and policies.

regulatory models. At the international level, initiatives like the OECD's "AI Principles" (OECD, 2019b) aim to support the development of "trustworthy AI" across jurisdictions. Beyond government-led efforts, normative guidance is also offered by professional associations, such as the Institute of Electrical and Electronics Engineers (2019), as well as academic (e.g., Future of Life Institute, 2017; Morley et al., 2023) and private-sector (e.g., de Laat, 2021) actors.

However, despite the increasing availability of such guidance, implementation remains scant (Tidjon & Khomh, 2022; Vakkuri et al., 2020). A principal shortcoming lies in the ongoing tendency to prioritize technical features like security and transparency while only peripherally addressing ethical dimensions. More fundamentally, ethical criteria are often articulated at a context-independent level, detached from the practical requirements of specific sectors (cf. *regulatory alignment problem*; Guha et al., 2024) (Grote, 2023; Mittelstadt, 2019; Sanderson et al., 2023). This lack of contextual grounding creates uncertainty regarding the criteria's precise meaning, which may result in them being neglected. Moreover, there is a risk that, without such specificity, the criteria's translation into domain-sensitive technology development processes will occur intuitively and in a manner that fails to consider the situated needs of those interacting with the systems.

A subset of publications is aimed at offering guidance specific to the healthcare sector (e.g., Callahan et al., 2024; Lekadir et al., 2025; National Academy of Medicine, 2025; Reddy et al., 2020; Siala & Wang, 2022; Solanki et al., 2023; WHO, 2021, 2023). However, these too largely fail to provide context-sensitive specifications for proposed criteria (Goirand et al., 2021; Lukkien et al., 2023). Notably, long-standing discourses on professional ethical guidance, particularly those originating from theories in nursing and healthcare,[10] are only marginally reflected. Furthermore, with the exception of, for example, Callahan (2024) and Lekadir et al. (2025), which incorporate clinicians and patient advocates in their development processes, direct stakeholder participation remains rare. To the best knowledge of this dissertation, none of these directives has been empirically substantiated through case studies involving healthcare practitioners or patients. Finally, the preponderance of frameworks under scrutiny relies chiefly on soft regulatory instruments, such as checklists and best-practice recommendations. Provisions

[10] See, for example, Beauchamp and Childress (2019), Häyry (2003), Rendtorff (2022), and Veatch (2020).

for risk assessment or mitigation remain largely ambiguous and are (in most cases) not associated with proposed criteria. Consequently, the development of healthcare-specific risk mitigation strategies – particularly the context-sensitive specification of ethical criteria – remains largely unresolved.

The need for context-sensitive specifications of ethical criteria is also acknowledged in the AI HLEG's (2019, 2020) "Ethics Guidelines for Trustworthy AI," which are referenced in the AI Act as a key reference point for guiding the ethically aligned design of AI systems.[11] Given the proposed criteria's high level of abstraction, the AI HLEG concludes that the "necessity of an additional sectorial approach, to complement the more general horizontal framework proposed in this document, should be explored" (p. 6).

As a horizontal legislative framework encompassing all industries, the AI Act, adopted in June 2024, is particularly relevant for the healthcare sector, given that existing healthcare-specific regulations, such as the Medical Device Regulation (EU) 2017/745 (MDR) (European Parliament & Council of the European Union, 2017), do not explicitly address AI applications.[12] A salient feature of the AI Act is its risk-based classification system, which delineates the following four levels of risk associated with AI applications: minimal or no risk (e.g., for medical translation tools), limited risk (e.g., for AI-generated medical reports), high risk (e.g., for patient triage systems), and an unacceptable level of risk (e.g., for real-time biometric surveillance systems). The requirements for regulatory oversight and compliance measures increase progressively. For high-risk AI systems, Article 27 *obliges* deployers to undertake a Fundamental Rights Impact Assessment, going beyond a mere recommendation to consider ethical criteria.[13] However, practical guidance

[11] As stated in the AI Act, these "guidelines contribute to the design of coherent, trustworthy and human-centric AI, in line with the Charter [of Fundamental Rights of the European Union] and with the values on which the Union is founded. […] They should in any case serve as a basis for the drafting of codes of conduct under this Regulation" (European Parliament & Council of the European Union, 2024, Recital 27).

[12] The integration of the AI Act within pre-existing vertical legalizations in the healthcare sector remains to be clarified. As stated in Recital 64 of the AI Act "medical devices products incorporating an AI system might present risks not addressed by the essential health and safety requirements set out in the relevant Union harmonised legislation, as that sectoral law does not deal with risks specific to AI systems. This calls for a simultaneous and complementary application of the various legislative act" (European Parliament & Council of the European Union, 2024). In addition, some AI applications adopted in the healthcare sector, such as general-purpose large language models (LLMs), may not fall within the regulatory scope of the MDR or other healthcare-related regulations and standards.

[13] Note that, particularly when used in person-related healthcare tasks, AI systems not classified as high-risk systems may still pose a significant risk (van Kolfschooten & van Oirschot, 2024). For example, a dermatology-focused AI model trained predominantly on lighter skin tones may systematically under-diagnose conditions in patients with darker skin tones, leading to healthcare disparities.

on carrying out these assessments remains limited. The European Union Agency for Fundamental Rights, the entity responsible for developing such assessments, is currently referring exclusively to existing checklists and guidelines – including the one developed by the AI HLEG (2019, 2020) – whose effective applicability remains unclear, also due to the absence of context-sensitive specifications for the proposed criteria (FRA, 2020).

In response to the widely recognized need for the specification of ethical design criteria for AI in healthcare, this thesis – through its paper "A context-specific analysis of ethical principles relevant for AI-assisted decision-making in health care" – presents the methodology and findings of a bottom-up case study on how proposed criteria (i.e., the foundational criteria outlined in the "Ethics Guidelines for Trustworthy AI") are conceptualized by healthcare stakeholders, namely nurses and care recipients (see **Section 4.3**). This investigation generates empirical insights into the extent to which these AI design criteria must be conceptually specified to meet domain-specific requirements.

It is evident that the alignment of normative and descriptive dimensions of ethical design criteria must go beyond merely considering stakeholders' moral judgments (Beauchamp & Childress, 2019; Sinnott-Armstrong & Skorburg, 2021). An ethically sound specification requires a balance between empirical research into what is acceptable to relevant stakeholders and normative reflection in the light of ethical theories, allowing for the mediation of diverging interests.[14] However, particularly in sensitive areas of application like the healthcare sector, where potential risks and consequences are particularly serious, it is *imperative* to take into account the perspectives of relevant stakeholder groups in order to ensure that AI systems are compatible with existing workflows and the needs of those directly affected by their implementation (Grobe, 2021).

2.2.2 Strategies for the Sustainable Integration of HCD Criteria Throughout the AI Lifecycle

Traditionally, the responsibility for risk assessment has been divided between the manufacturers and operators of healthcare-related technical devices. In the healthcare sector, product design regulations (e.g., the Medical Device Regulation (MDR)) stipulate that manufacturers are obligated conduct risk assessments during the product design stage.

[14] This may be accomplished, for instance, by employing a *reflective equilibrium* or a similar method that facilitates the iterative alignment of ethical theories and practical moral judgments (Rawls, 1971).

Conversely, operators are responsible for implementing occupational safety and health measures aimed at managing the interactions between working tools and potential workplace hazards. These measures are primarily centered on tool selection.[15]

Given that the adaptive nature of AI systems can result in workplace interactions that were not foreseeable during technology design, there is a growing consensus that risk management processes – to ensure compliance with normative design criteria – must shift from static, one-time evaluations to continuous monitoring and risk mitigation throughout the entire lifecycle of AI systems[16] or their components (e.g., OECD, 2023; WHO, 2023).[17] A fundamental component of this continuous risk management approach entails the integration of feedback loops between operational monitoring and earlier lifecycle phases, such as model development. These mechanisms are crucial for mitigating risks that are not foreseeable, or only foreseeable to a limited degree, during the design of AI systems (across all design criteria) (Poszler et al., 2024; WHO, 2023). By incorporating empirical insights on the effects of work practices from real-world deployment – for example, generated via adverse event reporting (Guha et al., 2024) – back into earlier lifecycle phases, the alignment between these descriptive observations and normative design measures aimed at fulfilling HCD criteria can be iteratively refined (Awad et al., 2022). **Figure 2** illustrates this need to iteratively refine risk management processes throughout the AI lifecycle.

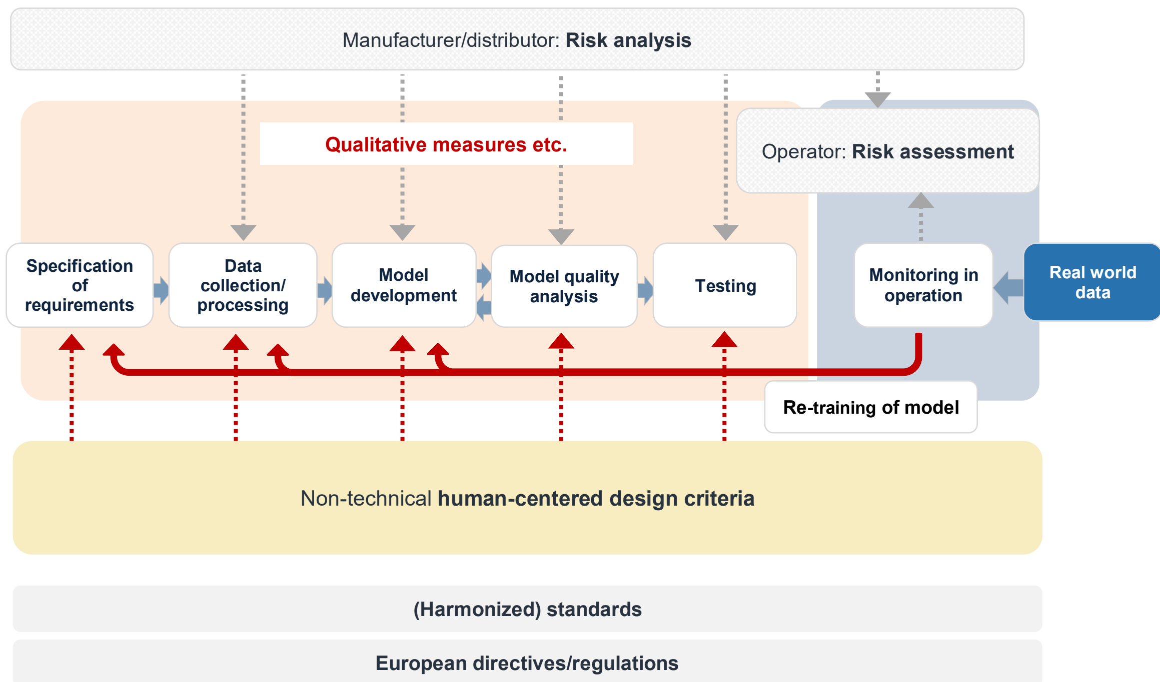
[15] In the specific case of the MDR, responsibilities are defined as follows: Manufacturers are tasked with conducting an initial risk assessment (e.g., ISO, 2019a), a conformity evaluation (CE marking), and a post-market clinical follow-up. Operators (e.g., healthcare facilities) are required to report identified risks to the manufacturer and relevant authorities. However, they are not obligated to conduct ongoing system risk monitoring.

[16] While there is no universally accepted definition of the lifecycle phases of AI systems – with particular differences in the granularity of described conception, development and deployment phases (e.g., de Silva & Alahakoon, 2022; Sujan et al., 2023) – iterative lifecycle models typically comprise the following phases: (1) requirement specification, (2) data collection and processing, (3) model or algorithm development, (4) model quality analysis, (5) real-world testing to validate performance under practical constraints, (6) operational monitoring, and (7) model re-training.

[17] The WHO, for example, states that in "view of the character of AI systems, it is important that the regulatory system enables continuous modifications for improvement to be made throughout the AI system's development lifecycle" (WHO, 2023, p. 18).

Figure 2

Schematic illustration of the proposed iterative refinement of risk management processes throughout the AI lifecycle



Note. This figure depicts the proposal of open feedback loops between operational monitoring and earlier lifecycle phases, thereby enabling the iterative integration of observed emerging risks (which are not, or only to a limited extent, foreseeable during the design of AI systems) into normative design measures aimed at fulfilling HCD criteria. Gray elements represent established risk assessment procedures, while red arrows indicate open desiderata. Source: Adapted from "Menschengerechte Gestaltung von KI im Gesundheitswesen – Impulse aus zwei Werkstattgesprächen" by U. Rösler, L. Schlicht, M. Hülsken-Giesler, T. Lennefer, B. Susec, P. Tegtmeier, S. Vock, S. Warneke, and A. Wöhrmann, 2025, *BAuA: Bericht kompakt*, p. 5. Federal Institute for Occupational Safety and Health.

For AI systems classified as "high-risk" (e.g., healthcare patient triage systems, emotion-recognition technologies) the AI Act mandates that continuous assessment procedures be in place post-deployment to detect and address any emerging risks (Recital 65; Article 9).[18,19] In parallel, a variety of standardization bodies have established technical standards that offer guidance on implementing a lifecycle-based AI risk management

[18] The AI Act provides the following rationale: "Whilst risks related to AI systems can result from the way such systems are designed, risks can as well stem from how such AI systems are used. … Deployers are best placed to understand how the high-risk AI system will be used concretely and can therefore identify potential significant risks that were not foreseen in the development phase, due to a more precise knowledge of the context of use, the persons or groups of persons likely to be affected, including vulnerable groups" (European Parliament & Council of the European Union, 2024, Recital 93).

[19] In addition, both the AI Act and the Ethics Guidelines for Trustworthy AI state that, irrespective of a system's risk classification, the voluntary risk assessment and mitigation related to HCD criteria should be informed by key performance indicators (AI HLEG, 2019, pp. 25–42; European Parliament & Council of the European Union, 2024, Recital 165).

framework. Notably, the Institute of Electrical and Electronics Engineers (IEEE), the German Institute for Standardization (DIN), the International Organization for Standardization (ISO), and the International Electrotechnical Commission (IEC) have established standards pertaining to the assessment of AI risks and their governance (e.g., DIN, 2019; IEEE, 2021; ISO/IEC, 2022, 2023a).[20] While these emerging standards offer structured frameworks that serve to mitigate the risks associated with technical design criteria (i.e., those pertaining to physical and environmental harm) throughout AI systems' lifecycles, current risk management approaches still largely lack methodologies for assuring compliance with ethical and work-related HCD criteria (Ortega-Bolaños et al., 2024).[21] Furthermore, although the AI Act contains provisions that implicitly support human-centered work design, it does not establish explicit requirements for the design of AI-assisted work processes. However, evolving regulatory approaches represent an opportunity to proactively embed criteria for human-centered work design at the outset of system development (cf. *precautionary principle*; WHO & Burton, 2010).

Beyond the risk management approaches presented by legislative frameworks and regulatory standards, various design instruments have been developed to support normatively aligned technology design through the application of HCD criteria at different phases of the technology development process and, in part, to incorporate stakeholders' experiences into the design process. These instruments come from fields like value-sensitive design (Friedman & Hendry, 2019; Umbrello & van de Poel, 2021), participatory design (Bannon & Ehn; 2013; Whitman et al., 2018), and ethics-by-design (Brey & Dainow, 2024). Tools such as the ELSI-SAT Health & Care online tool (Mehlich & Woopen, 2025) and the OECD guidance materials (2023) aid technology developers in formulating strategies to address ethically and socially sensitive aspects of AI systems, particularly in their early design phases. Furthermore, the CapAI procedure developed by

[20] In particular, the draft standards ISO/IEC 23894 (2023) and ISO/IEC 38507 (2022), building upon the established risk management standard ISO 31000 (2018) and the standard ISO/IEC 42001 (2023), introduce additional provisions specific to AI systems and components applicable across various AI technologies and operational contexts. Accordingly, manufacturers are encouraged to conduct ongoing risk assessments beyond the market release, thereby addressing the evolving nature of AI-related risks. Organizations deploying AI systems should systematically evaluate potential modifications and provide ongoing feedback to the manufacturer, who should promptly implement updates upon identifying emerging software-related risks.

[21] Existing tools that provide compliance measures often take a fragmented approach, concentrating on singular criteria like fairness (e.g., Corbett-Davies et al., 2023) or security (e.g., Mohassel & Zhang, 2017) without offering comprehensive solutions that address the broader sociotechnical complexities of AI deployment (Prem, 2023).

Floridi et al. (2022) supports technology providers in conducting conformity assessments of high-risk systems in accordance with the requirements laid out in the AI Act.

Although these tools are beneficial in guiding reflective processes, they exhibit certain limitations when it comes to the continuous (re-)design of AI systems: (i) There is often a failure to consider situational factors embedded in the specific application contexts, including transformative effects over time (e.g., Manders-Huits, 2011), (ii) the need for post-launch monitoring and the logging of key events is typically overlooked, despite both being critical for assessing actual risk reduction in applications contexts, especially for adaptive system, and (iii) there is a lack of specific considerations pertaining to human-centered work design, leading to a general disregard of pivotal aspects of work-related and organizational dynamics. Given the adaptive nature of AI systems and the dynamic interplay between technical, social, and organizational factors, it appears that these tools alone are insufficient to ensure that HCD criteria are effectively integrated and maintained throughout the AI lifecycle. Instead, there is a need for instruments that facilitate the iterative refinement of normative design measures to ensure that AI systems remain responsive to (evolving) contextual requirements (Awad et al., 2022; Goirand et al., 2021; Metcalf et al., 2021).

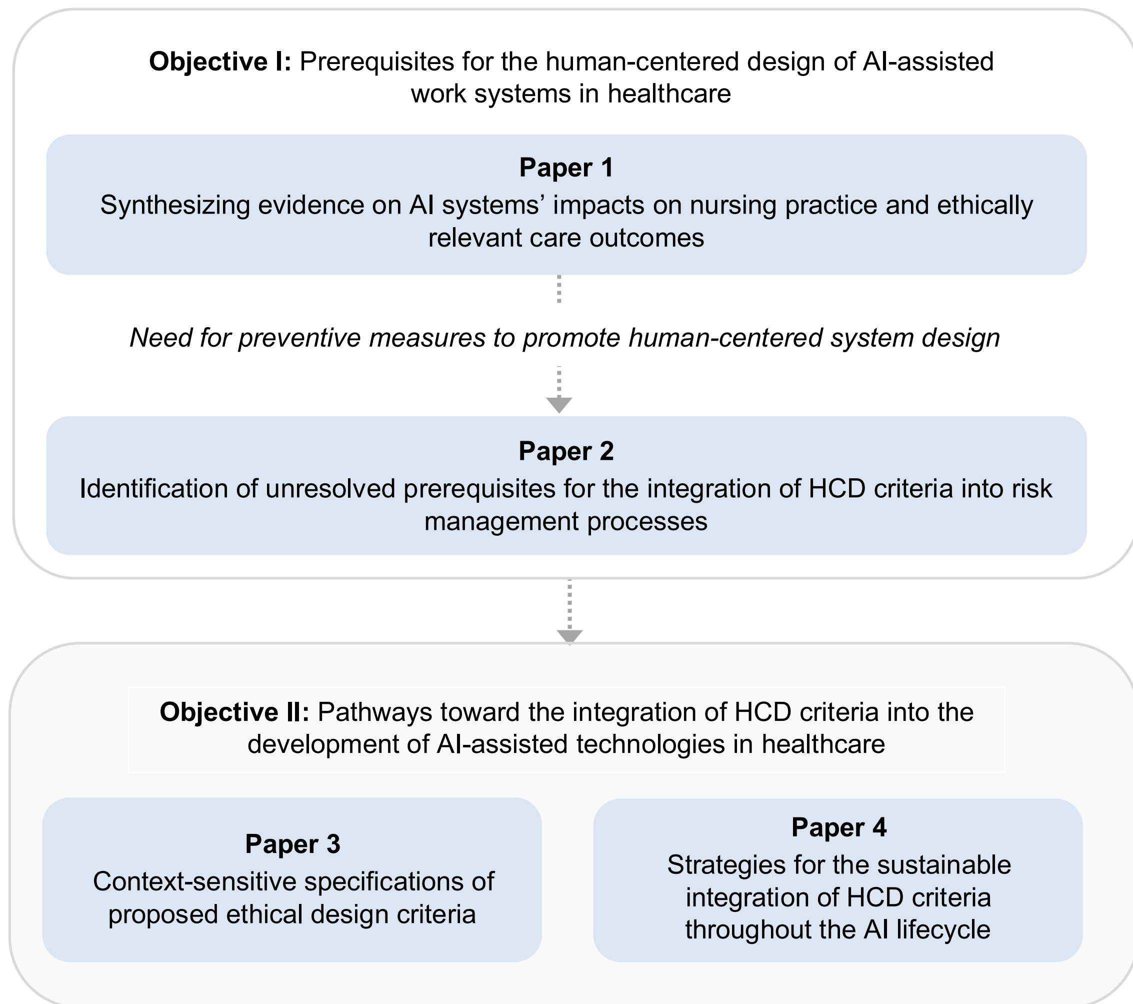
This thesis contributes to ongoing efforts to sustainably integrate normative design criteria into AI system design by proposing strategies and instruments aimed at enhancing risk management processes through mechanisms that enable the assessment of the impacts of AI systems on the situated needs and practices of stakeholders and that support continuous alignment with HCD criteria within the AI lifecycle (see “AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design” in **Section 4.4**).

3 Research Questions

As shown in the previous sections, there is a current lack of effective approaches to the integration of normative design criteria into the development of AI-assisted work systems in healthcare and, in turn, of ways to ensure the well-being of healthcare personnel and safeguard patient interests. Existing AI frameworks and guidelines generally formulate HCD criteria at a level that is detached from the practical requirements of the healthcare sector, and they fail to offer adequate guidance for their translation into risk management and compliance processes. This dissertation contributes to ongoing efforts to develop socially beneficial AI systems through two research objectives. First, it aims to determine which specific prerequisites exist for the development of measures for the human-centered design of AI-assisted work systems in the healthcare sector (*Objective I*). Second, it proposes exemplary pathways (i.e., strategies and instruments) toward the effective integration of normative design requirements throughout AI tools' lifecycles (*Objective II*). These objectives are addressed through four research papers, with Papers 1 and 2 focused on *Objective I* and Papers 3 and 4 focused on *Objective II* (see **Figure 3**).

Figure 3

Relationships among the research papers



Note. HCD = human-centered design.

Prerequisites for the human-centered design of AI-assisted work systems in healthcare

As a foundational step, this dissertation systematically examines the current research landscape on digital healthcare technologies (see **Section 4.1**), including through a focused analysis of AI-assisted technologies (see **Section 4.1.6**). *Paper 1* is a systematic analysis of the association between digital technologies (including AI-assisted technologies) on the one hand and *work-related* and *organizational factors*, nurses' *occupational safety and health*, and *ethics-related outcomes* for individuals in need of care

on the other hand. More specifically, the paper is guided by the following research questions:

- What digital (and AI-assisted) technologies are empirically investigated in reviews focused on digital technologies in nursing?
- What associations between the use of digital (and AI-assisted) technologies and work-related or organizational factors, as well as occupational safety and health outcomes, are reported in these reviews?
- What associations between the use of digital (and AI-assisted) technologies and ethically relevant outcomes for individuals in need of care are reported in these reviews?

Building on the findings from Paper 1, which underscores the need for preventive measures to promote human-centered technology design, *Paper 2* identifies to-date unresolved prerequisites for the effective integration of HCD criteria into risk management processes (see **Section 4.2**). The analysis underscores two fundamental requirements: (i) the context-sensitive specification of ethical design criteria, and (ii) the enhancement of risk management processes through mechanisms that enable runtime risk assessment of AI systems' impacts on situated stakeholder needs and practices and that, building on this, support *continuous* alignment with HCD criteria. Paper 2 is informed by the following research question:

- What are as-yet unresolved prerequisites for effectively aligning AI-assisted work systems in healthcare with HCD criteria through enhanced risk management processes?

Pathways toward the integration of HCD criteria into the development of AI-assisted technologies in healthcare

Addressing the identified requirement of a *context-sensitive specification of proposed ethical design criteria* and, more specifically, of *bottom-up case studies* involving direct stakeholders, *Paper 3* draws on semi-structured interviews with individuals who are potentially affected by the implementation of AI technologies in nursing care, i.e., nurses and care recipients (see **Section 4.3**). The focus of these interviews was on situations involving moral decision-making in everyday nursing care.

Participants were prompted to reflect on the ethical design criteria of *beneficence*, *respect for autonomy* and *justice*, as well as their expectations regarding the actualization of their conceptualizations of these criteria in the context of AI-assisted decision-making. Paper 3 is structured around the following research questions:

- How do direct stakeholders of the nursing sector (i.e., nurses and care recipients) conceptualize the ethical criteria of beneficence, respect for autonomy and justice?
- What potential influences do these stakeholders anticipate from the use of AI-assisted technology in situations that involve moral decision-making regarding the actualization of their conceptualizations of the criteria?

Finally, in response to the identified need develop strategies and instruments aimed at enhancing existing risk management processes through mechanisms that facilitate the assessment of AI systems' impacts on situated stakeholder needs and practices and support *continuous* alignment with HCD criteria, *Paper 4* presents the methodology and findings of a multi-stakeholder dialogue in which stakeholder groups with diverse roles and institutional backgrounds collaboratively identified such pathways through structured exchange (see **Section 4.4**). The guiding research question behind this paper was as follows:

- What strategies and instruments can facilitate the sustainable integration of HCD criteria into the development of AI systems in healthcare?

4 Manuscripts

4.1 Digital Technologies in Nursing: An Umbrella Review

Larissa Schlicht[*], Johannes Wendsche, Marlen Melzer, Letizia Tschetsche, Ulrike Rösler

Abstract

Background: Digital technologies promise to reduce nurses' workload and increase quality of care. However, considering the plethora of single and review studies published to date, maintaining a comprehensive overview of digital technologies' impact on nursing and effectively utilizing available evidence is challenging. *Objective*: This review aims (i) to map published reviews on digital nursing technologies, based on their aims and the specific technologies investigated, to synthesize evidence on how these technologies' uses is associated with (ii) nurses' work-related and organizational factors, professional behavior, and health and work safety and (iii) ethically relevant outcomes for people in need of care. *Design*: Preregistered overview of reviews (PROSPERO-ID: CRD42023389751). *Setting(s)*: We searched for systematic reviews in eight databases, five key journals, and reference lists of included reviews published in English until May 21, 2024. *Methods*: We used the AMSTAR 2 checklist to assess the methodological quality of included reviews reporting associations with nursing outcomes. The extracted data were analyzed by their frequency and narratively synthesized. *Results*: We identified 213 reviews on digital technologies' uses in the nursing sector. Most of these focused on information and communication technologies. The most frequently reported research objectives encompass technology usage and/or general experiences with it and technology-related consequences for care recipients. Regarding work-related and organizational factors, beneficial impacts were found for the execution of nursing tasks, information management and job control. Depending on the technology type, reviews reported mixed effects for documentation activities, communication/collaboration and mainly negative effects on nurses' workload. Concerning occupational safety and health-

related and further nurse outcomes, reviews reported mostly positive effects on nurses' job satisfaction and professional competence. Adverse effects related to mental and physical strain, such as increased frustration, fatigue, and burnout. Regarding ethically relevant outcomes, robotic and telecare technologies had the most reported findings. Most evidence concerned effects on the principles of beneficence/nonmaleficence and respect for autonomy. *Conclusions*: Digital nursing technologies' legitimacy hinges on their impact on patient outcomes and nurses' work, safety, and health. This review identifies a diverse array of these technologies, with both positive and negative effects. However, due to narrative limitations, meta-analysis was impractical. Future research should quantitatively assess the effects of various digital nursing technologies on work, safety, health, and ethical outcomes.

What is already known

- Digital technologies are increasingly being introduced in the healthcare sector and will influence nurses' work and health.
- Numerous single studies and reviews analyze digital technologies in nursing.
- Given the plethora of studies published to date, maintaining a comprehensive overview of digital technologies' impact on nursing and effectively utilizing available evidence is challenging.

What this paper adds

- Mapping of published reviews on digital nursing technologies, based on their aims and the specific technologies investigated.
- Synthesis of evidence on how the usage of various digital technologies is associated with nurses' work-related and organizational factors as well as related individual outcomes.
- Synthesis of evidence on how the usage of various digital technologies is associated with ethically relevant outcomes for people in need of care.

4.1.1 Background

Amid healthcare challenges like workforce shortages and aging populations, digital technologies offer the chance to enhance job demands for healthcare professionals and elevate care quality (EC, 2021a; WHO, 2016). Consequently, diverse scientific fields, including engineering, medicine, nursing, psychology, philosophy, and sociology have seen a surge in studies on digital healthcare technologies in recent years.

The interdisciplinary nature and diverse scope of the present research landscape render navigation complex and challenging. Furthermore, the vast majority of studies and reviews investigating the potential utility of digital technologies in healthcare seem to focus on physician or patient outcomes. However, professional nurses account for approximately 59 % of the world's healthcare workforce (WHO, 2020) and are considered key users of digital technologies (Rouleau et al., 2017; WHO, 2019). Nevertheless, numerous single studies and reviews also analyze digital technologies in nursing. Given the plethora of studies published to date, maintaining a comprehensive overview of digital technologies' impact on nursing and effectively utilizing available evidence is challenging.

Digital nursing technologies encompass a broad spectrum of tools designed to support nursing practice. Unlike non-digital technologies, they typically enable data processing and often allow tasks to be performed more efficiently, remotely, and with greater accuracy. Examples include electronic health records (for streamlining patient documentation), telecare systems (for remote patient monitoring), robots (to assist with routine tasks), and decision support systems (to aid clinical decision-making). A more detailed overview can be found in Huter et al. (2020).

As work tools, digital technologies can influence work demands and organizational structures, thereby affecting employee stress, safety and health (Parker & Grote, 2022). For example, a review by Wisner et al. (2019) showed that while the use of electronic health records can improve interprofessional communication, they may also increase nurses' cognitive load. Early identification of these changes is crucial to optimize benefits and prevent potential harm to employees and patients. In fact, decent work constitutes an overarching goal in the digital world (Deshpande et al., 2021; United Nations, 2015), and according to the International Occupational

Safety and Health Convention (C155; ILO, 1981) it is mandatory to ensure that digitalized workplaces, including working tools, equipment, and processes are safe and do not bear work-related health risks. However, to the best of our knowledge, no systematic overview has yet considered the impact of various digital nursing technologies on work-related and organizational factors, occupational safety or health-related outcomes. Several overviews of reviews have examined digital nursing technologies, focusing on specific technologies such as telehealth applications (Spelten et al., 2021; McLean et al., 2013; Zhang et al., 2023). They found, for example, that telehealth technologies can improve the accuracy of nursing care and provide a cost-effective solution, particularly in the care of the elderly. An overview of reviews by Huter et al. (2020) examined *various* digital technologies but focused solely on effectiveness outcomes. The review found that various digital nursing technologies have the potential to improve efficiency through improved patient safety, streamlined documentation and improved workflows.

Given the large number of relevant reviews, we chose to conduct an umbrella review to map, aggregate and synthesize findings from multiple systematic reviews. This approach enables us to offer a thorough overview of the topic across different settings and interventions. Additionally, we aimed to identify potential evidence gaps to help direct future systematic reviews and prioritize research efforts.

In addition, ethical aspects must be considered when developing digital technologies in the nursing sector. Nurses regularly make complex decisions involving multiple perspectives and individual care situations, often with significant moral consequences (Rainer et al., 2018). The risk of neglecting patient interests and repercussions in care processes is independent of digital technologies but can increase with their use, particularly for technologies that affect human relationships (Schlicht & Räker, 2024). Such technologies have the potential to alter the dynamics between nurses and patients, fundamentally challenging and/or transforming "traditional cultures of caring ethics" (Ramvi et al., 2023, p. 1124). This concerns, for example, tendencies toward risky and unsafe work behaviors, changing power dynamics and opportunities for empathic interaction between nurses and care-recipients. To ensure ethical alignment, information on the association of digital technologies with ethically relevant outcomes for people in need of care is needed (Brey, 2009). However, to our

knowledge, no review has yet synthesized evidence on this issue for various digital nursing technologies' usage.

Against this background, the present overview of reviews aims to (i) map existing reviews on digital nursing technologies, based on their aims and the specific technologies investigated, and synthesize evidence on how these technologies' use is associated with (ii) work-related and organizational factors, professional behavior, health- and safety-related outcomes among nurses (including midwives, see ANA, 2023), as well as (iii) ethically relevant outcomes for people in need of care. Based on this, we draw conclusions regarding the implications for future research and practice.

4.1.2 Methods

Our methodological approach followed the recommendations of Higgins et al. (2023), McCrae et al. (2015), and Smith et al. (2011). The review board included five scientists with methodological expertise, long-lasting expertise in the healthcare sector, and comprehensive knowledge on the digitalization of in-person-related tasks. The review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (ID: CRD42023389751; https://www.crd.york.ac.uk/prospero).

4.1.2.1 Research Questions

Our review addresses the following questions:

- Q1. How many reviews empirically investigating the use of digital technologies in the nursing sector have been published since 2010, which digital technologies were investigated, and which research objectives were stated by the authors?
- Q2. What associations between digital technologies' use and work-related or organizational factors, occupational safety and health, and distal nurse outcomes are reported in these reviews?
- Q3. What associations between digital technologies' use and ethically relevant outcomes for people in need of care are reported in these reviews?

4.1.2.2 Inclusion Criteria

Reviews were included if they (a) were systematic reviews (with or without meta-analysis), that is, those reporting clearly stated objectives, a reproducible methodology, eligibility criteria for reviews, databases, and the number of included studies; (b) were written in English; (c) investigated a specified digital technology; (d) investigated a technology that is typically used in the nursing context (and/or, at least half of the included single studies had to address nurses within the population(s) under research); (e) were published between January 01, 2010 and May 21, 2024; and (f) were published in a peer-reviewed journal.

4.1.2.3 Search Strategy

We conducted a systematic search in the electronic databases Cumulative Index to Nursing and Allied Health Literature (CINAHL), the Cochrane Library, EBSCOhost (including PsycINFO, PsycArticles, and Psyndex), Excerpta Medica database (Embase) (excluding PubMed/ MEDLINE), ProQuest, PubMed, Scopus, and Web of Science on April 13., 2022. The search was updated on May 21, 2024. Additionally, we manually searched five key journals in the field of nursing studies (International Journal of Nursing Studies, International Journal of Mental Health Nursing, Journal of Nursing Management, Intensive and Critical Care Nursing, and Worldviews on Evidence-Based Nursing). We also checked the reference lists of included reviews to reduce the risk of missing relevant reviews.

The keywords for each of these databases are listed in Appendix B1. The search terms were based on the PICOS scheme, excluding the comparison and outcome components, as we aimed to be inclusive and provide a broad overview of technologies used in or developed for the nursing sector. To develop the search string, we analyzed and integrated search strings used in other published reviews related to digital technologies in healthcare, as well as available MeSH terms. The search terms were discussed with experts for safety and health in a digitalized world of work from the German FIOSH and experienced librarians.

The bibliographic software package EndNote (version X9.3.3) was used to manage all articles analyzed in the research process (both included and excluded reviews).

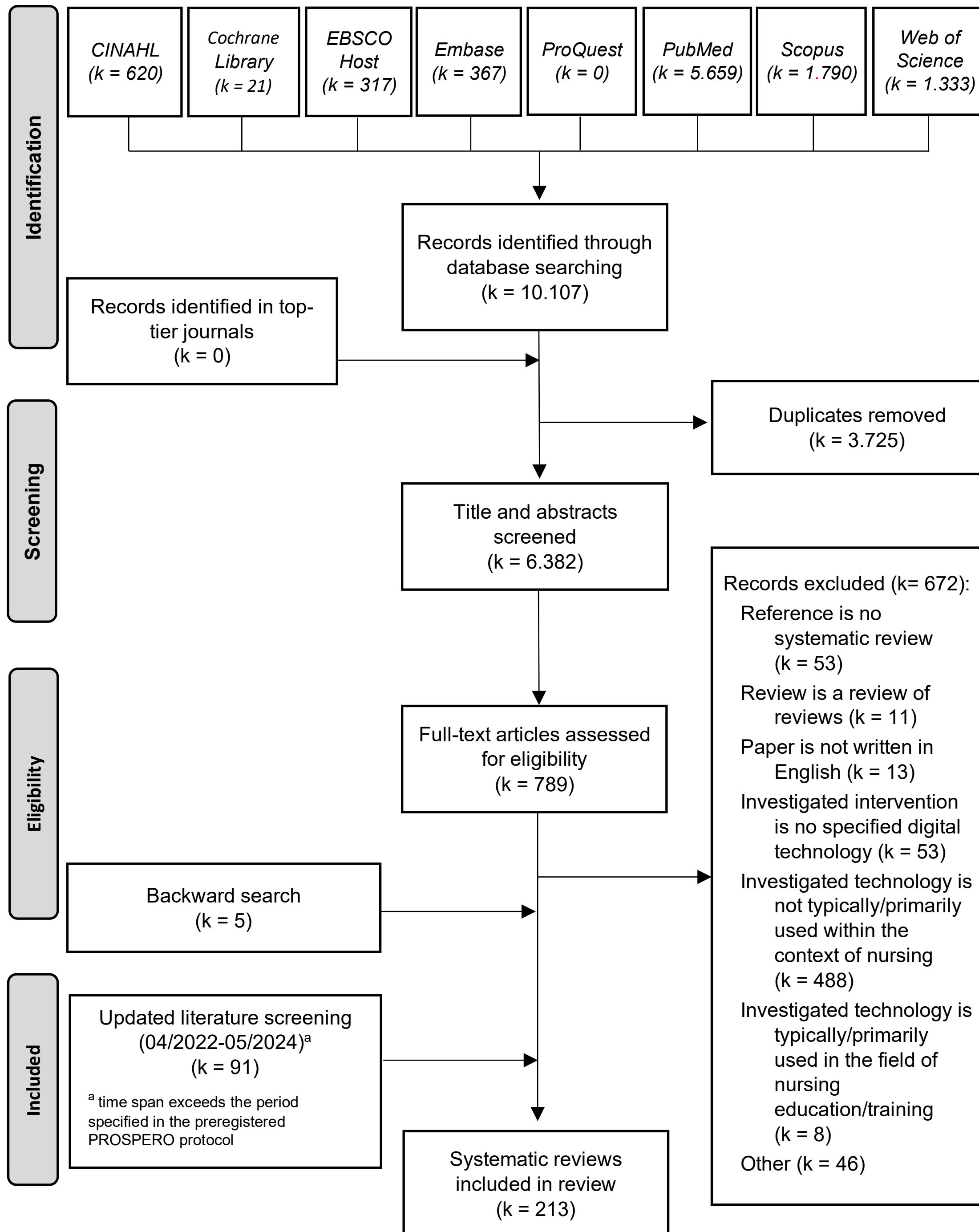
4.1.2.4 Study Selection

Figure 4 shows the flowchart of our literature search (following the PRISMA 2009 flow diagram of Moher et al., 2009). From the 10.107 records initially found, we excluded 3.725 duplicates, leaving 6.382 records for title and abstract screening. Initially, 50 references were selected and screened by all authors. This was followed by a discussion of criteria for inclusion and exclusion due to moderate agreement (κ = 0.49; 68 %). Another set of 50 references was then screened by pairs of authors, with subsequent discussion. At this stage, the interrater agreement was 84 %, i.e., there was *sufficient/good* agreement between the raters with Fleiss' kappa statistic κ = 0.70 (Fleiss, 1971). Each author continued to screen a set of the references by applying the eligibility criteria.

After the exclusion of 5.593 publications, all authors (LS, UR, MM, JW, LT) reviewed a set of the 789 full-text articles independently. We excluded 672 articles (see Appendix B2) that did not meet the inclusion criteria using the web-app Rayyan (Ouzzani et al., 2016), resulting in 117 included reviews. As a result of the literature update, 91 reviews were added. After screening the reference lists of the included reviews, we identified five additional reviews. The final sample comprised 213 reviews.

Figure 4

PRISMA flow diagram illustrating the systematic search and review selection process



4.1.2.5 Data Extraction and Quality Assessment

The reviews were coded for data extraction using IBM SPSS Statistics 29.0. We developed a standardized data charting form to extract relevant data from the selected papers. Before starting data collection, the entire team reviewed the form. In addition, three authors conducted a pilot test on 20 studies to confirm the accuracy of the form. The extracted data included information on the digital technology investigated, the reviews' objective(s), investigated work-related and organizational factors, occupational safety and health-related outcomes and related distal nurse outcomes, and ethically relevant outcomes for people in need of care. We also extracted information regarding the number of studies included and the healthcare settings investigated (in/outpatient long-term care and shortterm care) (see Appendix B3).

We used the technology categories developed by Huter et al. (2020) to classify digital nursing technologies. Two reviewers (LS, UR) iteratively developed all other categories during parallel coding in order to answer our research questions. In case of a disagreement, results were discussed between both to achieve consensus. The extracted data were analyzed by their frequency and narratively synthesized. The outcome data associated with the use of digital technologies were classified into four categories: impairments, inconsistent findings, no effect, and improvements. We did not statistically aggregate effect sizes because most of the included references that were analyzed for answering Q2 and Q3 (111 out of 118) were qualitative reviews. Due to the high heterogeneity among the included meta-analyses, a meaningful statistical summary was impractical.

Specifically, one meta-analysis investigated telecare technology (Flodgren et al., 2015), two investigated robotic technology (Abbott et al., 2019; Yen et al., 2024), two investigated monitoring/sensor applications (Areia et al., 2021; Cortes et al., 2021) and two investigated multiple technologies (Zhang et al., 2023; Tian et al., 2024). Consequently, reported associations reflect qualitatively described relationships.

We used the critical items 2, 4, 7, 9, 11, 13, and 15 of the AMSTAR 2 checklist to assess the reviews' methodological quality (i.e., for Q2 and Q3). Overall confidence was rated as *high*, *moderate*, *low*, or *critically low* (Shea et al., 2017).

4.1.3 Results

4.1.3.1 Number and Characteristics of Identified Reviews (Q1)

Methodological quality of the reviews

Regarding review quality (see Appendix B4), 101 out of 118 reviews answering Q2 and Q3 (86%) received a rating of critically low quality, i.e., they had at least two critical weaknesses. Eighteen reviews were evaluated as low quality, i.e., they had at least one critical weakness.

Digital technologies

Table 2 lists the number of reviews for each technology category. More than half of the reviews (k = 118; 55 %) focused on information and communication technologies. Most of these were telecare technologies (k = 43; 20 %), followed by electronic health/medical records (k = 37; 17 %), computerized decision support systems (k = 21; 10 %; in the following referred to as “decision support systems”), health institution information systems (k = 7; 3 %), communication support systems, and apps (both ks = 5; 2 %). The second largest category comprised robotic technology, which was investigated in 38 reviews (18 %). Moreover, six reviews (3 %) analyzed monitoring/sensor applications, five virtual and augmented reality technology (2 %) and three (1 %) assistive devices. The remaining reviews examined other technologies (k = 12; 6 %) or multiple technologies (k = 31; 15 %).

Table 2

Number of reviews differentiated for digital technologies and reported associations with nursing outcomes

Digital technology	Reviews investigating digital technologies (Q1)	Reviews reporting associations with work-related/organizational factors or safety and health-related outcomes (Q2)	Reviews reporting associations with ethically relevant patient outcomes (Q3)
	k (%)	k (%)	k (%)
Information and communication technologies	118 (55.1)	59 (56.7)	17 (40.5)
Health institution information systems	7 (3.3)	5 (4.8)	1 (2.4)
Electronic health/medical records	37 (17.4)	24 (23.1)	1 (2.4)
Computerized decision support systems	21 (9.9)	8 (7.7)	3 (7.1)
Telecare technologies	43 (20.2)	18 (17.3)	8 (19.1)
Communication support systems	5 (2.3)	1 (1.0)	2 (4.8)
App(s)	5 (2.3)	3 (2.9)	2 (4.8)
Robotic technologies	38 (17.8)	20 (19.2)	14 (33.3)
Monitoring/sensor applications	6 (2.8)	5 (4.8)	1 (2.4)
Assistive devices	3 (1.4)	1 (1.0)	0 (0.0)
Virtual/augmented reality	5 (2.3)	1 (1.0)	1 (2.4)
Other	12 (5.6)	7 (6.7)	0 (0.0)
Multiple technologies	31 (14.6)	11 (10.6)	9 (21.4)
Total (%)	213/213 (100)	104/213 (100)	42/213 (100)

Note. k = total number of reviews. Only one technology category could be selected per review, Q: research question.

Note that the following included reviews only refer to Q1: Aarskog et al. (2019), Andtfolk et al. (2022), Arruum et al. (2022), Bail et al. (2022), Barbosa Ide et al. (2016), Bernabei et al. (2013), Blythe et al. (2022), Borum (2018), Bright & Doody (2023) Brown et al. (2023), Burnazovic et al. (2024), Castro et al. (2023), Charalambous et al. (2024), Choi et al. (2023), Conte et al. (2023), de Diego et al. (2024), de Leo et al. (2023), Dendere et al. (2021), Dionisi et al. (2019), Domingos et al. (2017), dos Santos et al. (2023), Felding et al. (2023), Fenton et al. (2023),

Fernandes et al. (2024), Finley et al. (2021), Fithriyyah & Aulawi (2022), Galiano et al. (2024), Gillam et al. (2021), Gondim et al. (2022), Guardado et al. (2024), Hamade et al. (2019), Harada et al. (2023), Head et al. (2017), Hogan-Murphy et al. (2015), Holloway et al. (2024), Hsu & Kao (2023), Huryk (2010), Hwang et al. (2022), Hwang & Chang (2023), Islam et al. (2021), Jedwab et al. (2023), Kachouie et al. (2014), Kamei et al. (2013), Kang et al. (2020), Kappes et al. (2023), Kausch et al. (2021), Khairunisa & Triharini (2023), Khong et al. (2015), Kruse et al. (2015), Kulpa et al. (2021), Li et al. (2024), Linda et al. (2024), Long et al. (2017), Ma et al. (2023), MacDonald et al. (2023), Manietta et al. (2022), Mathijssen et al. (2023), McCarthy et al. (2019), Meissner & Schnepp (2014), Mieronkoski et al. (2017), Miller et al. (2021), Moerman et al. (2019), Molinari-Ulate et al. (2023), Mun et al. (2023), Nagel & Penner (2016), O'Connor et al. (2022a, 2024), Ozkaynak et al. (2017), Papadopoulos et al. (2020), Piaggio et al. (2023), Piazza & Drury (2023), Poitras et al. (2024), Qi et al. (2023), Ragno et al. (2023), Raymond et al. (2022), Redondo-Sáenz et al. (2023), Rezende et al. (2023), Ruksakulpiwat et al. (2024), Servaty et al. (2020), Sexton et al. (2022), Shamsabadi et al. (2023), Shishehgar et al. (2018), Sivakanthan et al. (2021), Stolic et al. (2023), Strudwick & Hall (2015), Tasçi et al. (2024), Tay Hui et al. (2012), Thompson et al. (2023), Toffaha et al. (2023), Toffoletto & Tello, 2020, Udsen et al. (2014), Uslu & Buldukoğlu (2016), Wan et al. (2024), Wen et al. (2024), and Yunara et al. (2023).

Research objectives

Numerous reviews aimed to investigate the relationships between digital technologies' use and the safety and health of people in need of care (k = 48; 23 %), while only a small proportion (k = 14; 7 %) considered this in relation to nurses. Twenty-seven reviews (13 %) sought to investigate technology implementation processes, and 46 reviews (22 %) assessed the impact on economic aspects. The impact of the investigated technologies on nurses' working practices was analyzed in 36 reviews (17 %). A relatively small proportion of reviews (k = 22; 10 %) addressed care quality, including ethical aspects. Approximately a fourth of the included reviews (k = 56; 26 %) aimed to examine technology usage and/or general experience with it. Approximately a firth (k = 43; 20 %) explored stakeholders' technology acceptance of

and/or attitudes toward a digital health technology. 27 reviews (13 %) sought to identify digital technologies suitable for supporting specific nursing activities.

Care setting

The studies included in the reviews were mostly conducted in shortterm care settings (e.g., hospitals) (k = 69; 32 %), followed by inpatient long-term care settings (e.g., nursing homes) (k = 35; 16 %). Only 14 reviews (7 %) included studies conducted in long-term outpatient (i.e., home care) settings. Of the reviews, 53 (25 %) focused on mixed settings and 31 (15 %) made no specification regarding the setting(s).

4.1.3.2 Associations between Digital Technologies, Work-Related or Organizational Factors, and Occupational Safety and Health-Related Outcomes (Q2)

The reported associations between the use of digital technologies and work-related or organizational factors, as well as occupational safety and health-related and distal nurse outcomes, covered a wide range of aspects. Owing to the multitude of outcomes, we built upon the classifications by Huter et al. (2020) and Parker and Grote (2022) and coded data into two main categories: (a) work characteristics, encompassing work-related and organizational factors (e.g., nurses' work behavior, job demands, and communication/collaboration) potentially affecting nurses' safety and health and (b) proximal indicators reflecting nurses' occupational safety and health-related outcomes, specifically (mental and physical health, occupational safety) and distal outcomes (e.g., nurses' job-related competence and job-related attitudes, nurse–patient relationship).

Work-related and organizational factors

We found 95 systematic reviews reporting associations between digital technologies' use and work-related and organizational factors. Across the various technologies, the included reviews indicated more favorable effects than adverse ones (see **Table B1** in Appendix B5). Specifically, decision support systems and electronic health records showed more positive than negative effects, whereas for monitoring/ sensor applications it was the opposite. Overall, most reported associations were for electronic health/medical records, followed by telecare systems.

The work-related and organizational factors examined covered aspects such as nurses' work behavior (i.e., general nursing activities or more specific documentation activities), quantitative demands (i.e., workload, time savings, staffing, and workflow), cognitive demands (i.e., cognitive load and information management), communication/collaboration, and job control. They represent important aspects of work design that must be considered when digital technology is integrated into work systems (Parker & Grote, 2022). Moreover, we also found several moderating variables.

Table 3 shows the associations between digital technologies and nurses' work-related and organizational factors. Most findings were available for associations to aspects of working time (k = 37 reviews on *time savings*), nurses' *workload* (k = 32) and *communication and collaboration* (k = 29). Twenty-four reviews reported on aspects of *nursing activities in general* and w*orkflow*, respectively, 23 on *information management* and 16 on *nursing documentation activities*. Evidence for associations with cognitive load (k = 5), nurses' *job control* (k = 6), and *staffing* (k = 4) was scarce.

Table 3

Associations between digital technologies and nurses' work-related and organizational factors

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
Nursing activities (general)		
ICT	HIS (k = 3)	(–) new staff roles without compensation (Ko et al., 2018)
		(0) no changes in time spent (Kruse et al., 2021; Waneka & Spetz, 2010)
	EHR/EMR (k = 3)	(0) no changes in individualized patient care (Stevenson et al., 2010)
		(+) more standardized care and prevention of complications (Hovde et al., 2015)
		(+/–) mixed results regarding documentation comprehensiveness (Hants et al., 2023)
	CDSS (k = 3)	(+) clinical work standardization (e. g. less deviations from protocols or reduction of cognitive bias) (Abdellatif et al., 2021; Harmon et al., 2012; Mebrahtu et al., 2021)
	Telecare technologies (k = 5)	(–) extra responsibility, rather than an efficient aid tool (Brewster et al., 2014); tasks changes: monitoring and responding to tele-homecare data, installing devices, training patients, resolving technical difficulties (Radhakrishnan et al., 2016)
		(+) reduced need to travel (Penny et al., 2018); increased communication and interaction with patients (Radhakrishnan et al., 2016); expansion of traditional roles was perceived as motivating and challenging (Tan et al., 2021)
	Communication support systems	[not reported]
	App(s)	[not reported]
Robotic technologies (k = 6)		(+/–) helpful for reminders, alarms and monitoring, but not for core nurse activities (Papadopoulos et al., 2018)
		(0) new tasks, including preparation and continuous monitoring of robotic technology (Celik et al., 2022; Martins et al., 2019; Scerri et al., 2021)
		(+) can assist nurses in the performance of routine tasks (in patients' home) (Dino et al., 2022; Ghafurian et al., 2021)
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		(+) sensors offer nurses' telecare and remote work (Behera et al., 2021)
Virtual-/augmented reality		[not reported]
Other (k = 2)		(0) changes in the nurses' role and work tasks (internet) (Ahmad et al., 2018)
		(+) less space required and less waste (drug distribution systems) (Ahtiainen et al., 2020)
Multiple technologies (k = 2)		(+) simplification of work tasks (ICT) (Fagerström et al., 2017); support for patient education (Saab et al., 2021)
Nursing activities (documentation)		
ICT	HIS (k = 3)	Quality: (+/–) (Ko et al., 2018) but also (+) improvements (Kruse et al., 2021; Waneka & Spetz, 2010)
		Time: (+/–) (Moore et al., 2020; Waneka & Spetz, 2010)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
	EHR/EMR (k = 3)	Quality: (+) improvements (da Costa & da Costa Linch, 2020)
		Time: (–) increased time spent on documentation (Forde-Johnston et al., 2023); (+/–) (Jedwab et al., 2019; Kelley et al., 2011); (+) reduction (Shiells, 2019)
	CDSS (k = 3)	[not reported]
	Telecare technologies (k = 5)	(+) enhanced accuracy in information assessment and documentation (Gagnon et al., 2024)
	Communication support systems	[not reported]
	App(s)	(+) more consistent documentation (Glanville et al., 2023)
Robotic technologies (k = 6)		[not reported]
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		(–) more documentation discrepancies (drug distribution systems) (Ahtiainen et al., 2020)
		(+) more accurate patient data assessment (speech recognition technology) (Joseph et al., 2020)
Multiple technologies (k = 2)		Quality: (+) improvements (O'Connor et al., 2022b); (–) high effort (Telecare) (Huter et al., 2020)
		Time: (–) increase in documentation time (Cofetti et al., 2023; HIS systems: Huter et al., 2020)
Workload		
ICT	HIS (k = 3)	(-) increased workload for senior nurses and those responsible for consultation preparation (Shelley et al., 2024)
	EHR/EMR (k = 3)	(+/–) increased during implementation (decrease with time) (Tolentino and Gephart, 2020)
		(0) changes (Stevenson et al., 2010)
		(+) reduction (Kelley et al., 2011; Nguyen et al., 2021)
	CDSS (k = 3)	(+) reduction (Abdellatif et al., 2021)
		(+/–) (Sariköse & Şenol Çelik, 2024)
		(0) no changes (Dunn Lopez et al., 2017)
	Telecare technologies (k = 5)	(–) increased workload (Radhakrishnan et al., 2016; Tan et al., 2021; Wahyuni et al., 2023; Young et al., 2011), due to increased time spent on interaction (Golden et al., 2024), frequent task switching, interruptions, and collaboration with technicians (McNamara, 2024), burdensome alerts and reminders (Lundereng et al., 2023)
		(0/–) inconsistent reported association (Koivunen & Saranto, 2018; Valk-Draad & Bohnet-Joschko, 2022)
	Communication support systems	[not reported]
	App(s)	(–) increased problems with life-domain balance because of messages during off-job time (de Jong et al., 2020)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
		(+) reduction (regenerating function by allowing leisure activities during breaks) (Fiorinelli et al., 2021)
Robotic technologies (k = 6)		(–) increased (PARO system (robotic animal)) (Budak et al., 2021)
		(+/–) (Ohneberg et al., 2023), distracted residents and reduced wandering behavior (Ghafurian et al., 2021)
		(+) reduction (Kangasniemi et al., 2019; Loveys et al., 2022)
Monitoring/sensor applications		(–) adverse consequences of alarms and technology use for burden of care and workload (Areia et al., 2021; Cortes et al., 2021; Davis et al., 2014)
		(+/–) improved alarm efficacy vs. need to deal with frequent device errors (Mileski et al., 2019)
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		(+/–) changes depending on system (drug distribution systems) (Ahtiainen et al., 2020)
Multiple technologies (k = 2)		(–) increased (HIS system) (Huter et al., 2020), feelings of time pressure and increased workload during implementation (Cofetti et al., 2023)
		(+/–) inconsistent findings (HIS, apps, virtual-/augmented reality, assistive devices) (Mohammadnejad et al., 2023); (+) reduction (e.g., walking distances, use of robots for lifting patients) (Huter et al., 2020), decreased pressure (Zhou et al., 2023)
Time savings		
ICT	HIS (k = 3)	(+) improved (fewer phone calls and visits) (Shelley et al., 2024)
	EHR/EMR (k = 3)	(–) less patient care time due to increased time spent on documentation (Forde-Johnston et al., 2023; Harmon et al., 2020; Kelley et al., 2011)
		(+/–) (Jedwab et al., 2019; Kruse et al., 2017; Mohsin-Shaikh et al., 2019), initial increase in documentation time, but decrease with frequent use (Saraswasta & Hariyati, 2018)
		(+) improved (da Costa & da Costa Linch, 2020; de Sousa et al., 2012; Fuller et al., 2018; Hovde et al., 2015; Park et al., 2024)
	CDSS (k = 3)	(+) improved (Abdellatif et al., 2021; Sariköse & Şenol Çelik, 2024)
	Telecare technologies (k = 5)	(+) improved (e.g., reduced clinical time, patient waiting times) (Gagnon et al., 2024; Gordon et al., 2022; Koivunen & Saranto, 2018)
		(0) no effects on hospital transfers (Gordon et al., 2022)
	Communication support systems	[not reported]
	App(s)	(+) improved (e.g., for information search) (de Jong et al., 2020; Fiorinelli et al., 2021; Glanville et al., 2023)
Robotic technologies (k = 6)		(+/–) (Haubold et al., 2020)
		(+) time for data collection and drug administration (Kangasniemi et al., 2019; Maalouf et al., 2018)
Monitoring/sensor applications		(–) lead nurses require more time for data management with risks for inadequate staffing (Davis et al., 2014),
		(+) improved time management (Omotunde & Wagg, 2023)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
Assistive Devices (k = 1)		(+) reduction of time for non-care tasks (e.g., traveling) (Behera et al., 2021)
Virtual-/augmented reality		(+) improved (Wuller et al., 2019)
Other (k = 2)		(+/–) (drug distribution systems) (Ahtiainen et al., 2020)
		(0) unplanned overtime hours [which was expected to be reduced] (digital workforce management systems) (Tuominen et al., 2018)
		(+) improved (automated pharmacy systems: Batson et al., 2021; speech recognition technology: Joseph et al., 2020; medication dispensing and administration technology: Zheng et al., 2021); reduction of time for scheduling, including plans and shift exchanges (automated scheduling and rostering systems) (O'Connell et al., 2024)
Multiple technologies (k = 2)		(–) system errors perceived as waste of time (ICT) (Fagerström et al., 2017)
		(+) improved (Fagerström et al., 2017), improved for data management and documentation (EHR/EMR) (Huter et al., 2020), better time management (Saab et al., 2021)
Staffing		
ICT	HIS (k = 3)	(0) no effects on staff replacement and turnover (Ko et al., 2018)
	EHR/EMR (k = 3)	[not reported]
	CDSS (k = 3)	[not reported]
	Telecare technologies (k = 5)	(+/–) possibility to overcome challenges associated with staff shortages during nights and weekends as well as in rural hospitals but also concerns about potential negative effect on overall staffing levels (Xyrichis et al., 2021)
	Communication support systems	[not reported]
	App(s)	[not reported]
Robotic technologies (k = 6)		(+) less need for manpower in ICU by providing robot support to healthcare providers (Dino et al., 2022)
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		(+) reduced turnover rate (digital workforce management systems) (Tuominen et al., 2018)
Multiple technologies (k = 2)		[not reported]
Workflow		
ICT	HIS (k = 3)	(+/–) inconsistent for time-related fade-out (Ko et al., 2018)
		(+) improvements (Waneka & Spetz, 2010)
	EHR/EMR (k = 3)	(–) impaired (da Costa & da Costa Linch, 2020), more difficulties due to technical problems (Fraczkowski et al., 2020; Gephart et al., 2015; Kelley et al., 2011; Tolentino & Gephart, 2020)
		(+/–) (Mohsin-Shaikh et al., 2019)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
		(+) improved (Collins et al., 2011; Fuller et al., 2018; Hardiker et al., 2019; Park et al., 2024), better inclusion of nurses in intensive care processes (de Sousa et al., 2012), better staff coordination (Shiells, 2019)
	CDSS (k = 3)	[not reported]
	Telecare technologies (k = 5)	(+/–) (Golden et al., 2024; Ramnath et al., 2014)
		(+) uninterrupted periods of rest, fewer interruptions (Young et al., 2011)
	Communication support systems	(+/–) nurses expressed concerns with the adjustment of the web camera, but postintervention most nurses experience communication to be convenient and user friendly (Epstein et al., 2017)
	App(s)	(-) perception of smartphone as possible distractor (cause of distraction, loss of attention and medical errors) (de Jong et al., 2020; Fiorinelli et al., 2021)
		(+) improved (Glanville et al., 2023), increased efficiency of nurses' workflow (due to the possibility of more direct communication with physicians) (de Jong et al., 2020)
Robotic technologies (k = 6)		(–) interruption through frequent alarms (David et al., 2022)
		(+/–) (Haubold et al., 2020)
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		[not reported]
Multiple technologies (k = 2)		(–) more distractions (Saab et al., 2021)
Cognitive load		
ICT	HIS (k = 3)	[not reported]
	EHR/EMR (k = 3)	(–) increased (Gephart et al., 2015; Wisner et al., 2019), cognitive overload related to, e.g., alert fatigue and navigating the EHR (Harmon et al., 2020)
		(0/–) low technology satisfaction: increased cognitive failures (Park et al., 2024); (+) better and less mentally demanding clinical decision-making (Harmon et al., 2020)
	CDSS (k = 3)	(0) no changes (Akbar et al., 2021)
	Telecare technologies (k = 5)	[not reported]
	Communication support systems	[not reported]
	App(s)	[not reported]
Robotic technologies (k = 6)		[not reported]
Monitoring/sensor applications		(–) increased (Mileski et al., 2019)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		[not reported]
Multiple technologies (k = 2)		[not reported]
Information management		
ICT	HIS (k = 3)	(+) enhanced information use for care planning (Shelley et al., 2024)
	EHR/EMR (k = 3)	(–) maintaining information overview as risk (Wisner et al., 2019)
		(0) no changes (Kelley et a., 2011)
		(+) decrease of information loss, interruptions and omission errors (Collins et al., 2011) and better access to patient information (de Sousa et al., 2012; Fuller et al., 2018; Gephart et al., 2015; Harmon et al., 2020; Kruse et al., 2017; Park et al., 2024; Saraswasta & Hariyati, 2020)
	CDSS (k = 3)	(+) technology generated information helpful for patient discharge planning (Araujo et al., 2020)
		(–) inappropriate presentation of alerts leads to information loss (due to distractions) (Miller et al., 2015)
	Telecare technologies (k = 5)	(–) concerns about missing important patient information (Lundereng et al., 2023)
		(+) increased access to information (Gagnon et al., 2023; Koivunen & Saranto, 2018), improved decision making (Penny et al., 2018)
	Communication support systems	[not reported]
	App(s)	(+) flexible access to patient data (Fionrinelli et al., 2021)
Robotic technologies (k = 6)		[not reported]
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		(–) risk of missed patient information (i.e., relevant symptoms) as the focus is directed away from the patient (Wuller et al., 2019)
		(+) easy information retrieval, observation from different perspectives (Wuller et al., 2019)
Other (k = 2)		[not reported]
Multiple technologies (k = 2)		(+) better information access (Saab et al., 2021; Huter et al., 2020; Zhou et al., 2023); support for information management and clinical decision making (ICT) (Tahsin et al., 2023)
Communication and collaboration		
ICT	HIS (k = 3)	(+) improved, also teamwork (Ko et al., 2018)
	EHR/EMR (k = 3)	(–) reduction in face-to face communication (Shiells, 2019); impaired interaction among clinicians (Park et al., 2024)

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
		(+/–) inconsistent for interprofessional communication (de Sousa et al., 2012; Jedwab et al., 2019; Mohsin-Shaikh et al., 2019; Wisner et al., 2019)
		(+) communication among staff and between shifts (Hovde et al., 2015)
	CDSS (k = 3)	(+/–) inconsistent effects regarding team interaction (Sariköse & Şenol Çelik, 2024)
		(0) no changes in nursing culture (Abdellatif et al., 2021)
		(+) enhanced teamwork (between healthcare professionals) and communication (Abdellatif et al., 2021); increased ability to communicate with the multidisciplinary team (Harmon et al., 2012), better role distribution between nurses and physicians (Abdellatif et al., 2021)
	Telecare technologies (k = 5)	(–) conflicting recommendations from ICU and teleclinicians (Young et al., 2011), role conflicts because of changed responsibility in decision making (between nursing staff in care homes and external healthcare providers) (Tan et al., 2021)
		(+/–) interprofessional (Radhakrishnan et al., 2016)
		(+) improved (interdisciplinary) communication (Gagnon et al., 2024; Penny et al., 2018) and cooperation between internal and external teams (Valk-Draad & Bohnet-Joschko, 2022)
	Communication support systems	[not reported]
	App(s)	(–) decreased interdisciplinary communication and nurse performance through use of mobile devices for personal use during work hours (Fiorinelli et al., 2021), organizational policies/regulation and organizational support low or problematic (de Jong et al., 2020)
		(+) improved between staff (de Jong et al., 2020; Fiorinelli et al., 2021; Glanville et al., 2023)
Robotic technologies (k = 6)		(–) poor communication, i.e., limited nonverbal cues and direct eye contact, between surgeon, who is physically separated, and the team (robot assisted surgery) (Moloney et al., 2023)
		(0) changes in communication style requiring more interaction and increased cooperation (Lee et al., 2024)
Monitoring/sensor applications		[not reported]
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		[not reported]
Multiple technologies (k = 2)		(+) improved (interprofessional/interdisciplinary) communication (Cofetti et al., 2023; Huter et al., 2020; O'Connor et al., 2022b; Saab et al., 2021), better colleague collaboration and information exchange (ICT) (Fagerström et al., 2017; Tahsin et al., 2023), also between health and social workers (Yutong et al., 2023)
Job control		
ICT	HIS (k = 3)	[not reported]
	EHR/EMR (k = 3)	[not reported]

Digital technology		Findings from systematic reviews (with direction of impact in brackets)
	CDSS (k = 3)	[not reported]
	Telecare technologies (k = 5)	(+) improved autonomy (Young et al., 2011), improved ability to work independent and flexible (e.g., working times, workplace, remote opportunities) (Koivunen & Saranto, 2018; Golden et al., 2024)
	Communication support systems	[not reported]
	App(s)	[not reported]
Robotic technologies (k = 6)		[not reported]
Monitoring/sensor applications		(+) more responsibility (i.e., task delegation) and autonomy (Davis et al., 2014)
Assistive Devices (k = 1)		[not reported]
Virtual-/augmented reality		[not reported]
Other (k = 2)		(+) improved (automated scheduling and rostering systems) (O'Connell et al., 2024)
Multiple technologies (k = 2)		(–) loss of autonomy and control (ICT) (Fagerström et al., 2017)
Moderating variables		
ICT	HIS (k = 3)	work experience: novice nurses experience a greater impact on their workload compared to senior nurses (Shelley et al., 2024)
	EHR/EMR (k = 3)	less open culture and bottom-up communication can be hindrances (Tolentino & Gephart, 2020); problems, if no training and participation was applied during system implementation (Gephart et al., 2015); alignment of nurses' workflows and work practices with organizational policies and structures when using technology (Fraczkowski et al., 2020; Fuller et al., 2018; Hardiker et al., 2019; Shiells, 2019; Tolentino & Gephart, 2020); authentic leadership and technical support as drivers of success (Tolentino & Gephart, 2020)
	CDSS (k = 3)	technology usage is influenced by organizational factors (leadership, culture, structure, training, resources, support, champions) and patient factors (patient complexity) (Piscotty & Kalisch, 2014)
	Telecare technologies (k = 5)	involvement of staff during implementation is beneficial for acceptance (Brewster et al., 2014); potential barriers for efficient implementation: bad sound and video quality, missing technical support and missing staff training, implementation requires time and practice, interruptions, poor communication, inaccurate information (Penny et al., 2018; Ramnath et al., 2014)
	Communication support systems	[not reported]
	App(s)	[not reported]
Robotic technologies (k = 6)		implementation preparation, fit to patient needs, time for other tasks, preparation time, easy handling (Haubold et al., 2020); on-side peer-training is more effective for learning than off-side (Moloney et al., 2023); prevention of nurse interruptions (e.g., due to technical failures or additional nursing tasks) is linked to workflow advantages (Ohneberg et al., 2023)
Monitoring/sensor applications		high alarm sensitivity increases adverse effects (Mileski et al., 2019)

Digital technology	Findings from systematic reviews (with direction of impact in brackets)
Assistive Devices (k = 1)	[not reported]
Virtual-/augmented reality	[not reported]
Other (k = 2)	centralized vs. hybrid system (drug distribution systems) (Ahtiainen et al., 2020)
Multiple technologies (k = 2)	organizational factors (e.g., care-IT collaboration, nurse involvement during implementation, management support, change readiness in teams) and person factors (e.g., valence of ICT experiences, ICT skills, age, gender) (Cofetti et al., 2023); demand-side factors (e.g., low confidence and trust), technical factors (e.g., low infrastructure) and systemic factors (e.g., inadequate legislative framework) (Yutong et al., 2023)

Note. Synthesis of evidence from 95 systematic reviews. k = total number of reviews. (–): impairment, (+/–): inconsistent finding, (0) no effect, (+) improvement; ICT: Information and communication technologies, HIS: Health institution information system, EHR/EMR: Electronic health/medical record, CDSS: Computerized decision support system.

Nurses' work behavior. Many reviews reported that digital technologies support *nursing activities*. For example, Abdellatif et al. (2021), Harmon et al. (2012), and Mebrahtu et al. (2021) consistently reported an increase in clinical work standardization associated with the use of decision support systems. Two reviews found that robotic technologies could assist nurses in performing routine tasks (Dino et al., 2022; Ghafurian et al., 2021).

Quantitative demands. Most reviews reported negative or inconsistent findings regarding the association between digital technologies' use and nurses' *workload*. Additionally, some reviews had contradictory results. Areia et al. (2021), Cortes et al. (2021), and Davis et al. (2014) found an increased workload associated with the use of monitoring/sensor applications. Radhakrishnan et al. (2016), Scerri et al. (2021), Young et al. (2011) and Wahyuni et al. (2023) reported similar effects for telecare technologies, especially for home care nurses. In contrast, two reviews examining electronic health/medical records (Kelley et al., 2011; Nguyen et al., 2021) reported an increased chance for improvement associated with the technology use, while Tolentino and Gephart (2020) reported an increase in nurse workload during the implementation phase (decreasing over time). Regarding the use of robotic technologies, Kangasniemi et al. (2019) and Loveys et al. (2022) found a positive impact on nurses' workload, Ohneberg et al. (2023) and Ghafurian et al. (2021) report inconsistent results whereas Budak et al. (2021) found an increased workload for nurses.

Improvements in documentation time spent (*time savings*) have been reported particularly for the use of electronic health and medical records (da Costa & da Costa Linch, 2020; de Sousa et al., 2012; Fuller et al., 2018; Hovde et al., 2015; Park et al., 2024). Da Costa and da Costa Linch (2020) found that this reduction in time spent documenting increased the time spent communicating within the team. However, three reviews (Forde-Johnston et al., 2023; Harmon et al., 2020; Kelley et al., 2011) reported increased documentation time associated with the implementation of this technology, resulting in decreased time for patient care. Moreover, four reviews reported inconsistent effects of electronic health/medical records on time savings, such as an initial increase in documentation time, but a decrease with frequent use (Jedwab et al., 2019; Kruse et al., 2017; Mohsin-Shaikh et al., 2019; Saraswasta & Hariyati, 2018).

Regarding the effects on *staffing*, available evidence is scarce. Dino et al. (2022) found that robotic technologies could reduce the need for manpower in intensive care units. Xyrichis et al. (2021) reported mixed effects for telecare technologies. While some results indicated the suitability of these technologies for overcoming challenges associated with staff shortages at night, on weekends, and in rural hospitals others suggested potential negative effects on overall staffing levels.

Associations between digital technologies and nurses' *workflow* are mainly found for electronic health/medical records. The included systematic reviews reported both adverse and desirable effects. On the one hand, four reviews found improved workflows for nurses using such technology (Collins et al., 2011; Fuller et al., 2018; Hardiker et al., 2019; Park et al., 2024), and de Sousa et al. (2012) reported that nurses were more involved in intensive care processes. Similarly, Shiells et al. (2019) found indications of improvements in staff alignment. On the other hand, five reviews reported disrupted workflows, partly due to technical difficulties (da Costa & da Costa Linch, 2020; Fraczkowski et al., 2020; Gephart et al., 2015; Kelley et al., 2011; Tolentino & Gephart, 2020).

Cognitive demands. Although findings on the impact of digital technologies on nurses' *cognitive load* are generally scarce, three reviews (Gephart et al., 2015; Harmon et al., 2020; Wisner et al., 2019) on electronic health/medical records found evidence of an association with increased cognitive overload.

In contrast, eight reviews identified improvements in nurses' *information management* associated with the use of such technology. For instance, Harmon et al. (2020) reported an overall improvement in clinical decision making and Collins et al. (2011) reported reductions in information loss. Six reviews (de Sousa et al., 2012; Fuller et al., 2018; Gephart et al., 2015; Harmon et al., 2020; Kruse et al., 2017; Park et al., 2024; Saraswasta & Hariyati, 2020) found indications of an improved access to patient information associated with electronic health/medical records.

Communication/collaboration. Regarding work-related communication and collaboration among nurses and other health professionals, systematic reviews have mainly provided evidence of positive or inconsistent effects. For example, Abdellatif et al. (2021) and Harmon et al. (2012) found a positive impact of decision support systems on teamwork among healthcare professionals and on communication

opportunities within multidisciplinary teams. Four reviews found inconsistent effects of electronic health and medical records on interprofessional communication (de Sousa et al., 2012; Jedwab et al., 2019; Mohsin-Shaikh et al., 2019; Wisner et al., 2019).

Job control. Regarding nurses´ perceived job control, three reviews reported positive effects of telecare technologies, such as managing to work more independently and flexibly (Koivunen & Saranto, 2018).

Moderating variables. Finally, the reviews identified several moderating variables that shaped the association between the use of digital technology and related outcomes. These factors include facilitators such as the training and involvement of healthcare staff during technology implementation (Brewster et al., 2014; Gephart et al., 2015), organizational culture, and alignment of nurses' workflows and work practices with organizational policies and structures when using technology (Fraczkowski et al., 2020; Fuller et al., 2018; Hardiker et al., 2019; Shiells et al., 2019; Tolentino and Gephart, 2020). In contrast, lack of staff training and inaccurate information were identified as potential barriers to efficient technology implementation (Penny et al., 2018; Ramnath et al., 2014).

Safety, health and distal nurse outcomes

We found 58 systematic reviews reporting associations between digital technologies and occupational safety and health-related outcomes or more distal nurse outcomes, such as job attitudes or changes in professional competence, which are potentially related to health and safety. The highest overall number of reported associations was for telecare systems and electronic health/medical records, followed by robotic and multiple technologies, and decision support system use (see **Table B2** in Appendix B6). Across all technologies, the included reviews reported more positive than negative outcomes. Mainly positive findings were identified for robotic technologies, and more negative findings for electronic health/medical records.

Table 4 summarizes the associations among the included systematic reviews on digital technologies, occupational safety, and health-related as well as distal nurse outcomes. Across all technologies, there was most evidence for effects on the nurse–patient relationship (k = 33), followed by effects on nurses' physical and mental health

(k = 21), professional competence (k = 19) job attitudes (k = 18) and nurse occupational safety (k = 7).

Table 4

Associations between digital technologies and occupational safety and health and distal nurse outcomes

Digital technology		Physical and mental health	Occupational safety	Professional competence	Job-related attitudes	Nurse-patient relationship
ICT	HIS (k = 1)	[not reported]	[not reported]	(+) technology serves as a supportive learning tool, especially for novice nurses (Shelley et al., 2024)	(+/–) regarding job satisfaction (Ko et al., 2018)	(+) improved communication between (Shelley et al., 2024)
	EHR/EMR (k = 13)	(–) adverse emotional reactions (da Costa & da Costa Linch, 2020), frustration (Hardiker et al., 2019) and burnout (Nguyen et al., 2021) (0/–) low technology satisfaction (causing workflow interferences): increased burnout, stress, and frustration (Park et al., 2024) (+) less stress experience (Fuller et al., 2018)	[not reported]	(–) fear that nurses would become deskilled (Stevenson et al., 2010) (+) development and improvement of clinical reasoning and judgment skills (de Sousa et al., 2012)	(0/–) low technology satisfaction: increased job dissatisfaction and higher intent to leave (Park et al., 2024) (+) better job satisfaction (Weinschreider et al., 2022)	(–) impaired communication/interaction (Shiells, 2019; Park et al., 2024), less face-to-face communication (more attention to computer screen than patient); more automatic and bureaucratic communication patterns (Forde-Johnston et al., 2023) (+) improved communication (Hovde et al., 2015; Saraswasta & Harauti, 2020); more time for nurse-patient interaction (Saraswasta& Hariyati, 2018)
	CDSS (k = 5)	(–) more fatigue (Abdellatif et al., 2021)	[not reported]	(+/–) improvement of decision-making ability after implementation, decrease with time (Akbar et al., 2021) (+/0) inconsistent effects regarding	(+) higher nurse satisfaction (Mebrahtu et al., 2021; Sariköse & Şenol Çelik, 2024); higher professional commitment (Abdellatif et al., 2021)	(+) better nurse-patient communication (Abdellatif et al., 2021)

Digital technology		Physical and mental health	Occupational safety	Professional competence	Job-related attitudes	Nurse-patient relationship
ICT	CDSS (k = 5)			professional knowledge (Araujo et al., 2020) (0) no changes (Abdellatif et al., 2021) (+) improvements in professional knowledge (Mebrahtu et al., 2021)		
	Telecare technologies (k = 9)	(–) increase of physical stress and boredom (Young et al., 2011); negative affective reactions due to changes in task execution (Tan et al., 2021); feelings of anxiety related to (perceived) lack of evidence of improved maternal outcomes (Golden et al., 2024) (+) less stress experiences (Koivunen & Saranto, 2018; Young et al., 2011); reduced infection anxiety (Joo et al., 2022)	(+) better team safety and team safety climate (Young et al., 2011); reduced infection risk during SARS-CoV-2 pandemic (Golden et al., 2024; Joo et al., 2022)	(+) improvements in knowledge and skills (Koivunen & Saranto, 2018) and learning opportunities (Gagnon et al., 2024; Tan et al., 2021); enhanced symptom assessments (Lundereng et al., 2023	(–) fear of changes (Koivunen & Saranto, 2018) and belief that technology affects job role and might induce (ethical) role conflicts (Brewster et al., 2014) (+) better job satisfaction (Brewster et al., 2014; Koivunen & Saranto, 2018)	(–) adverse effects such as decreased interactivity, conflicting changes (Brewster et al., 2014; Gagnon et al., 2023); less empathy, reduced information exchange, and fewer problems presented (Joo et al., 2022) (+/–) (Golden et al., 2024) (+) improved patient-nurse communication and relationships (Koivunen & Saranto, 2018; Lundereng et al., 2023; Radhakrishnan et al., 2016)
	Communication Support systems (k = 1)	[not reported]	[not reported]	[not reported]	[not reported]	(+) better interaction with families (Epstein et al., 2017)
	Apps (k = 3)	(–) more distractions and loss of attention (Fiorinelli et al., 2021)	(–) safety concerns reported (Fiorinelli et al., 2021) but also	(0) no changes in clinical decision-making competence	(+) higher job satisfaction (Fionrinelli et al., 2021)	(+) better communication with patients (de Jong et al., 2020)

Digital technology	Physical and mental health	Occupational safety	Professional competence	Job-related attitudes	Nurse-patient relationship
	(+) better recovery opportunities during breaks and routine work (Fiorinelli et al., 2021)	(+) improved personal safety (e.g., walking to vehicles at night) (de Jong et al., 2020)	and self-efficacy (Glanville et al. (2023) +) increased computer literacy skills (Glanville et al., 2023)		
Robotic technologies (k = 8)	(–) annoyance from technical errors (Ghafurian et al., 2021); stress from lack of understanding, fear of harming patients, and missing guidelines (Moloney et al., 2023)	(–) concerns about nurses' hygiene and injury risks (Papadopoulos et al., 2018) (+) reduction of radiation dose (device used for radioactive material) (Kangasniemi et al., 2019)	(+) opportunity for professional development (Celik et al., 2022)	(+) increased nurse satisfaction (Kangasniemi et al., 2019); potential to make the job more attractive (Papadopoulos et al., 2018); pride in working with cutting-edge technology within surgical teams (Moloney et al., 2023)	(–) concerns about social connections to patient (Papadopoulos et al., 2018); decreasing frequency of patient-caregiver-interactions (Ghafurian et al., 2021) (+) better social connections to patients (Dino et al., 2022) and more time for patients (Kangasniemi et al., 2019); technology as communicative "icebreaker" between staff and residents (Abbott et al., 2014); improved social interactions (Scerri et al., 2021)
Monitoring applications (k = 4)	(–) fatigue due to false alarms (Cortes et al., 2021); increased noise load (Mileski et al., 2019)	[not reported]	[not reported]	[not reported]	(–) potential of reduced nurse-patient interaction (Omotunde & Wagg, 2023) and of lower care quality due to fewer face-to-face patient visits (Davis et al., 2014) (+) alarms increase chance of more interactions

Digital technology	Physical and mental health	Occupational safety	Professional competence	Job-related attitudes	Nurse-patient relationship
					(Mileski et al., 2019)
Assistive devices (k = 1)	[not reported]	(+) sensors used to offer telecare and remote work can reduce nurses' infection risks (Behera et al., 2021)	[not reported]	[not reported]	[not reported]
Virtual/-augmented reality (k =1)	[not reported]	[not reported]	[not reported]	[not reported]	(–) more challenging communication with the patient (Wuller et al.,
Other (k = 4)	(+) less stress for nurses with positive attitudes toward internet (internet: Ahmad et al., 2018); less absence rates, fatigue/need for recovery, and better/longer sleep (automated scheduling and rostering systems) (O' Connell et al., 2024) (+/0) positive vs. no effect on work-life balance (O' Connell, 2024	[not reported]	(+) better information exchange and access to evidence-based information and knowledge (internet) (Ahmad et al., 2018)	(+) higher job satisfaction (digital workforce management systems: Tuominen et al., 2018; automated scheduling and rostering systems: O' Connell et al., 2024), especially for nurses with positive attitudes toward internet (internet: Ahmad et al., 2018)	(+) more time for nurse-patient interaction (internet Ahmad et al., 2018; speech recognition technology: Joseph et al., 2015)
Multiple technologies (k = 8)	(+) reduced stress (due to simplification of work-related tasks) (ICT); increased sense of professional security (CDSS) (Fagerström et al., 2017); improved well-being (Huter et al., 2020)	[not reported]	(–) technology can hamper critical reflection and judgments (Fagerström et al., 2017)	(–) fear of being replaced (O' Connor et al., 2022b; Jayousi et al., 2024)	(–) EHR/EMR: reduced time for patient interaction (Huter et al., 2020) (+/–) ICT: facilitation of patient participation but also ICT as relationship threat (Fagerström et al., 2017)

Digital technology	Physical and mental health	Occupational safety	Professional competence	Job-related attitudes	Nurse-patient relationship
	(–) feeling of stress because of additional documentation time (Cofetti et al., 2022)		(+) technology as a learning tool (Saab et al., 2021) and for strengthening professional development (Fagerström et al., 2017); potential to improve nursing training and education (Martinez-Ortigosa et al., 2023); enhanced decision-making quality (O' Connor et al., 2022b; Jayousi et al., 2024)		(+) better partnership (Jayousi et al., 2024); enhanced interaction (ICT) (Tahsin et al., 2023

Note. Synthesis of evidence from 58 reviews; k = total number of reviews. (–): impairment, (+/–): inconsistent finding, (0) no effect, (+) improvement; ICT: Information and communication technologies, HIS: Health institution information system, EHR/EMR: Electronic health/medical record, CDSS: Computerized decision support system.

Safety and health-related outcomes. The impact of digital technologies, particularly electronic health and medical records and monitoring and sensor applications, on nurses' *physical and mental health* has been largely perceived as negative. For electronic health/medical records use, Hardiker et al. (2019), da Costa and da Costa Linch (2020) and Nguyen et al. (2021) found associations with feelings of frustration, with adverse emotional reactions, and burnout when compared to the use of paper charts. Regarding the use of monitoring/sensor technologies the included reviews reported increased fatigue owing to false alarms (Cortes et al., 2021) and increased noise exposure (Mileski et al., 2019). Telecare technologies have been reported as both positively and negatively related to nurses' health. While Koivunen and Saranto (2018) reported a reduction in nurses' stress experiences, Young et al. (2011) found both, studies reporting less stress, as well as an increase in physical stress and boredom. Tan et al. (2021) reported negative affective reactions owing to changes in task execution through telecare technologies and Golden et al. (2024) identified feelings of anxiety related to a (perceived) lack of evidence of improved maternal outcomes compared to face-to-face prenatal care.

Reviews addressing how technologies influence *occupational safety* were rare, with limited evidence regarding robotic technology. The reviews found address nurse hygiene and injury risks associated with robots performing nursing activities such as feeding (Papadopoulos et al., 2018). In contrast, one review (Kangasniemi et al., 2019) reported a reduction in the potential radiation exposure associated with the use of an automated injection system.

Distal nurse outcomes. Regarding nurses' *professional competence*, the reviews included in this study predominantly reported mostly positive effects. In their review of 35 studies, Mebrahtu et al. (2021) found positive effects of decision support systems on nurses' professional knowledge. However, a review by Akbar et al. (2021) suggested an improvement in decision competence shortly after the implementation of a decision support system, and a decrease over time. Three reviews reported improvements in knowledge and skills, as well as learning opportunities associated with the use of telecare technologies (Gagnon et al., 2024; Koivunen & Saranto, 2018; Tan et al., 2021). Further, improved patient symptom assessment was found for telecare (Lundereng et al., 2023), increased computer literacy skills for apps (Glanville et al., 2023) and professional development for robotic technologies (Celik et al., 2022).

Many reviews have reported beneficial effects of digital technologies on *nurses' job-related attitudes*. Abdellatif et al. (2021) reported increased professional commitment among nurses and Mebrahtu et al. (2021) and Sariköse and Şenol Çelik (2024) reported increased overall satisfaction associated with the use of decision support systems. Similarly, robotic technologies have been reported to increase nurses' satisfaction (Kangasniemi et al., 2019) and make nursing tasks more attractive (Moloney et al., 2023; Papadopoulos et al., 2018).

Regarding the effects on *nurse-patient relationship*, reviews indicated more positive than negative effects. For instance, "robopets" (i.e., pet- or animal-like robots) have been reported to act as a communicative "icebreaker" between staff and residents (Abbott et al., 2019), to reduce patient strain and negative emotions, leading to improved social interactions (Ghafurian et al., 2021; Scerri et al., 2021) and to enable better social connections with patients (Dino et al., 2022). However, Papadopoulos et al. (2018) identified concerns regarding potential disruptions to social connections with patients. Regarding telecare technologies, three reviews (Koivunen & Saranto, 2018; Lundereng et al., 2023; Radhakrishnan et al., 2016) concluded that such technologies can improve patient–nurse/staff interactions, whereas three other reviews reported adverse effects (Brewster et al., 2014; Gagnon et al., 2024; Joo, 2022). Regarding the use of electronic health/medical records, three reviews reported improved communication and/or more time for nurse–patient interaction (Hovde et al., 2015; Saraswasta & Hariyati, 2020, 2018), while Forde-Johnston et al. (2023), Park et al. (2024) and Shiells et al. (2019), and reported impaired communication.

4.1.3.3 Associations between Digital Technologies and Ethically Relevant Outcomes for People in Need of Care (Q3)

We identified 42 systematic reviews reporting associations between digital technologies and a broad range of ethically relevant outcomes for people in need of care (see **Table 5**). Given the diverse array of outcomes, we built categories based on the *four principles of biomedical ethics* (Beauchamp & Childress, 2019), a widely recognized framework for ethical assessment within the domain of healthcare practices. Accordingly, we classified the data into three categories of principles: (a) *beneficence*, encompassing norms, dispositions, and actions aimed at promoting the well-being of patients alongside nonmaleficence, which stresses the duty to abstain from causing harm to patients, (b)

respect for autonomy, highlighting the obligation to honor autonomous actions, disclose information, and foster capacities for autonomous choice, and (c) *justice* emphasizing the obligation to equitably distribute benefits, risks, and costs, particularly in conditions of limited resources.

Table 5

Associations between digital technologies and ethically relevant patient outcomes

Digital technology		Beneficence, Nonmaleficence	Respect for Autonomy	Justice
ICT	HIS (k = 1)	[not reported]	(+) increased patient autonomy (Shelley et al., 2024)	[not reported]
	EHR/EMR (k = 1)	(–) risks for patient safety (Fraczkowski et al., 2020)	[not reported]	[not reported]
	CDSS (k = 3)	(–) situational adaptability to individual needs (pain assessment tools) (Harmon et al., 2012)	[not reported]	(–) indications of ageism (Islam et al., 2021) and speech discrimination (Sexton et al., 2022)
	Telecare (k = 8)	(–) (perceived) decrease of ethical responsibility of caregivers for care-recipients (Brewster et al., 2014); increased focus on physical issues due to difficulties in discussing interpersonal matters over the phone (Schüssler & Glarcher, 2023); risks for patient safety due to potential miscommunication and misinterpretation (Martin et al., 2023) (0/+) inconsistent findings regarding general quality of life (Flodgren et al., 2015; Komariah et al., 2021) (+/–) inconsistent effects on assessment of visible social cues such as patients' living situation (Lundereng et al., 2023) (+) disease-specific quality of life (Flodgren et al., 2015); increased sense of safety during SARS-CoV-2 pandemic (Joo, 2022)	(–) decreased patient privacy (Penny et al., 2018) (+/–) inconsistent findings (Martin et al., 2023) (+) increased patient autonomy (Komariah et al., 2021) and shared decision-making (Lundereng et al., 2023); improved and more timely information for patients (Schüssler & Glarcher, 2024)	(+) potential to promote health equity (Joo, 2022; Martin et al., 2023); prioritization of patients based on individual patient needs (Lundereng et al., 2023)

Digital technology	Beneficence, Nonmaleficence	Respect for Autonomy	Justice
Communication support (k = 2)	(+) quality of life (e.g., perception of decreased social isolation and loneliness) during SARS-CoV-2 pandemic (Beogo et al., 2023) and of persons with dementia (e.g., confidence, self-esteem) (Hung et al., 2021)	(–) privacy concerns (touchscreen tablets) (Hung et al., 2021)	[not reported]
App(s) k (k = 2)	[not reported]	(–) decreased patient privacy (de Jong et al., 2020[a]; Fiorinelli et al., 2021)	[not reported]
Robotic technologies (k = 14)	(–) patient safety concerns (robotic surgery: Moloney et al., 2023; Persson et al., 2021); infection concerns (robopets) (Budak et al., 2021); risk of infantilization (robopets) (Abbott et al., 2019[a]; Scerri et al., 2021[a]) (+/–) inconsistent regarding quality of life (e.g., perception of decreased loneliness but also of personal space) (robopets) (Abbott et al., 2019[a]; Bemelmans et al., 2012[a]; Budak et al., 2021; David et al., 2022[a]; Scerri et al., 2021[a]) (+) assistive social robots: increased quality of life (e.g., perceived loneliness, well-being) (Ghafurian et al., 2021[a]; Haltaufderheide et al., 2023[a]; Yen et al., 2024) and increased perceptions of social support (Loveys et al., 2022[a]) (+) assistive social robots: increased quality of life (e.g., perceived loneliness, well-being) (Ghafurian et al., 2021[a]; Haltaufderheide et al., 2023a; Yen et al., 2024) and increased perceptions of social support (Loveys et al., 2022[a])	(–) decreased patient privacy (Hung et al., 2022) (0/–) inconsistent regarding patient privacy (Ghafurian et al., 2021[a]; Vandemeulebroucke et al., 2021[a]) (+) (Persson et al., 2021); increased perception of independence (Dino et al., 2022[a]; Vandemeulebroucke et al., 2021[a])	[not reported]

Digital technology	Beneficence, Nonmaleficence	Respect for Autonomy	Justice
Robotic technologies (k = 14)	(–) patient safety concerns (robotic surgery: Moloney et al., 2023; Persson et al., 2021); infection concerns (robopets) (Budak et al., 2021); risk of infantilization (robopets) (Abbott et al., 2019[a]; Scerri et al., 2021[a]) (+/–) inconsistent regarding quality of life (e.g., perception of decreased loneliness but also of personal space) (robopets) (Abbott et al., 2019[a]; Bemelmans et al., 2012[a]; Budak et al., 2021; David et al., 2022[a]; Scerri et al., 2021[a]) (+) assistive social robots: increased quality of life (e.g., perceived loneliness, well-being) (Ghafurian et al., 2021[a]; Haltaufderheide et al., 2023[a]; Yen et al., 2024) and increased perceptions of social support (Loveys et al., 2022[a]) (+) assistive social robots: increased quality of life (e.g., perceived loneliness, well-being) (Ghafurian et al., 2021[a]; Haltaufderheide et al., 2023[a]; Yen et al., 2024) and increased perceptions of social support (Loveys et al., 2022[a])	(–) decreased patient privacy (Hung et al., 2022) (0/–) inconsistent regarding patient privacy (Ghafurian et al., 2021[a]; Vandemeulebroucke et al., 2021[a]) (+) (Persson et al., 2021); increased perception of independence (Dino et al., 2022[a]; Vandemeulebroucke et al., 2021[a])	[not reported]
Monitoring/sensor applications (k = 1)	(+) increased quality of life (e.g., well-being, social participation) (Omotunde and Wagg, 2023)	(+) increased perception of independence (Omotunde and Wagg, 2023)	[not reported]
Assistive devices (k = 0)	[not reported]	[not reported]	[not reported]
Virtual/augmented reality (k = 1)	(+/–) inconsistent regarding quality of life (mixed findings regarding loneliness but also improvement of well-being) (Li et al., 2022)	not reported]	not reported]

Digital technology	Beneficence, Nonmaleficence	Respect for Autonomy	Justice
Other (k = 0)	[not reported] (Loveys et al., 2022a)	[not reported]	[not reported]
Multiple technologies (k = 9)	(–) discouragement of independent thought (ICT) (Fagerström et al., 2017); less comprehensive assessment of patient well-being (O' Connor et al., 2022b[a]) and individual needs (Ramvi et al., 2023); decreased quality of life (Zhang et al., 2024) (+/–) loss of nonverbal clues but easier information sharing with nurses (telecare) (Ramvi et al., 2023) (0) no effect on quality of life (monitoring/ sensor applications: Huter et al., 2020; ICT: Tian et al., 2024) (+) increased quality of life (Zhou et al., 2023[a]); reduced perceived loneliness and enhanced well-being (robotic technology) Huter et al., 2020[a]); enhanced social interactions (virtual/augmented reality) and improved patient safety (Jayousi et al., 2024) as well as sense of security (monitoring/ sensor applications) (Huter et al., 2020)	(–) decreased patient privacy (O' Connor et al., 2022b[a]; monitoring/ sensor applications: Alves et al., 2023; HIS: Jayousi et al., 2024) (0) no effect on perceived autonomy (monitoring/ sensor applications) (Huter et al., 2020) (+) decrease in information-asymmetry between patients and nurses (Zhou et al., 2023[a]); more reciprocal, collaborative relationships between nurses and patients (Ramvi et al., 2023)	(+) potential to reduce inequalities ICT) (Jayousi et al., 2024)

Note. Synthesis of evidence from 42 reviews k = 42; k = total number of reviews. (—): impairment, (+/—): inconsistent finding, (0) no effect, (+) improvement; ICT: Information and communication technologies, HIS: Health institution information system, EHR/EMR: Electronic health/medical record, CDSS: Computerized decision support system. [a] Finding refers to an artificial intelligence-assisted technology.

Overall, the reviews reported more impairments or inconsistent findings than improvements in ethically relevant outcomes for people needing care. Robotic technologies and telecare technologies had the highest overall number of reported findings, followed by telecare systems (see **Table B3** in Appendix B7). Considering associations with individual ethical principles, the most evidence was found for effects on beneficence/nonmaleficence (k = 32), followed by respect for autonomy (k = 21). Few reviews reported associations with the principle of justice (k = 6).

Beneficence/nonmaleficence. The impact of digital technologies, particularly robotic technologies, on the realization of the principles of beneficence/nonmaleficence has been perceived as beneficial in some cases and potentially harmful in others.

Regarding assistive social robots, three reviews (Ghafurian et al., 2021; Haltaufderheide et al., 2023; Yen et al., 2024) found a positive association with care recipients' quality of life and Loveys et al. (2022) an increased perception of social support. However, two reviews (Moloney et al., 2023; Persson et al., 2021) found indications of potential risks to patient safety, inter alia in the context of robotic surgery. Additionally, Abbott et al. (2019) and Scerri et al. (2021) reported that robopets might evoke feelings of infantilization. Four reviews (Abbott et al., 2019; Bemelmans et al., 2012; David et al., 2022; Scerri et al., 2021) found inconsistent effects, such as a lower level of perceived loneliness as well as concerns about the perceived personal space of living in home care facilities. Moreover, reviews examining telecare technologies reported that such could negatively affect nurses' ethical responsibility for care-recipients (Brewster et al., 2014), or also lead to an increased emphasis on physical issues, as interpersonal matters can be challenging to address over the phone (Schuessler & Glarcher, 2024). However, the reviews also noted benefits, such as an enhanced sense of safety during the SARS-CoV-2 pandemic (Joo, 2022).

Respect for autonomy. Regarding the effects on the principle of respect for autonomy the reviews reported both positive and negative effects, primarily in relation to telecare as well as robotic technologies. Lundereng et al. (2023) reported an improvement in shared decision-making and Schuessler and Glarcher (2024) more timely information for patients associated with the use of telecare technologies. In contrast, three reviews Penny et al. (2018) reported a reduction in patient privacy linked to these technologies. Meal robots were reported to contribute to more patient autonomy (Persson et al., 2021)

and gaze-controlled wheelchairs increased independence for patients with amyotrophic lateral sclerosis (Dino et al., 2022; Vandemeulebroucke et al., 2021). However, perceptions of assistive social robots' (SAR) impact on patient privacy were inconsistent (Ghafurian et al., 2021; Vandemeulebroucke et al., 2021), and the use of telepresence robots was considered to negatively impact patient privacy, due to "the possibilities of witnessing residents' personal and private situations, overhearing workers' conversations, and recording [of] videos by remote users" (Hung et al., 2022, p. 15).

Justice. Regarding the principle of justice, reviews indicated positive effects associated with the use of telecare technologies and negative effects associated with decision support systems, particularly triage systems. Telecare technologies have been reported to promote health equity by reducing health disparities among vulnerable populations (Joo, 2022; Martin et al., 2023) and to enable the prioritization of patients based on individual needs through the use of patient-generated data (Lundereng et al., 2023). For decision support systems, Komariah et al. (2021) reported ageism in relation to care service recommendations, and Penny et al. (2018) reported language discrimination, i.e., patients with higher language proficiency were more likely to receive advice with a higher urgency level.

4.1.4 Discussion

4.1.4.1 Summary of Evidence

In this systematic review, we synthesized the findings from 213 systematic reviews focusing on digital nursing technologies. More than half the reviews examined information and communication technologies, particularly by telecare technologies and electronic health/medical records, followed decision-support systems. After information and communication technologies robotics was the most investigated technology. The most frequently reported research objectives encompassed technology usage and/or general experiences with it, followed by technology-related consequences for the safety and health of care recipients and the impact on economic aspects.

Although not explicitly stated as a research question in most reviews, almost half of the reviews included findings on the impact of digital technologies on work-related and organizational factors. This was especially true for electronic health/medical records, telecare, and robotic technologies. Overall, the results within each technology category

were mixed; that is, reviews reported impairments, inconsistent findings, no effects, and improvements. Technology type and particular work-related or organizational factors are pivotal in explaining such inconsistencies. Chances of improvement in work design were particularly reported for decision support systems and electronic health records, whereas monitoring/ sensor applications were more often associated with adverse consequences such as increased fatigue.

Across all technology categories, we found cumulative evidence that technology use has (mainly) beneficial effects on the execution of nursing activities in general (e.g., standardization of workflows, routine task support), information management, and job control, and it often results in time savings. Depending on the technology type, reviews reported mixed effects with regard to documentation activities, communication/ collaboration and nurses' workflow and predominantly negative or inconsistent effects on nurses' workload, particularly for telecare and monitoring/sensor applications.

Safety and health-related or distal nurse outcomes were investigated in 58 of the 213 reviews. Again, the findings varied within each technology category. Improvements were particularly reported for robotic technologies, whereas evidence for the use of electronic health and medical records was comparatively critical across the outcomes.

Job attitudes, especially job satisfaction, seem to be positively affected by digital technologies. We also found that digital technology might promote nurses' professional competence. In contrast to such protective effects, several reviews have reported that the use of digital nursing technologies can translate into detrimental mental and physical strain effects, such as increased frustration, fatigue, and burnout.

Approximately one-fifth of the included reviews reported associations between digital nursing technologies and *ethically relevant outcomes for people in need of care*. Most of the reviews addressed aspects related to principles of beneficence/nonmaleficence and patient autonomy, whereas patient outcomes related to the principle of justice were less often investigated. Notably, we found the highest number of reported findings for robotic technologies. Overall, we found ethically adverse or inconsistent effects more often than positive or null effects.

4.1.4.2 Availability and Quality of Systematic Reviews

Our literature search confirmed that the current database on nursing technology is complex (Huter et al., 2020). The included reviews primarily focused on information and communication technologies and robotic systems. In contrast, monitoring/sensor applications, assistive devices, and virtual/augmented reality have been examined significantly less frequently.

These differences may be attributed to the uneven distribution of digital technologies in the nursing sector. However, to the best of our knowledge, no representative statistics show the dissemination of these technologies in nursing practice. Therefore, whether the available reviews address the requirements of nursing practice with regard to the technologies under study is unclear.

Furthermore, the quantity of evidence, (i.e., the number of included single studies) differs among the reviews and the digital technologies they investigate. For example, for electronic health/medical records the scope of included studies within the reviews is broad, from four single studies (Gephart et al., 2015) to 120 studies (Jedwab et al., 2019). In contrast, in the five reviews investigating communication support systems, the range of the included single studies was between four (Beogo et al., 2023) and 18 (Ju et al., 2021) (see also Appendix B3).

An analysis of the research objectives of each review revealed that the focus is primarily on the relationship between the use of digital technologies and patient health and safety, on economic aspects or on technology usage and/or general experiences with it. Other important consequences of introducing digital technologies into the nursing work system, such as work design, work organization, nurses' safety and health, and potentially associated ethical dilemmas, have rarely been considered in the reviews so far. However, the World Health Organization (2016, 2020) and the Socha-Dietrich (2021) advocate for concerted efforts to alleviate the burden on healthcare workers and harness the potential of digital technologies as essential components of future-proof healthcare systems. Therefore, systematic reviews that directly address work and health-related consequences for nurses, using digital technologies, are needed.

Regarding the methodological quality of the integrated reviews, all received a low or critically low quality rating, according to the AMSTAR 2 checklist, a quality assessment

tool commonly used in overviews of reviews. Consistent with de Santis et al. (2023), we discovered difficulties in applying the checklist. First, the authors of AMSTAR 2 have pointed out that aggregating item ratings into overall scores is not recommended (Shea et al., 2017). Rather, researchers should adopt quality ratings based on specific questions and data. Following these suggestions in our review limits the comparability when applying the AMSTAR 2 checklist across studies and the practicability of the tools. Second, the reviews predominantly considered descriptive studies, with more robust quasi-experimental designs or randomized controlled trials being exceptions. Against this background, the AMSTAR 2 checklist is strict. After careful consideration, we decided to include all reviews in the synthesis of evidence but to make the quality assessment transparent.

4.1.4.3 Work-Related and Organizational Factors

We identified a variety of work-related and organizational factors, whereby job demands, time savings and social aspects were most frequently addressed across the reviews. While occupational health researchers have identified job control as an important job resource that shapes the workload of workers (Karasek, 1979; Karasek & Theorell, 1990; Parker & Grote, 2022), only six reviews have considered this factor in relation to digital technologies. We could not derive any findings regarding skill variety, skill use, or job feedback. Another essential aspect of work, particularly in the context of nursing, was insufficiently addressed in the reviews: the interactive dialogical demands inherent to the core characteristics of work in this sector. We identified technology-related effects on the nurse–patient relationship. However, from a work design perspective, it is imperative to consider not only the quality of the relationship but also the prevention of stress-related demands associated with interactive dialogical tasks (Zapf & Holz, 2006).

Notably, future reviews (and probably single studies) should analyze these currently less considered but important work-related factors (job control, skill variety and use, job feedback, and interactive-dialogical demands), as digital nursing technologies will only be successfully and sustainably implemented in nursing if they promote safe and healthy work, thereby contributing to a decent work environment. This imperative is aligned with the global strategy on human resources for health outlined in the World Health Organization (2016).

Second, we considered the heterogeneous effects of digital nursing technologies on work-related and organizational factors within and between different digital technologies. Our findings indicate that certain technologies are frequently linked to work-related improvements (e.g., decision support systems), whereas others are more frequently associated with unfavorable effects (e.g., monitoring/sensor applications).

However, it is not only the technology that determines nurses' work tasks and work organization and, in turn, the potential risks for safety, health, and ethical behavior. It is also a matter of task-technology fit (Goodhue & Thompson, 1995), person-environment fit (Caplan, 1987), and implementation process characteristics (Parker & Grote, 2022).

Following the sociotechnical work design approach, the successful implementation of digital technologies in nursing should collaboratively optimize both the technical and social aspects of the work system (Parker et al., 2001; Parker & Grote, 2022). Different stakeholder groups (e.g., engineers, work design experts, healthcare management, nurses, and patient representatives) should be involved in a participatory approach during both phases of technology development and implementation to consider diverse knowledge and interests effectively.

4.1.4.4 Safety and Health-Related and Further Nurse Outcomes

Considering safety and health-related outcomes, we found that current evidence mainly relates to the acute consequences of digital technology use, such as negative emotions, frustration, stress, boredom, and fatigue, which might develop from technology stressors, such as false alarms or distraction from other nursing tasks. Against the background of empirically proven typical health impairments in nursing (e.g., Fronteira & Ferrinho, 2011; Rosa et al., 2019) one might wonder why potential musculoskeletal complaints, emotional and physical exhaustion, and depressive symptoms were rarely considered in the investigation of technology-related effects on nurses' health. Therefore, future research should also consider middle- and long-term health consequences to assess whether digital technologies, alongside other known work stressors in nursing (e.g., shift work), pose potential risks for occupational illnesses.

Regarding the direction of the effects, as previously noted in relation to the influences on work system factors, we found that digital technology could affect nurses' health both positively and negatively. On the one hand, several reviews reported adverse

technostrain effects that mirror acute strain reactions of employees in the initial weeks of technology implementation (Brod, 1984; Salanova et al., 2013). However, as discussed above, the question remains whether such effects become chronic, or under what circumstances nurses adapt. We also found some evidence that the nurse–patient relationship may be impaired and that nurses' job roles might change when implementing telecare technologies. On the other hand, many other reviews have reported beneficial effects for nurses associated with the use of digital technologies, such as reduced stress, improved recovery opportunities, increased job satisfaction, and improved professional competencies. Surprisingly, despite the frequently warned risk of deskilling associated with digital technologies, current data do not substantially support this concern. In sum, further research is necessary to precisely determine why and under what circumstances digital technologies affect nurse outcomes, and what role related changes in work and organizational characteristics play in this regard.

4.1.4.5 Ethically Relevant Outcomes for People in Need of Care

Regarding ethically relevant outcomes, the evidence related mainly to robotic technologies and, in recent years, to telecare technologies. Although scarce, there was also evidence of associations with other technologies, such as decision support or communication systems. In addition, many reviews addressing ethically relevant outcomes fell into the category of "multiple technologies".

A closer examination of the technologies for which ethical aspects were analyzed in the reviews reveals that they may directly impact human–human relationships and/or have unintended consequences associated with a dehumanization of care. Most evidence was found for effects on beneficence/nonmaleficence, which are principles that inherently build on the relationships and communication between nurses and care recipients. Only six reviews that addressed ethically relevant outcomes of technology use related to the principle of justice – which is particularly pertinent in situations requiring prioritization of nursing activities before interacting with patients.

While many studies have discussed the role of ethical aspects related to the implementation of digital nursing technologies in general (Ali et al., 2022; Ramvi et al., 2023) and specifically to the use of robots (e.g., Gibelli et al., 2021; Vandemeulebroucke et al., 2018), to our knowledge, the central role of robotic systems, particularly social and

assistive robots, as well as telecare technologies has not yet been established in a comprehensive overview of empirical studies on various digital nursing technologies.

A considerable portion of the investigated (particularly robotic) technologies relies on algorithms driven by artificial intelligence (AI). AI systems can imitate human problem-solving, enabling them to aid or execute tasks that demand cognitive abilities (Parker & Grote, 2022). This underscores the necessity for the ethical design and implementation of digital nursing technologies within work systems (Bird et al., 2020; WHO, 2021). Furthermore, it prompts a closer examination of ethically significant outcomes linked to technologies that may be less prominent than robotic systems (which are still relatively uncommon, especially in Europe), yet possess the ability to mimic human problem-solving and impact human-human interaction, such as communication support systems or decision support systems.

Finally, our overview of reviews showed that published reviews reported a wide range of ethically relevant findings, considering the specificities of concrete application areas. However, the comparability of the findings was impaired by the lack of a common ethical framework – such as that used by Beauchamp and Childress (2019), or also those based on relational theories of health care and nursing (e.g., Noddings, 1984; Tronto, 1993) – explicitly used in the studies and, accordingly, by the inconsistencies in the terminology used to describe the findings.

4.1.4.6 Strengths and Limitations of Our Systematic Review of Reviews

As a strength, this review has a thorough evidence-based approach to elucidating the influence of digital technologies on multiple aspects of nurses' work system design and related individual outcomes. These include work-related and organizational factors, health and safety, job attitudes, professional behavior and competence, and ethical considerations. A key asset was the thorough development of the search string, which enhanced the robustness of the study methodology. Moreover, our review of reviews is based on a comprehensive literature search of eight international databases encompassing 14 years of research. We applied the dual control principle during screening and coding of retrieved reviews and, in accordance with recommendations by Smith et al. (2011), used the AMSTAR 2 tool for quality assessment of included reviews. However, because of the narrative nature of (most) the included reviews and due to the high heterogeneity of the included meta-analyses, it was not possible to aggregate (the) associations of interest in a

meta-analytical manner. Such a meta-analysis would be desirable, as it would allow the comparison of risks and potentials of the technologies' introduction with those of other work factors on a common scale.

4.1.4.7 Implications for Research, Policy and Practice

Nine million additional nurses and midwives are needed by 2030 to reach "Good Health and Well-being," which is one of the Sustainable Development Goals declared by the United Nations. To attract numerous people to this important profession in the near future, following the global strategy on human resources for health, the "uphold the personal, employment and professional rights of all health workers, including safe and decent working environments" is crucial (WHO, 2016, p. 8).

The legitimacy of digital nursing technologies should be evaluated based on their influence on patient outcomes as well as their contribution to improving nurses' work and promoting their safety and health. Although our review offers initial insights, a significant amount of work remains to gain a thorough understanding of the impacts of these technologies. Future research should aim to quantitatively summarize the effects through meta-analyses and conduct high-quality studies investigating the impact of different digital nursing technologies on various aspects of work characteristics, safety, and health. The World Health Organization (WHO) emphasizes the importance of ensuring favorable working conditions, particularly in the nursing profession, which faces unique challenges. To this end, it is imperative to explore how digital technologies intersect with the interactive nature of nursing and how they influence work stressors and patient care. Discussions should also consider the potential exacerbation effects and the role of moderators in influencing technology outcomes.

Our overview of reviews shows a need for further investigation of ethically relevant outcomes associated with non-robotic technologies that may (nevertheless) affect human-human interaction. Moreover, we posit that establishing a unified framework for ethical considerations associated with the use of digital nursing technology could aid in identifying a broader spectrum of aspects. This, in turn, could facilitate the efficient translation of ethical principles into practical application.

Policy efforts should focus on optimizing the contributions of nursing practice, leveraging digital nursing technology opportunities, and incorporating nurses'

perspectives into governance decisions. Technology impact assessments, such as those conducted through technology assessments, should be integrated into policy discussions to support decision-making. In addition, more attention should be paid to the need to include ethical aspects in the (further) development of methodological approaches for the assessment and evaluation of work-related risks in the care sector.

In practice, it is essential to involve stakeholders from the beginning of technology development and to foster collaborative and participative approaches to optimize the use of digital technologies. Empowering the health workforce to utilize the digital revolution fully is crucial; however, it is equally important to educate stakeholders on decent work design principles to ensure successful technology implementation. References to frameworks such as the European Commission's checklist for digital transformation can provide valuable guidance, although adaptation to specific contexts and incorporation of additional criteria are necessary. Overall, a concerted effort across the research, policy, and practice domains is needed to realize the full potential of digital nursing technologies while safeguarding the well-being of nurses and patients.

4.1.5 Conclusion

In this overview of 213 reviews of digital nursing technologies, we observed a diverse landscape of research focusing on various technological domains. Information and communication technologies, particularly electronic health/medical records, telecare technologies, and decision-support systems, were among the most investigated. While the predominant research objectives revolved around nurses' technology attitudes/acceptance and/or the impact of technology on the safety and health of care recipients or economic aspects, approximately half of the reviews also reported effects on work-related and/or organizational factors, and approximately a quarter on safety and health-related or distal nurse outcomes.

Although the findings varied among the different technology categories, certain trends became apparent. The use of digital nursing technology has shown beneficial effects on nursing activities, information management, and job control, and often resulted in time savings. The impact on documentation activities and communication/collaboration showed mixed results and that on nurses' workflow, as well as workload showed predominantly negative or inconsistent effects, with telecare and monitoring/sensor

applications, particularly associated with an increase in workload. Safety- and health-related outcomes were explored in a subset of reviews that revealed both improvements and concerns across different technology types. Job attitudes and nurses' professional competencies tended to benefit from digital technologies, while physical and mental health did not. Review outcomes related to ethical considerations, although addressed in a smaller proportion of reviews, underscored the importance of the principles of beneficence/ nonmaleficence as well as patients' autonomy, with robotic and telecare technologies attracting significant attention in this regard. Overall, adverse or inconsistent ethical effects were slightly more prevalent than positive or null effects.

This comprehensive review highlights the complexity of digital technology integration in nursing and underscores the need for nuanced research to better understand its multifaceted impact on nursing practices and patient care. Finally, digital nursing technologies are not the silver bullets in the struggle for a sustainable workforce. Multiple interventions at multiple levels are needed, including human-centered technology implementation. Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnurstu.2024.104950.

Amendments to the study protocol

During the peer review process, minor amendments were made to the study protocol. These included a revision of the study title and an extension of the literature search period, now encompassing January 2010 to May 2024.

4.1.6 Special Analysis: Reviews Examining AI-Assisted Technologies

This special analysis focuses on the subset of reviews included in the umbrella review that specifically address AI-assisted technologies. The subsequent section presents a concise summary of the key findings. A more detailed presentation of the results can be found in the attached article in Appendix D1.

The following revised research questions were formulated by concentrating on the analysis of AI-assisted technologies:

- Q1. How many reviews empirically investigating the use of AI-assisted technologies in the nursing sector have been published since 2010, and which research objectives were stated by the authors?
- Q2. What associations between the use of AI-assisted technologies and work-related or organizational factors, occupational safety and health, and distal nurse outcomes are reported in these reviews?
- Q3. What associations between the use of AI-assisted technologies and ethically relevant outcomes for people in need of care are reported in these reviews?

Number and characteristics of identified reviews

A total of 59 systematic reviews specifically focused on AI-assisted nursing technologies. Most of these reviews investigated robotic technologies (k = 33; 56 %), followed by decision support systems (k = 10; 17 %). One review each (2 %) investigated electronic health/medical records, telecare systems, and assistive devices. Three reviews (5 %) were categorized under “other technologies,” including pain management tools, automated surveillance algorithms, and internet-of-things applications for nursing care in hospital settings. Additionally, 10 reviews (17 %) examined multiple technologies.

Most reviews assessed the impact of the investigated technologies on economic aspects (k = 12; 20 %). Ten reviews (17%) each examined the effect on nurses’ working practices, technology usage and/or general user experience, and the relationship between the use of digital technologies and the safety and health of care recipients. Technology acceptance and/or stakeholder attitudes toward digital health technologies were analyzed in eight reviews (14 %). Seven reviews (12 %) sought to identify digital technologies suitable for supporting specific nursing activities. Only a few reviews investigated the

implementation process (k = 3; 5 %), the impact on the quality of care (k = 3; 5 %), or the safety and health of nurses (k = 1; 2 %).

Associations between AI assisted technologies and work-related, organizational, occupational safety, or health-related factors

Sixteen reviews (27 %) reported associations between the use of AI-assisted technologies and work-related or organizational factors. These reviews primarily identified positive effects of the use of AI technology on *nursing tasks*, *information management*, and potential *time savings*. For instance, decision support systems were found to promote more consistent caregiving practices by reducing deviations from treatment protocols. AI-assisted technologies were also found to aid nurses in routine tasks and to contribute to improvement in care quality. Two reviews reported improved access to information, such as in facilitating discharge planning. Time savings were particularly associated with robotic technologies. Findings regarding nurses' *workload* were mixed: One review described reduced time pressures, while another – focused on socially assistive technologies like robotic animals – reported an increase in workload. Overall, *workflows* were perceived as disrupted rather than improved by AI-assisted technologies. Alarm systems that monitor vital signs and issue alerts to caregivers were cited as examples of such disruptions. Similarly, findings on *communication and collaboration* were mixed, although some reviews reported benefits for interprofessional or interdisciplinary communication. None of the included reviews found associations with nurses' *cognitive load or job control*.

Eleven reviews (19 %) reported associations between the use of AI-assisted technologies and various aspects of occupational safety, health and/or distal nurse-related factors. Most findings relate to *job-related attitudes*, *professional competencies*, and impacts on the *nurse-patient relationship*. One review indicated that the adoption of AI technologies evokes fears of job displacement. However, decision support systems and robotic technologies were frequently associated with increased job satisfaction. These technologies were also linked to enhanced learning and professional development opportunities within daily practice. Regarding the nurse-patient-relationship, four reviews described positive effects, including improved social interaction with care recipients. Robotic technologies, for instance, were noted to function as communicative

"icebreakers". Conversely, two reviews noted negative outcomes, such as a decrease in the frequency of nurse-patient interactions.

Three reviews (5 %) reported findings related to occupational health and safety, all concerning robotic technologies. One review highlighted benefits such as reduced physical strain, including lower exposure to radiation associated with the use of automated injection systems that enable staff to avoid proximity to radiation sources during imaging procedures. Another raised concerns about risks like non-compliance with hygiene standards and increased likelihood of injury. Additionally, one review noted a negative impact on mental health due to increased workplace disruptions.

Associations between AI-assisted technologies and ethically relevant outcomes for people in need of care

Approximately one-quarter of the included reviews (k = 14; 24 %) reported associations between the use of AI-assisted technologies and ethically relevant outcomes for individuals in need of care. In relation to the principles of *beneficence/non-maleficence,* ten reviews (17 %) described both positive and negative effects. Benefits included greater life satisfaction and increased social support, particularly linked to the use of social robots. However, reviews also found indications for increased loneliness, safety risks, and diminished quality in holistic care assessments. Seven reviews (12 %) explored outcomes linked to the principle of *respect for autonomy*. Benefits included a stronger sense of independence among care recipients and less information-asymmetry between nurses and patients. At the same time, issues related to data privacy issues were frequently cited as a concern. Just one review (2 %) reported effects on the principle of *justice*, suggesting that the use of decision support systems may contribute discriminatory effects against older care-recipients.

Conclusion

Overall, the findings suggest that the implementation of AI-assisted nursing technologies can yield positive beneficial outcomes, including the enhancement of consistent caregiving practices, the facilitation of enhanced social interactions with care recipients, and the reduction of information asymmetry between nurses and patients – but may also pose challenges, including increased workloads, workflow disruptions, and less frequent nurse-patient interactions. The findings also demonstrate that extant reviews

primarily focus on the economic implications of technology adoption and its impact on care-recipients' safety and health. Conversely, relatively few of the included reviews address impacts on work demands, nurses' health outcomes, and the ethical dimensions of care, thereby unveiling a salient research deficit.

Furthermore, the variability in findings related to work and organizational factors underscores the complexity of AI-assisted technologies' effects in healthcare. Importantly, outcomes appear to be contingent less on the specific technology itself and more on the on the conditions of its implementation and usage, and particularly how they are aligned with existing workflows, practices, patient needs. Relatedly, several reviews have indicated that the adoption of technology is in influenced by the extent to which nurses participate in the initial stages of technology selection process and the existence of a comprehensive digitalization strategy that facilitates integration into established work practices. Finally, the reviews underscore the necessity of evaluating whether a technology fosters patient well-being and respects their autonomy prior to its implementation.

Reviews included in special analysis: Aarskog et al. (2019), Abbott et al. (2019), Andtfolk et al. (2022), Araujo et al. (2020), Bemelmans et al. (2012), Blythe et al. (2022), Budak et al. (2021), Burnazovic et al. (2024), Celik et al. (2022), Choi et al. (2023), David et al. (2022), Dino et al. (2022), Felding et al. (2023), Fernandes et al. (2024), Ghafurian et al. (2021), Gondim et al. (2022), Haltaufderheide et al. (2023), Haubold (2020), Hsu and Kao (2023), Hwang et al. (2022), Islam et al. (2021), Kachouie et al. (2014), Kang et al. (2020), Kangasniemi et al. (2019), Kausch et al. (2021), Kulpa et al. (2021), Li et al. (2024), Loveys et al. (2022), Ma et al. (2023), Maalouf et al. (2018), MacDonald et al. (2023), Manietta et al. (2022), Martinez-Ortigosa et al. (2023), Mebrahtu et al. (2021), Mieronkoski et al. (2017), Moerman et al. (2019), O'Connor et al. (2022a), O'Connor et al. (2022b), O'Connor et al. (2024), Ohneberg et al. (2023), Papadopoulos et al. (2018), Papadopoulos et al. (2020), Persson et al. (2021), Piaggio et al. (2023), Ragno et al. (2023), Raymond et al. (2022), Redondo-Sáenz et al. (2023), Ruksakulpiwat et al. (2024), Scerri et al. (2021), Servaty et al. (2020), Shishehgar et al. (2018), Thompson et al. (2023), Toffaha et al. (2023), Vandemeulebroucke et al. (2018), Vandemeulebroucke et al. (2021), Wan et al. (2024), Yen et al. (2024), Zhou et al. (2023).

4.2 An Integrative and Transdisciplinary Approach for a Human-Centered Design of AI-Based Work Systems

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Abstract[22]

Psychological and ethical criteria are to date not systematically covered in the system design process. We suggest extending existing model-based system engineering approaches with new elements capable of integrating these and, in particular, that allow for the implementation of psychological risk analysis and ethical evaluation of work systems already in the design phase. The need for a systematic integration of not only safety but also ethical and psychological considerations in the system design is strengthened by the growing complexity of work systems and the increasing use of artificial intelligence-based algorithms, which have the potential to replace distinctive human capabilities and are associated with a shift of responsibility from humans to machines. We identify essentially two factors impeding the development of an innovative integrative system design approach. First, at present, there is no legally predefined iterative process including an open feedback loop between the operator and the system designer that enables continuous risk assessment. Second, available methods do not provide a framework to integrate ethical and psychological criteria. We propose four steps for the development of an integrative system design approach: (1) an in-depth investigation of current methods suitable for holistic system design processes, (2) the development of a transdisciplinary terminology, (3) a context-sensitive and iterative specification of ethical criteria, and (4) testing of the developed approach in a digital system model by using a suitable use case.

Keywords: Artificial intelligence, technical risk assessment, psychological risk analysis, values in design, model-based system engineering

[22] Note: This paper – originally published in the *Proceedings of the ASME 2021 International Mechanical Engineering Congress and Exposition. Volume 13: Safety Engineering, Risk, and Reliability Analysis* – has been slightly edited with the permission of ASME Press. The overarching content and scientific contributions remain unchanged. Sections that have been revised at a content-related level are clearly indicated by underlining to ensure transparency regarding the adjustments made.

4.2.1 Introduction

> *A hospital manager is providing an automated guided vehicles (AGV) system for flexible transport of meal to assist the hospital staff. In addition, the implemented master controller – henceforth – applies not only algorithms based on artificial intelligence (AI) to find optimal routes for the AGVs but also for nursing staff working in wards in which the transport of meal is not yet carried out exclusively by the AGVs. After a few weeks, it becomes apparent that the system assigns more trips to nurse Alice than to her colleague Bert. This is the case since Alice is working faster than Bert. The inequality in the assignments – and thus of both nurses' workload – further increases as the year progresses. Alice completes her assignments ever faster since she would not be able to keep up with the pace of the AGVs. At some point, she becomes inattentive and is increasingly exhausted.*
> (*Note*. This scenario is adapted from Adler et al. (2020).)

With the further advancement of powerful algorithms based on AI, their application is spreading in the world of work analogously to the consumer world. Tasked with a specific goal, AI-based systems "act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected (…) data, reasoning on the knowledge, or processing the information (...), and deciding the best action(s) to take to achieve the given goal" (AI HLEG, 2019, p. 36).

Due to their inherent ability to perform tasks commonly associated with intelligent beings, i.e., tasks requiring *cognitive* functions such as learning and problem solving, they may improve the efficiencies of workplaces but equally imply a shift of responsibility from humans to machines as well as impact various aspects of occupational safety and health. To date, AI-based algorithms can be found in the fields of process optimization, predictive analytics, condition monitoring, quality control, or, more generally, in master control functions as illustrated by the example above. Applications can, for example, support employees in managing complex tasks, adopt time-consuming routine tasks and possibly enhance participation for people with disabilities. In this way, AI-based work systems may contribute to the fulfillment of characteristics of well-designed tasks (DIN, 2008; ISO, 2016, 2019b). Conversely, they may also lead to reduced decision-making autonomy,

unilaterally demanding tasks and work intensification or increasing levels of work performance monitoring (Apt et al., 2018; Rothe et al., 2019). In the example above, the implementation of the algorithms leads to a situation in which some employees experience an intensification of work, whereas others are exposed to even lower demands. Although such psychological risks can arise without the application of AI-based algorithms, with their use the rationale underlying such risks may often be less transparent to and thus also influenceable by employees. Equally though, the implementation of AI-based systems inheres the chance to prevent such risks *a priori*.

In addition, the transfer of responsibility from humans to machines may significantly influence how moral principles are manifested within work systems. In the scenario described above, most would likely consider the fact that both nurses are progressively exposed to unequal demands as a violation of the principle of fairness. Moreover, decisions made by such systems can have a greater impact on stakeholders' interests than those made by individual employees, as the systems' target functions usually affect a larger number of people. For this reason, ethical considerations in the system design process gain increasing importance (AI HLEG, 2019) – particularly when systems are conceptualized to prepare decisions previously made independently by humans, or when decision-making is fully automated.

Against this background, we argue that risk analysis methods currently used in day-to-day engineering practice might be – particularly with regard to the development of AI-based technologies – inadequate in the future. Ensuring the fulfillment of legal requirements regarding workers' safety and health in work systems that employ technical systems aimed at optimizing predefined goals, as in the case of many AI-based systems, may require standard engineering processes that not only allow to identify potential risks in terms of physical and environmental harm. In many cases, the identification of possible impacts on fundamental rights and values of those encountering the systems as well as on characteristics of well-designed tasks seems equally important. This particularly applies when human-machine interaction is collaborative and cooperative and when the AI components are integrated into a decision-making functionality.

At present, the development and design of technical systems is usually carried out without systematic consideration of ethical or psychological criteria. General principles of user-centered design (cf. *human factors engineering*) are rarely considered in day-to-day-

engineering. Moreover, existing occupational health and safety measures focusing on potential interactions between technical aspect of work and mental and physical strain concentrate on the selection of means of work. Associated risks are therefore only detected during or even after the implementation of a technical system into the workspace, making adjustments complicated and effortful (Kern & Schmauder, 2005). According to Collingridge, at this stage, the "steering of technology is either impossible, marginally possible, or prohibitively expensive" (van den Hoven, p. 2, referring to Collingridge, 1980). Possible influences on ethical criteria – such as privacy, fairness and nonmaleficence (Jobin et al., 2019) – are so far not systematically assessed by risk analysis tools at all. Consequently, potential tendencies of work systems to contribute to an undermining or manifestation of certain ethical aspect in specific systems contexts (i.e., tasks and users) are rarely recognized.

We conclude that in order to ensure that AI-based work systems better meet human competencies, needs, and values – i.e., that technological innovation can be considered human-centered innovation – an innovative system design approach integrating psychological and ethical criteria along an iterative process throughout the entire lifecycle of the systems is necessitated. In line with our proposal, the European Commission (2021b) recommended a regulatory framework on AI that addresses the safety risks of AI-based systems and formulates the requirement to ensure the protection of fundamental rights and user safety. While the EC stated that the estimation and evaluation of risks should be conducted on the basis on preliminary defined metrics and thresholds, the process of achieving such an operationalization is still open. This is where our considerations concerning an integrative and transdisciplinary approach for a human-centered design of AI-based work systems discussed in this paper come in.

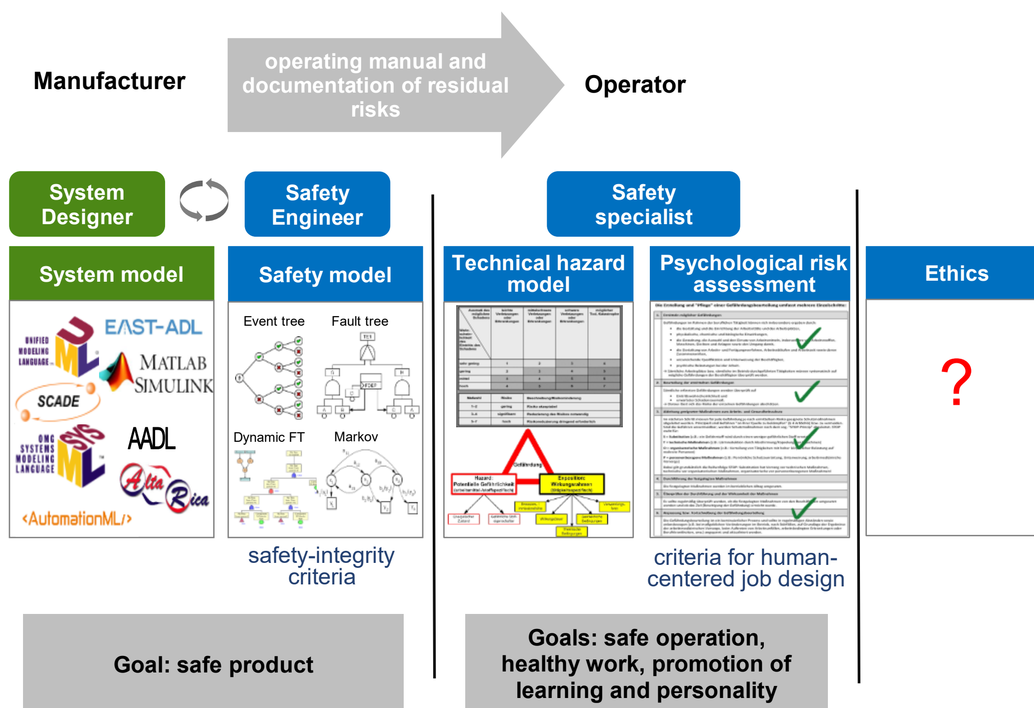
Starting with a description of the legal framework for technology design currently applied in Europe (**Section 4.2.2**), we explore arguments as well as potential methods for a systematic integration of psychological and ethical criteria into the system design process (**Section 4.2.3** and **Section 4.2.4**). Furthermore, we suggest an innovative system design approach that allows an integration of technical, psychological and ethical criteria (**Section 4.2.5**) and outline four steps that seem expedient its development (**Section 4.2.6**).

4.2.2 European Legal Framework, State of the Art, and Lived Practice in System Engineering

The current European framework for safe design and safe operation of products in occupational contexts is depicted schematically in **Figure 5**. The scheme illustrates the division between the safety engineering on the manufacturer's side and operational risk assessment on the operator's side. The European legislation requires manufacturers to carry out an iterative risk assessment to identify hazards, estimate and evaluate associated risks and to consider them during the design and construction process of machinery or parts of machinery (European Parliament & Council of the European Union, 2006). An approach for such a risk assessment and risk mitigation is described in the international standard ISO 12100 (2010). This standard aims at integrating safety and health protection into the design and construction process from the outset.

Figure 5

Schematic representation of the currently separated process of product safety assessment on the manufacturer side and risk assessment during deployment on the operator side



One of the steps within the legally required iterative risk assessment procedure is the estimation of residual risks. This requires detailed knowledge of the dependability of

safety-relevant parts of the technical system, including its software components, and the application of appropriate metrics and risk evaluation methods.

The increasing complexity of modern technical systems and their deeply intertwined physical and software components pose new challenges for classical safety assessment. Static risk models, such as event trees and fault trees, no longer suffice to tackle the challenges coming along with an increased number of functionalities, properties like dynamic reconfiguration and recombination, evolution in time, human-in-the-loop concepts and autonomous decision-making (Bolbot et al., 2019; Morozov et al., 2019). Combining model-based systems engineering (MBSE) and advanced safety models is the current approach to master these challenges (Lisagor et al., 2011; Munk & Nordmann, 2020; Prosvirnova, 2014). According to the International Council of Systems Engineering (INCOSE), MBSE is "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases" (INCOSE, 2007). This allows for a tight integration between safety assessment and design artifacts on the manufacturer's side (as sketched in the left side of **Figure 5**) (Lisagor et al., 2011).

After the completion of the legally required product safety assessment and the deployment of the product, the legal area of product safety is left and the legal area of operational safety is entered. Now, the operator is in charge to perform the technical risk assessment during operation as well as to assess possible other negative effects of the product on her or his employees' physical and mental health. To enable the operator to carry out the risk assessment, the manufacturer provides a detailed instruction manual and a documentation of the residual risks (in accordance with the European Machinery Directive 2006/42/EC, Article 5, in conjunction with Annex I, Section 1.7.4).

In contrast to the above-described iterative process on the manufacturer's side, there is no legally predefined iterative process scheduling feedback loops on the operator side. However, as illustrated in the example given in the introduction, the deployment of a technical system can entail risks that are not (or only to a limited extend) identifiable during system design. Clearly, this must be seen as a hindering factor for the development of an innovative integrative system design approach that also considers psychological as well as ethical risks.

The integration of AI-based components into work systems poses additional challenges to the strictly separated responsibilities of the manufacturer and operator. Dynamic and adaptive systems require a continuous assessment of possible risks for safety and health. A prerequisite for minimizing these risks already during the technology development stage would be an open feedback loop between the operator and the system designer that enables continuous risk assessment.

Recently, a model-based engineering approach has been proposed again as a solution for runtime safety assessment of adaptive systems (Moncada et al., 2021). So far, however, this approach focuses primarily on safety aspects. To the best of our knowledge, approaches for a simultaneous integration of psychological or ethical criteria into risk assessment have not yet been proposed. This conclusion is supported by an overview of (proposed) methods for risk assessment of AI algorithms in safety-critical applications (Siedel et al., 2021). The authors visualize the relatedness of crucial terms identified in titles and keywords of approximately 1200 references previously identified as relevant to the topic. The terms "philosophical aspects" and "trustworthiness" are in a significant distance from the main cluster of technical terms (details are described in ibid.). This indicates that technical terms and ethical aspects rarely occur together. Moreover, the connection to the main cluster is established through the terms "privacy" and "risk awareness". This, too, might be interpreted as strengthening our assumption that holistic, integrative approaches are not yet available.

4.2.3 Integration of Psychological and Ethical Criteria into the System Design Process

In the following, we discuss arguments for the integration of psychological and ethical criteria into the AI system design process. In addition, we explore existing methodological approaches that are suitable for integrating these criteria throughout the technology development process (or for being further developed for this purpose).

4.2.3.1 Considerations for the Integration of Psychological Criteria

Modern work is characterized by profound and complex forms of interaction between the working individual and various aspects of the workplace, including work-related technologies. To ensure employees' safety and health, the European directives 89/391/EEC and 2001/95/EC (and corresponding laws of the member states) call for

regular assessment and evaluation of work demands and potential risks emanating from the workplace, as well as for interventions aimed at minimizing these risks and promoting human-centered work. Currently, three methodological approaches for the assessment und evaluation of work-related risks are available: Questionnaires, workshops and observation-based job or work analyses. In operational practice, these methods are often combined.

Although the claim for prospective work design has been brought up for decades within the field of work and organizational psychology (Ulich et al., 2018; Wächter et al., 1989), risk assessment methods are still primarily applied in established work systems. In view of the integration of AI-based technologies in work systems, we question whether this will be sufficient in the future, as AI-based technologies have the potential to substitute distinctive human abilities, skills and competencies and are thus likely to significantly affect work characteristics. Due to their potential to perform tasks requiring higher-level cognitive abilities (e.g., decision-making), these systems may thwart core principles of human-centered work design constituted in European and international standards (DIN, 2008; ISO, 2016, 2019b) – such as adequate workload, control with regard to scheduling, the utilization of work equipment or work-related cooperation, skill discretion, or opportunities for learning and development. In this respect, AI-based technologies differ significantly from other technologies developed for supporting people in work systems, such as lifting assistances supporting the transport of heavy work equipment.

Given the new challenges and potential burdens AI-based technologies may bring for employees as well as for supervisors, their implementation in work systems needs to be carefully planned in advance (cf. *prospective work design*) – to ensure that the aforementioned criteria for human-centered work design are considered and, thus, adverse effects on working individuals are avoided. From our perspective, the consideration of psychological criteria for human work design would be reasonable already at the stage of technology development (see **Figure 6**), when system and safety engineers cooperate to create a safe product. This early consideration of psychological criteria is not only indicated by the premise of adapting work to the individual than the other way around (Parker & Grote, 2020), it would also avoid high effort (including costs) necessary for a later redesign of the work system (cf. *corrective work design*).

Among the aforementioned methodological approaches for psychological risk analysis, only one of the three seems suitable for this purpose: The method of observation-

based work analyses conducted by experts. This approach has its origin in research on occupational safety and health in the 1960s and 70s (Hacker et al., 1991; Ulich, 1981). Based on (semi-)standardized workplace observations and corresponding protocols documenting work activities, tasks and their characteristics, work systems and the tools used are evaluated with regard to their potential health-related risks and chances for well-designed work design. This process requires expert knowledge of the associations between different forms of work design and person-related outcomes.

An example of a contemporary instrument conceptualized for observation-based work analysis is the TAG-MA (Rau et al., 2018). In contrast to prior expert instruments, it was developed with consideration of psychological criteria for the evaluation of work design quality relating to standards as well as legal regulations for occupational safety and health. Thus, the TAG-MA may be also capable of estimating the design quality of future work systems – e.g., systems including AI-based components. Adapting an instrument like this demands occupational psychologists to develop a deep understanding, i.e., a mental model, of technologies being developed and their potential interactions within the work system. In doing so, they have to specifically focus on the interfaces between the working individual(s) and technology, and intensively discuss and confer with the system designer.

Because some AI-based components may (beyond potential adverse health-related risks) also impact fundamental rights and interests of individuals coming into contact with the systems such an advanced prospective risk analysis needs to explicitly make allowance for ethical criteria as well. Why this is important and how it may be achieved will be addressed in the following section.

4.2.3.2 Considerations for the Integration of Ethical Criteria

Particularly for systems that assist in decision-making in socially relevant application contexts, the consideration of ethical aspects – in addition to occupational safety and health aspects – gains increasing importance. As artifacts, technical systems are not ethically neutral *per se* (DIN & DKE, 2022; Florman, 1987). A salient example is the overpasses built in New York in the 1920s, which were constructed so low that buses from Black neighborhoods could only reach beaches, predominantly visited by white middle-class residents, via a detour (Winner, 1980). Although, today, it is widely recognized that technology design not only fulfills functional requirements but also reflects the moral values of its designers (and, vice versa, may influence personal and societal values (Thaler

et al., 2008)), there are so far no established methods for explicitly incorporating ethical criteria into design processes.

A particular ethical risk associated with the use of AI-based systems – especially algorithmic decision-making systems – arises from their capacity to autonomously derive decision rules from data and information. On this basis, such systems can prepare decisions – or even make them independently – that were previously reserved for human judgment and expertise. In the workplace, AI-based technologies may accordingly support task allocation, assist in evaluating employee performance and behavior, or support employees in carrying out tasks. Since the associated transfer of responsibility from humans to machines can have significant effects on how ethical conduct is shaped within work systems, we argue that also ethical criteria should be taken into account during system design. In the example of an algorithmic system that calculates optimal routes for both AGVs and nursing staff, the applied algorithms achieved the intended process optimization by factoring in the working speed of the nurses. However, the resulting situation, in which the system assigns more routes to nurse Alice than to her colleague Bert, seems unjust from an ethical point of view.

Since 2018, a subgroup of the international standards committee responsible for standardization in the field of AI (ISO/IEC JTC 1/SC 42), jointly led by the standards development organizations ISO and IEC, has been providing guidance on how trustworthiness of AI-based systems can be promoted. This subgroup, along with other ethical AI standardization initiatives, primarily investigates potential societal concerns. In line with our proposal for an integrative and prospective design of AI-based work systems, (inter)national standardization activities, moreover, indicate the necessity to identify specific situations in which AI-based systems impact ethical criteria and fundamental rights, and to develop corresponding methods and, in particular, regulatory instruments that promote ethical technology design (British Standards Institution, 2016; The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, 2019).

Although these efforts, aside from those led by the British Standards Institution, remain in an exploration phase, aimed at assessing the general potential for standardization in the field of AI, three primary regulatory approaches have been pointed out: (1) selecting and balancing training data based on ethical criteria, (2) defining criteria for risk assessment throughout the system development and deployment process, and (3) ensuring

transparency (e.g., through labels) for regulators, users and affected individuals regarding the factors that influence decisions prepared or made by the algorithms.

A critical prerequisite for approaches (1) and (2) is a context-sensitive formulation of proposed criteria, ensuring that they address the situated needs of those interacting with the systems. Undoubtedly, ethical imperatives cannot be derived from descriptive observations alone; relying solely on stakeholder interests to justify normative criteria would risk an *is-ought fallacy* (Moore, 1903). At the same time, without accounting for variations in moral beliefs and practices (including those across cultures), the knowledge base regarding potential ethical risks remains incomplete (Orwat et al., 2024), and defined evaluation criteria for risk assessment risk being morally questionable (Zwart, 2015). Yet, while there is broad consensus that promoting, for example, internationally recognized human rights (UN General Assembly, 1948, 1979, 2006) and sustainable development goals (UN, 2015) within AI technology design requires risk analysis tools that adequately account for the sociotechnical context of a specific application, the development of such tools remains a largely unmet objective.

Independent of specific technologies, a variety of design approaches have already been developed that address the need to explicitly consider stakeholders' perspectives. The first such theoretically grounded approach was the *Value Sensitive Design* approach (Friedman, 1999; Friedman & Hendry, 2019). Since then, several approaches have emerged, such as *Value-Sensitive Algorithm Design* (Zhu et al., 2018), *Values in Design* (Star & Bowker, 1999), *Values and Design* (Nissenbaum, 2001), and *Design for Values* (van den Hoven et al., 2015). A common characteristic of these approaches is that they propose to consider and explicate stakeholders' interpretations of ethical criteria in relation to use of specific technical systems. Although such approaches have already been applied in the development of digital technologies (Miller et al., 2007), they have not yet become common practice. More importantly, although they provide useful guidance for ethical reflection, these approaches generally neglect the influence of context-specific, dynamic factors that shape the fulfillment of proposed ethical requirements (Manders-Huits, 2011). This limitation becomes particularly salient in the case of AI systems, whose adaptive behavior and entanglement with social, technical, and organizational dimensions demand a more iterative and context-responsive integration of ethical criteria throughout their lifecycle.

In addition, the field of *Technology Assessment* has introduced methodologies aimed at identifying and integrating moral and societal considerations into the process of technology design (Rip, 2018; Schot & Rip, 1997). One promising technique is that of *value* or *objective trees*, which aim to make values (resp. criteria) operational (Renn, 2015; van de Poel, 2013). Starting from the most general and abstract objectives (i.e., intrinsic values), these trees cascade into increasingly specific criteria that define to means considered necessary to fulfill these objectives. This hierarchical structure enables more concrete interpretation of high-level ethical goals while embedding them within the technology's application context. Despite its potential, this method has not (yet) found its way into practice. One reason for this could be that value trees currently still place more emphasis on what should be achieved rather than how to achieve it. Bridging this gap may require the development of approaches that translate ethical objectives into the language and structures of engineering design methodologies.

Beyond the question how ethical aspects of AI-based work systems can be adequately assessed, another important question is which systems need to be regulated with regard to ethical criteria in the first place. Certainly, not all AI-based systems are ethically problematic. While there is wide consensus that not all AI-based technologies need to be regulated to the same degree (AI HLEG, 2019; Council of Europe, 2020; EC, 2021b), various actors have developed different risk-adapted regulation schemes varying, e.g., with regard to whether means of regulation should apply to certain AI subtypes (independent of application contexts) or only to specific application contexts associated with particular ethical risks. For example, the Data Ethics Commission, set up by the German federal government in 2018, recommends determining the degree of criticality using an overarching model for all systems, defining the level of criticality based on the likelihood of harm occurring in relation to its severity (German Data Ethics Commission, 2019). Researchers from the Weizenbaum Institute propose a scheme focused on ADM-systems, weighing system-based risks (i.e., risks arising from the technologies themselves) against application-based risks (i.e., risks resulting from the specific use of the technology) (Müller et al., 2021). The EC recommends imposing regulatory burdens only when AI systems "in the light of their intended purpose, (...) pose a high risk of harm to the health and safety or the fundamental rights of persons, taking into account both the severity of the possible harm and its probability of occurrence" (EC, 2021b, p. 26).

In conclusion, it can be stated that while the importance of regulating AI-based work systems and developing suitable ethical evaluation criteria is widely acknowledged, the creation of operational frameworks remains an ongoing challenge that demands further research and collaborative effort.

4.2.4 Consolidation and Status Quo

As shown in the Section 4.2.2 and 4.2.3, there are strong arguments for the (mandatory) integration of psychological and ethical criteria, as well as for the application of suitable methodological approaches throughout the technology development process – particularly, with regard to AI-based systems that may pose so far unknown risks to health and safety, or give rise to violations of fundamental rights or other ethical concerns. However, an exploratory literature search revealed that methods for sustainably integrating these criteria into system engineering processes are not yet available. Before proposing an integrative system design approach in Section 4.2.5, we summarize the findings and key points from the previous sections, highlighting the needs for research and action.

(1) The current framework for the safe design and operation of products in the occupational context appears inadequate against the backdrop of the increasing use of AI-based systems:

- The consideration of psychological and ethical criteria in product development is not yet part of the standard engineering practice. However, their integration could enable a more holistic approach to system design in the era of AI-based systems.
- The deployment of a technical system can entail risks that are not fully identifiable during system design. The strict separation between manufacturers' and operators' responsibilities hinders iterative feedback loops, which are necessary for integrating ethical and psychological criteria into ongoing risk assessments.
- The integration of AI-based systems into work systems increases the necessity to:
  - strengthen the information exchange between system design with system operation,
  - develop an integrative risk assessment approach,
  - enable semi- or fully automated assessments during system runtime.

(2) Work analysis methods need to be adapted to fit into the system design process:

- Established psychological criteria for human-centered work design must be scrutinized regarding their validity, accuracy and completeness within a digitalized world of work.
- A shared understanding (and terminology) regarding goals, constructs, and methods relevant to constructive cooperation between system designers, safety engineers, occupational psychologists, and ethics experts is are prerequisite for a successful process. Such a terminology has yet to be developed.
- It is unknown to what extent current tools for observation-based work analysis are suitable for integration into system engineering processes, or how such integration could be practically achieved.

(3) No established methods exist to guide ethically aligned technology design throughout the development and deployment process. To address this gap, we propose to:

- Account for the moral values of stakeholders considered relevant, despite the fact that such are interpreted differently across individuals and societies (which may introduce ambiguity in their specification),
- Address the influence of context-specific and dynamic factors on the fulfillment of proposed ethical requirements,
- Supplement ethical criteria with suitable means to fulfill their objectives, such as methods that allow translate ethical objectives into the language and structures of engineering design methodologies
- Reach consensus on the formulation of risk-adapted regulation schemes.

4.2.5 Suggestions of an Innovative System Design Approach for Integrating Technical, Psychological and Ethical Criteria

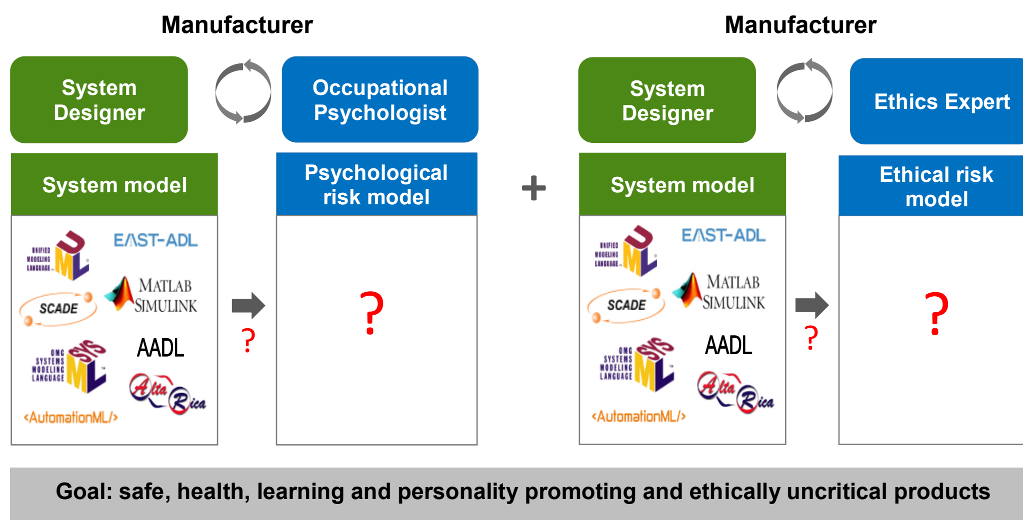
Comprehensive research and development are needed to address the challenges of integrating not only technical but also ethical and psychological criteria into system design processes. In the model-based risk assessment approach, as depicted in Section 4.2.2, we see the starting point for further activities. This approach allows for a stronger integration of safety assessment and design artifacts and is suitable for complex, highly reconfigurable and adaptive systems (Lisagor et al., 2011; Morozov et al., 2019; Munk & Normann, 2020). Moreover, it is proposed as a solution for runtime safety assessment of adaptable systems and, hence, addresses key requirements formulated in Section 4.2.4. Following

the model-based risk assessment approach, we further propose a direct integration of psychological and ethical criteria into the system engineering process.

This suggestion is in line with Sillitto et al. who argue that a “transdisciplinary approach [in systems engineering] may be needed in unprecedented situations or where there is a significant degree of complexity involved” (Sillitto et al., 2019, p. 6). Highly adaptive AI-based work systems exemplify these characteristics.

Figure 6

Schematic representation of an approach that dissolves the strict boundaries between the manufacturer and operator side



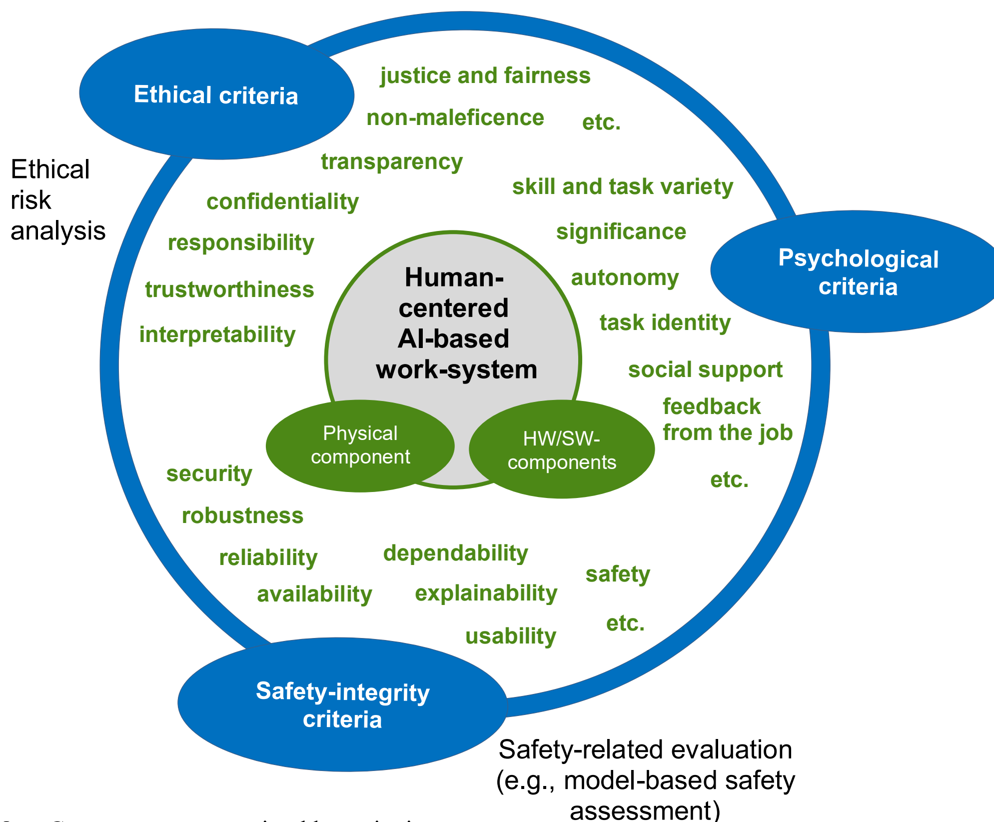
Note. Suitable psychological and ethical risk models for the proposed approach are not yet approved.

However, appropriate risk models for such systems are not yet available and further research concerning a system modelling paradigm suitable to integrate human-centered requirements is needed. Resolving this gap in knowledge and methods will be a fundamental part of the work ahead. While the concept of prospective system engineering is not new and has already been extensively discussed, the approach proposed here fundamentally differs from previous ones by adhering to the premise of an integrated set of methods. Current methods are usually additional, “on top” solutions, which can but do not need to be integrated in the system design process (e.g., the REBA tool (Pohlandt et al., 1999) or the task analysis methods compiled in Müller et al. (2018)). In addition, the applicability of most available methods has been demonstrated for industrial use cases, while a substantial percentage of today’s jobs occurs in the service sector. Finally, for a complex adaptive system, as sketched in the scenario at the beginning of this article, a

runtime assessment becomes necessary. Given these shortcomings of current approaches, we propose to extend existing system modelling in a way that facilitates the capture of system properties relevant from a psychological and ethical perspective (see **Figure 7**). This also requires a system model capable of processing temporal sequences. From a technical point of view, the challenge remains to integrate AI components, with their adaptive and complex nature, not only into the design-time verification process but also into a runtime assurance (Burton et al., 2017; Serna et al., 2020; Seshia et al., 2020).

Figure 7

Schematic representation of the proposed integration of psychological and ethical design criteria



Note. Green: system properties; blue: criteria.

We propose an integrative system model capable of describing the influence of an embedded AI component on technical, psychological, and ethical aspects and is extendable by components and formalisms that allow to describe interactions between technical elements and both psychological and ethical functional elements. Ultimately, these functional elements must be able to describe the impact of specific technical system functions on defined psychological and ethical criteria. Ideally, such a system model would be automatically transformable into a risk model, which would be an important prerequisite for runtime assurance of adaptive systems.

4.2.6 Conclusion: Four Steps to Go

Step 1: In-depth investigation of current methods suitable for holistic system design processes

To our knowledge, there are so far no transdisciplinary, integrative approaches that have found their way into system design. However, singular methods suitable for this process do exist. Before drawing up a new approach, future research should systematically investigate relevant methods that could be applied and/or further elaborated for this purpose. Pre-eminently, there is need for a systematic investigation of factors hindering a widespread application of methods allowing for a consideration of psychological and, respectively, ethical criteria in system development. It should be analyzed whether these methods are applicable to the development of AI systems with adaptive decision-making components and what challenges they pose for system design.

Step 2: Development of a transdisciplinary terminology

To ensure that potential consequences of AI-based systems are identified prior to their practical application, an integrative system design approach that includes a transdisciplinary paradigm involving technical, psychological and ethical expertise must be developed. An elementary precondition for this is a shared understanding of the constructs used across the disciplines involved (Müller, 2015). Constructs such as *harm*, *nonmaleficence* and *risk* are used in all three disciplines and intersect in their meanings. Moreover, to ensure that potential violations of psychological and ethical considerations are addressed already during the design phase, it is necessary to translate criteria from disciplines such as work and organizational psychology and ethics into the terminology of engineering system design methods. Importantly, an integrative terminology that makes psychological and ethical criteria suitable as well as accessible for the development of human-centered technical systems must also allow to determine *how* to integrate these criteria into system design (i.e., to translate qualitative criteria into technical system requirement).

Step 3: Context-sensitive and iterative specification of ethical criteria

As outlined in Section 4.2.3.2, most theoretically grounded design approaches advocate that the specification of ethical criteria should integrate stakeholders'

interpretations of ethical design principles within specific application contexts. We concur that the definition of ethical requirements for technology design must take into account the broader application context within the work system, including the expert knowledge of those who interact with these applications. Potential risks do not stem from technical systems in isolation but emerge through their interaction with the entire sociotechnical application context (Grunwald, 2013, 2024). Moreover, to address the adaptive behavior of AI systems and their entanglement with the social, technical, and organizational dimensions of workplace settings, there is a need – beyond existing approaches – for methodological approaches capable of capturing the influence of context-specific and dynamic factors on the realization of specified ethical requirements (Manders-Huits, 2011).

Step 4: Testing in a digital system model

The proposed integrative approach requires testing – first in an experimental setting. One promising step in the process is the development of use cases suitable for mapping onto a digital system model. Importantly, since this system model must allow not only for a safety analysis but also for the mapping of technical, ethical as well as psychological criteria, it needs to allow not only the simulation of technical data and physical components but also the simulation of work tasks and the human operators interacting with the system. In this way, the development of an AI-based work system could be continuously accompanied by an ongoing evaluation of psychological and ethical criteria. Moreover, such an approach could pave the way for an online-assessment of systems during operation, thus helping to overcome the new challenges posed by AI-based systems, particularly in relation to their dynamic and probabilistic way of influencing human-machine-interaction.

By following these four steps, the proposed innovative system design approach provides an opportunity to identify both risks and opportunities of modern technologies and work systems from a human-centered work design perspective and could thus make an important contribution to ensure a healthy workforce in the 21st century.

4.3 A Context-Specific Analysis of Ethical Principles Relevant for AI-Assisted Decision-Making in Health Care

Larissa Schlicht*, Miriam Räker

Abstract

Artificial intelligence (AI)-assisted technologies may exert a profound impact on social structures and practices in care contexts. Our study aimed to complement ethical principles considered relevant for the design of AI-assisted technology in healthcare with a context-specific conceptualization of the principles from the perspectives of individuals potentially affected by the implementation of AI technologies in nursing care. We conducted scenario-based semi-structured interviews focusing on situations involving moral decision-making occurring in everyday nursing practice with nurses (N = 15) and care recipients (N = 13) working, respectively, living in long-term care facilities in Germany. First, we analyzed participants' concepts of the ethical principles beneficence, respect for autonomy and justice. Second, we investigated participants' expectations regarding the actualization of these concepts within the context of AI-assisted decision-making. The results underscore the importance of a context-specific conceptualization of ethical principles for overcoming epistemic uncertainty regarding the risks and opportunities associated with the (non)fulfillment of these ethical principles. Moreover, our findings provide indications regarding which concepts of the investigated ethical principles ought to receive extra attention when designing AI technologies to ensure that these technologies incorporate the moral interests of stakeholders in the care sector.

Keywords: Artificial intelligence, Nursing, Ethics, Stakeholder perspectives, Interview study

4.3.1 Introduction

The application of algorithms based on artificial intelligence (AI)[23] is spreading in the world of work and also in the healthcare sector. AI systems have the ability to imitate human problem solving, allowing them to assist with or perform tasks that require cognitive abilities (e.g., Parker et al., 2022). The transfer of agency from humans to AI-assisted technologies may, therefore, have a significant impact on social structures as well as practices in the health care context and the social and moral norms[24] manifested therein. Recently, there has been an increase in the research and development of AI-assisted technologies for nursing care (Buchanan et al., 2020; Seibert et al., 2021; von Gerich et al., 2021). Against the backdrop of current challenges in professional care, such as the shortage of skilled workers, workforce aging and growing care needs resulting from increasingly aging societies and population growth (WHO, 2020), AI technologies promise to optimize nursing workflows, e.g., by providing automated tracking and analysis of care recipients' activities and health data as well as identifying options for clinical decision-making (Ng et al., 2021; Seibert et al., 2021).

Nurses assist individuals in activities that "contribute to their health or recovery or to dignified death that they would perform unaided if they had the necessary strength, will, or knowledge" (ICN, 2022). In this, they take responsibility for the well-being of humans who are limited in their decision-making ability and/or dependent on professional care.

Advocating for the interests and needs of those in need of care is a key aspect of professional care. Hence, nurses are often confronted with complex decisions that require the inclusion of multiple perspectives, taking into account the individual situation of care recipients. Frequently, their decisions have morally significant consequences (e.g., Rainer et al., 2018; Suhonen et al., 2018).

[23] While there is, at least for the time being, no agreed definition of AI technologies, it is generally assumed that such technologies include computer-based systems that can, for a given set of objectives, influence their environment by producing outputs such as predictions, recommendations or decisions. The Organisation for Economic Cooperation and Development (OECD), for instance, specifies that an AI system uses machine and/or human-based data and inputs to "(i) perceive real and/or virtual environments; (ii) abstract such perceptions into models manually or automatically; and (iii) use Model Interpretations to formulate options for outcomes" (OECD, 2019b, p. 7).

[24] A widely shared assumption in ethics as well as the social sciences is that *social norms* are exogenous informal rules that govern (and often constrain) behavior in groups and societies (Bicchieri et al., 2018). *Moral norms*, in particular, can be defined as ideals (i.e., moral imperatives) that prescribe how people – considered free to decide – should behave toward others and themselves. The influence of technologies on such norms can be understood as tendencies to condition their environments to behave or be organized according to the rationales of the norms (Brey, 2009, p. 47).

Areas of application of AI-assisted technologies already in use range from activity and health tracking to care coordination and communication; the systems are based on, e.g., computer vision, predictive modeling, natural language processing, or speech recognition (von Gerich et al., 2021). It has been shown that such technologies can make assessments and processes more efficient – such as by early detection and prevention of adverse events or by reducing the time needed for documentation – enabling nurses to focus on humanistic aspects of care, including communication (e.g., Ng et al., 2021). Moreover, AI may offer the opportunity to make care services more personalized (by integrating individual health data) and to provide evidence-based health information for decision-making (Morley et al., 2020). However, the implementation of AI-assisted technologies also creates new challenges. It has been discussed that the adoption of such technologies may be associated with adverse effects such as a depersonalization of the nurse-patient relationship (Rubeis, 2020) and impaired communication (Rogers, 2021), thereby undermining the holistic approach to care practice. Depending on the system design and the field of application, the individuality of those in need of care could gradually disappear aside from what can be empirically captured (the so-called datafication of patients) (e.g., Mittelstadt & Floridi, 2016; Tsamados et al., 2021). Furthermore, a nonrepresentative selection of datasets and/or the quantification and categorization of data for the training of AI models contain the potential to discriminate against particular (sociodemographic) groups, such that their needs and characteristics are overlooked (Beil et al., 2019; Siala & Wang, 2022). Another possible drawback is that the reliance of nurses on algorithms could lead to a loss of the ability or willingness to critically reflect on their actions (e.g., Rubeis, 2020).

Overall, it can be said that the risk of neglecting care recipients' interests and (behavioral) repercussions within care processes is already present (i.e., independent of AI technology) but can be exacerbated by this technology and particularly by systems that have a direct impact on human-human relationships.

To ensure that the implementation of AI applications supports human agency in an ethically aligned way, there is a need to provide early identification of possible tendencies of implemented algorithms to contribute to a perpetuation or change of social structures and the moral norms anchored therein (e.g., Brey, 2009). At present, unintended consequences associated with a dehumanization or impersonalization of care are not being

systematically assessed during the system design process though. Existing ethical guidelines for AI are usually formulated as highly abstract ethical principles that appear to be too indeterminate, i.e., normatively unambiguous to guide the design of technologies based on moral claims (Morley et al., 2021). To effectively inform choices made during the design process guidelines need to be specified for specific contexts of use.

This study complements ethical principles considered relevant for the design of AI-assisted technology in health care with a context-specific conceptualization of the principles from the perspectives of individuals potentially affected by the implementation of AI technologies in long-term care facilities in Germany. With this approach, we provide indications regarding which concepts of the investigated ethical principles ought to receive particular attention during the design of AI technologies to ensure that these technologies are not blind to the moral interests of stakeholders in the German care sector.

4.3.2 The Need to Contextualize AI Ethics Frameworks

The need to develop norms and standards to achieve ethically aligned AI systems is being critically discussed by various organizations (e.g., EC, 2021; OECD, 2019b, 2019c), the private sector (e.g., Crawford et al., 2019) and researchers (e.g., Bostrom & Yudkowsky, 2014; O'Neil, 2016). Consequently, numerous ethical guidelines for AI have been developed in recent years (Jobin et al., 2019; Prem, 2023). However, these guidelines seem to be rarely considered in practice (Vakkuri et al., 2020). This cannot solely be explained by the number of frameworks to choose from and/or the limited (sanction) mechanisms to date reinforcing their normative claims. An obstacle to the effective translation of ethical principles into practice is the high degree of epistemic uncertainty regarding the risks and opportunities associated with the (non-)fulfillment of ethical principles. To resolve this uncertainty, context-specific conceptualizations of the proposed principles, e.g., via bottom-up case studies with relevant stakeholders, are needed (Le Dantec, 2009; Mittelstadt, 2019). The current guidelines are usually formulated as highly abstract principles that "leave much room for interpretation as to how they can be practically applied in specific contexts of use such as LTC [long-term care]" (Lukkien et al., 2023, p. 2).

Correspondingly, it is widely agreed that the design of technologies implemented in socially sensitive areas, such as the healthcare sector, should not solely be informed by

predefined normative principles (adapted to the technology's abilities) but also by local phenomena (i.e., thick ethical concepts)[25] that appear morally salient to those that are potentially affected by the implementation of such technology (e.g., AI HLEG, 2019; Mittelstadt, 2019; WHO, 2021). To adequately assess and operationalize stakeholders' perspectives, several researchers have stressed the need for a stronger investigation not only of stakeholders' situated conceptualizations of proposed principles (e.g., Pommeranz et al., 2012) but also of possible associations of these conceptualizations with specific tasks (van Wynsberghe, 2013). Existing approaches that aim to translate stakeholder perspectives into design requirements in a principled manner, such as Value-Sensitive Design (Friedman & Hendry, 2019) or Participatory Design (Robertson & Simonsen, 2013), usually do not consider aspects that address ethical principles' realization through situational factors embedded in specific real-life contexts (e.g., Manders-Huits, 2011).

Aiming to complement ethical principles with context-specific perspectives of individuals potentially affected by AI-assisted decision-making, we focus on the framework proposed by Beauchamp and Childress (2019). A mapping review conducted by Floridi et al. (2018) of the literature on ethical guidelines for AI suggests that the key principles incorporated by many AI initiatives are consistent with the ethical principles proposed herein.[26] The most influential framework in health care practice (hereafter, referred to as principles of biomedical ethics) proposes the following four prima facie principles for the ethical evaluation of health care practice:

- *Beneficence*: all norms, dispositions and actions aiming to benefit or promote the well-being of other persons (Beauchamp & Childress, 2019, pp. 217–218). It "(1) present[s] positive requirements of action, [that] (2) need not always be followed impartially, and (3) generally do not provide reasons for legal punishment when agents fail to abide by them" (ibid., p. 219).
- *Nonmaleficence*: obligates to abstain from causing harm to others (ibid., p. 155). It is conceptualized as "(1) negative prohibitions of action, [that] (2) must be

[25] Thick ethical concepts denote descriptive features of a situation that may be (considered) morally relevant. Within moral philosophy, situational ethicists emphasize the importance of taking such features into account to determine considerations relevant to the ethical evaluation of a particular situation (Richardson, 2018).

[26] Note: Floridi et al. identify explicability as an additional, frequently discussed, instrumental (i.e., aiming to realize intrinsic principles), principle. In this study, however, we initially aimed to investigate intrinsic principles (versus instrumental principles).

followed impartially, and (3) provide moral reasons for legal prohibitions of certain forms of conduct" (ibid., p. 219).

- *Respect for autonomy*: both the negative obligation that autonomous actions should not be subjected to controlling constraints and the positive obligation to disclose information as well as to promote the capacities for autonomous choice (ibid., p. 105). The realization of the principle is assumed to require liberty (independence from controlling influences) and agency (capacity for intentional action) (ibid., p. 100).
- *Justice*: broadly defined as the obligation to fairly distribute benefits, risks and costs under conditions of scarce resources (ibid., pp. 13, 250). In the absence of social consensus on specific theories of justice (such as utilitarian, libertarian, communitarian, egalitarian, capability and well-being theories), policies are expected to integrate various elements of these theories on a case-by-case basis (ibid., p. 313).

Further references on ethical principles considered relevant in care contexts occur in nursing theories with their respective value orientations (Kangasniemi, 2019), in professional codes of ethics (e.g., ANA, 2019; ICN, 2021) and to some extent in other (bioethical) approaches of health care ethics (Häyry, 2003; Rendtorff, 2022; Veatch, 2020). In particular, relational theories of health care and nursing, such as the ethics of care (Gilligan, 1982; Noddings, 1984; Tronto, 1993), make normative claims against the principles of biomedical ethics. Based on the assertion that social relationships and the recognition of the vulnerability of those in need of care should be the focus of ethical considerations of care work, the principle respect for autonomy, in particular, is thought to be based on an overly individualistic view of human beings. We assume that such perspectives are not necessarily incompatible with the principles of biomedical ethics; instead, they could be integrated, along with complementary ethical principles with their context-specific conceptualization, into the framework. In fact, Beauchamp and Childress conceptualized their principles as an analytical framework of general norms derived from common morality[27] that serves as a practical instrument for moral reasoning (Beauchamp

[27] Common morality is considered to contain "moral norms that are abstract, universal and content-thin (such as 'Tell the truth')" (ibid., p. 5), in contrast to particular moralities, which are considered to "present concrete, nonuniversal, and content-rich norms (such as "Make conscientious oral disclosures to and obtain a written informed consent from all human research subjects" (ibid., p. 5).

& Childress, 2019, p. 17) and requires further specification to provide direct guidance within specific contexts (p. 9).[28]

However, we narrowed our search space to the three principles of *beneficence*, *respect for autonomy* and *justice. Nonmaleficence* requires intentional avoidance of actions that (may) cause harm and are therefore legally prohibited (p. 219).[29] In our study, however, we wanted to encourage participants to reflect on decision-making situations in which their moral intuitions are (presumably) not primarily guided by internalized rules of conduct. More importantly, we decided not to include a scenario prompting reflection on the principle of *nonmaleficence* because we aimed to respond to the (potential) vulnerability of participants in the care-recipient group and minimize the risk of causing psychological/emotional harm (such as feeling uncomfortable, embarrassed, or upset) to them (Council for International Organizations of Medical Sciences, 2016; Deutsche Gesellschaft für Pflegewissenschaft e. V., 2016). Due to the mutual relations between the principles, it must still be assumed that some participant statements may also be related to the principle of *nonmaleficence*.

4.3.3 Research Questions

While former studies have assessed, e.g., medical students' views of the *principles of biomedical ethics* (based on four scenarios) (Hébert et al., 1992), the influence of the principles on health care practitioners' attitudes toward AI technology (Wang et al., 2023) and student rankings of the principles within decision-making in ethical scenarios (Page, 2012), to our knowledge, no qualitative study has assessed whether the principles are morally salient to direct stakeholders in the German care sector. Moreover, no study to date has examined which situational factors of specific real-life contexts are thought to promote the actualization of ethical principles by stakeholders. As outlined in previous section, it is assumed that such complementary data will help to translate ethical principles

[28] Specifically, Beauchamp and Childress argue that the "content of (...) rules and principles is too abstract to determine the specific acts that we should and should not perform. In the process of specifying and balancing norms and in making particular judgments, we often must take into account factual beliefs about the world, cultural expectations, judgments of likely outcome, and precedents to help assign relative weights to rules, principles, and theories" (ibid., p. 427). The framework can thus be seen as a hybrid model combining top-down approaches, which provide deductive generation of moral justification, and bottom-up approaches, which assume that moral justification ought to be derived inductively through contextualized reasoning (Ridge & McKeever, 2020).

[29] Examples of specific moral rules that are supported by the principle of *nonmaleficence* include, for example, "do not kill," "do not cause pain or suffering," and "do not incapacitate" (ibid., p. 156).

into practice. Therefore, the present study first aimed to illuminate the established *principles of biomedical ethics* from the perspective of direct stakeholders in the German care sector, nurses and care recipients (to ensure that multiple perspectives are factored into the analysis (Archibald & Barnard, 2018). To meet this goal, we formulated the following research questions:

Q1: Are the principles of *beneficence*, *respect for autonomy* and *justice* morally salient to participants?

Q2: How do participants conceptualize the principles? Which situational factors (in particular, demands) do participants regard as promoting the actualization of their concepts of these principles in situations involving moral decision-making occurring in everyday nursing practice?

We further aimed to provide initial indications of which concepts of the investigated ethical principles ought to receive particular attention when designing AI technologies to ensure that they are not blind to the moral interests of stakeholders in the German care sector. We therefore analyzed participant expectations regarding the actualization of their concepts of the principles in the context of AI-assisted decision-making in the third question.

Q3: Which potential influences do participants anticipate from the use of AI-assisted technology in situations involving moral decision-making (care tasks) with regard to the actualization of their concepts of the principles?

4.3.4 Methods

We conducted scenario-based semi-structured interviews (Carroll, 1995; Nathan et al., 2007) focusing on situations involving moral decision-making occurring in everyday nursing practice. With this approach, we prompted participants to reflect upon the three ethical principles of *beneficence*, *respect for autonomy* and *justice* as well as the potential influences of AI-assisted technology on the actualization of the principles.

4.3.4.1 Participants

In total, semi-structured interviews were conducted with 15 nurses and 15 care recipients between October 2021 and May 2022. In the care-recipient group, two interviews were excluded due to insufficient comprehensibility of their statements,

resulting in 13 analyzable interviews. Recruitment took place through telephone and e-mail inquiries to long-term care facilities within Germany. Participants in the nurse group had to be employed as registered nursing professionals. Participants in the care-recipient group had to be at least 18 years old, without cognitive or communicative impairment (in everyday social life in the facility) and to have already received care for at least one year. Their demographic characteristics are reported in **Table 6**.

Table 6

Participants' sociodemographic characteristics

Characteristic	**Nurses (n)**	Characteristics	**Care recipients (n)**
Age (years)		Age (years)	
18–30	3	18–30	0
31–45	6	31–45	3
46–55	2	46–55	1
56+	3	56+	9
Gender		Gender	
Female	9	Female	7
Male	6	Male	6
Diverse	0	Diverse	0
Function		Length of stay in a long-term care facility (years)	
Nursing staff	5	1–4	6
Nursing management	8	5+	7
Other	2		
Occupational experience (years)			
5	4		
5–9	0		
10–19	6		
20–29	4		
30+	1		

Note. N = 28; N = 15 in the group of nurses and N = in the group of care recipients.

4.3.4.2 Procedure

For the nurse group, the duration of interviews ranged from 60 to 90 minutes.[30] We originally planned to conduct the interviews on-site (i.e., at the facility in which the participants lived or worked); however, in some cases, this was not possible due to the

[30] We did not set time limits to answer individual questions and encouraged participants to take some time to consider their answers. Empirical evidence suggests that moral evaluations made after a time delay are more influenced by deliberative reasoning than those made without such delays (Rand, 2016).

coronavirus disease 2019 (COVID-19) pandemic. Therefore, some interviews were conducted digitally. In the care-recipient group, the length of the interviews was limited to 60 minutes. Most of these interviews were conducted at the nursing home in which the care recipients lived at the time. Interview audio was recorded using a conventional voice recorder. All interviews were conducted by one of the authors.

4.3.4.3 Scenarios

With a multidisciplinary group of researchers and a registered nurse, we developed three scenarios, depicting different care tasks associated with moral decision-making as potential fields of application for AI technology (Buchanan et al., 2020; Seibert et al., 2021; von Gerich et al., 2021). The scenarios were revised after pilot testing with two individuals. To assess the ecological validity of the scenarios, participants were asked whether they experienced decision-making situations in their (professional) everyday life similar to those described in the scenarios. Overall, agreement was high for all scenario variants.[31]

The first scenario (see Appendix C4) describes a situation in the field of basic care (bodily care), and the second scenario (see Appendix C5) describes a situation in the field of social care (interaction and relationship). In both scenarios, a nurse must decide whether to follow the expressed will of a person in need of care or to perform a care task against his or her will, i.e., the nurse must weigh the principles of *respect for autonomy* and *beneficence*. The third scenario (see Appendix C6) describes a situation in which workflows must be prioritized (organization of workflows) due to staff shortages; specifically, a nurse has to decide between caring for one person (who needs emotional support) or caring for many (as part of routine on-site care). This scenario prompts reflection on the principle of *justice*. Two versions of each scenario were presented, one in which the nurse decides with the support of an AI-assisted technology and one in which the nurse makes the decision without this technology.

Analysis of results related to Q1 and Q2 was primarily based on statements referring to scenarios *without* AI technology; in contrast, analysis of results related to Q3 primarily focused on statements referring to scenarios *with* AI technology. The

[31] Approximately two-thirds of participants agreed that they frequently experienced comparable situations. The level of agreement was slightly lower in the care-recipient group than in the caregiver group.

presentation of both versions of each scenario was designed to increase the salience of the difference between the two situations. The resulting six situations were presented to participants in written form or, if necessary, aloud.

For each situation, participants were asked to answer questions concerning (a) possible implications of the outlined decision, (b) their moral evaluation of the outlined decision, and (c) their rationale for the evaluation made in (b). In addition, the participants were asked to describe their conception of *good care*. In order not to influence the moral reasoning of the participants and to be able to assign their statements inductively to the ethical principles, the participants were not given the definitions of the principles.

4.3.4.4 Data Analysis

The recorded interviews were first pseudonymized and then transcribed. A content analysis following that of Kuckartz (2014) using MAXQDA analysis software (VERBI, 2022) was carried out. Participants were pseudonymized as follows: nurses were labeled as G1, G2,..., and G15; and care recipients were labeled as R1, R2,..., and R13. The transcripts were analyzed by a stepwise construction of codes. Initial main codes were derived deductively from our research questions; further main codes and subcodes were derived inductively from the data. Together with a third researcher, we independently performed coding; occasional differences in our codes were discussed and resolved within the research team.

4.3.5 Results

4.3.5.1 Contextualization of Biomedical Ethics Principles

In the qualitative content analysis, participant moral reasoning clearly reflected the three principles of *beneficence*, *respect for autonomy* and *justice* (Q1). However, the results also suggested that the principles' definitions may need to be extended to care-specific concepts.

Superordinate findings regarding participants' contextualized perspectives of the principles (Q2) are described below (principle concepts are italicized). Tables of all key aspects associated with the principles (including situational factors considered to promote the actualization of their concepts of the principles) as well as corresponding anchor quotations are provided in the Appendix C.

Beneficence

Participants' concepts of *beneficence* were highly multifaceted. Many facets referred to the relationship between the nurse and care recipient as well as specific caring actions. In other words, participants seemed to think of the principle as a dynamic process within care procedures that also impacts the actualization of the other principles.

The participants largely agreed that the overarching aim of *beneficence* is, on the one hand, the prevention of (physical) harm as well as the satisfaction of basic needs and, on the other hand, the promotion of care recipients' emotional well-being. This conceptualization is largely consistent with the definition of Beauchamp and Childress (2019).

As shown in **Table C1** (see Appendix C1), participant statements regarding critical requirements to achieving these aims (in situations involving moral decision-making) can be broadly grouped into three categories, namely, *recognizing needs*, *assuming responsibility* and *meeting needs*. These requirements provide a nuanced understanding of the principle of *beneficence* within the context of long-term care. In particular, participants highlighted demands that specified "positive requirements for actions" (Beauchamp & Childress, 2019, p. 204). Participants pointed out that the recognition of care recipients' needs is the basis for the realization of subsequent aspects and demands on nurses to, inter alia, holistically assess care recipients' needs; e.g., "Caring requires perceiving the persons in need of care as comprehensively as possible. Their wishes, needs, problems" (G9).

The assumption of responsibility, preceding the performance of concrete nursing actions, was viewed as closely linked to the demand of obtaining extended information on the (health) condition of patients as well as weighing possible consequences associated with the available options for action. In addition, many participants highlighted that communication plays a central role for building trust within this stage of caring processes: "If we talk to the patients, for example, explain why a particular treatment is important, the patients usually allow the treatment to be carried out" (G15).

Finally, participants stressed that meeting care recipients' needs often requires nurses to respond to their patients according to a given situation and, if necessary, to adapt their (planned) actions accordingly; e.g., "The art of nursing involves applying abstract knowledge to the person and the specific situation" (G9).

Respect for Autonomy

Participants' contextualized understanding of *respect for autonomy* was roughly categorized into the concepts of *individual autonomy* and *relational autonomy*, which differ in their respective aims and demands (see **Table C2** in Appendix C2).

In line with the definition of Beauchamp and Childress (2019), many participants argued that *respect for autonomy* requires care recipients to be self-determined as well as free from interference when making decisions; e.g., "respect for autonomy requires that I regard the person in need of care as the decision-maker" (G9). Correspondingly, participants emphasized that nurses should trust in patients' decision-making competency and, if necessary, improve their ability to make fully informed and independent decisions; e.g., "it is important to promote competence to make their own decisions... To do this, we often have to provide information" (G7). Limits to this understanding of patient autonomy are identified in associated risks of self-endangerment and harm for uninvolved persons[32] as well as regarding care recipients with cognitive impairments.

At the same time, many participants pointed out that patients' exercise of agency is usually embedded in social relationships and that patients may not be capable of claiming the right to autonomy. Accordingly, some participants reasoned that patient autonomy may also be preserved by retaining a person's sense of identity rather than independence, particularly with cognitively impaired persons. Thus, autonomy should be understood as a relational process involving the demand to holistically assess care recipients' individual situation and motives. Several participants argued that nurses should consider the possibility of internalized incapacitation. Moreover, participants assumed that (relational) autonomy can also be preserved within shared decision-making. Relatedly, many emphasized the possible demand of ascertaining care recipients' motives and needs through nonverbal communication as well as through consulting colleagues; e.g., "to strengthen the autonomy of people in need of care, it is important to talk to colleagues from other professional groups about particular residents. This opens up new perspectives" (G12).

[32] Note that in this case, participant statements could also be attributed to the principle of nonmaleficence.

Justice

As depicted in **Table C3** (see Appendix C3), participants identified *nondiscrimination* and, more particularly, *distributive justice*, i.e., the fair allocation of resources, as focal concepts of *justice* in everyday nursing practice. These concepts also fit well into the broad definition of *justice* proposed by Beauchamp and Childress (2019).

Several participants argued that their concept of *justice* prohibits treating people differently due to characteristics such as "their religion or the color of their skin" (G6). Many participants emphasized the relevance of a fair allocation of time and attention to care recipients, presumably due to the frequent scarcity of nursing staff, demanding that health professionals set priorities. However, the participants held different views on what constitutes a *fair* distribution of these resources. While some reasoned that nurses "... shouldn't concentrate on an individual patient because [they] might get the impression that he or she needs [them] more than other patients" (G4) (i.e., the *equality principle*), others articulated the view that the allocation of resources should be based on individual needs for basic care and/or social support (i.e., the *need principle*).

Additionally, several participants mentioned that the realization of these concepts is not always achievable in (professional) everyday life. An obstacle to the realization of the first concept is seen in that some care recipients may be more "visible" than others. An idiosyncratic issue with allocating resources on a strictly needs-oriented approach is considered to be the fact that care recipients' ability to articulate their needs may be limited due to cognitive and/or communicative impairments.

4.3.5.2 Expected Influence of AI Technology on the Actualization of the Principles

Participant statements relating to their expectations regarding the actualization of the principles of *beneficence*, *respect for autonomy* and *justice* in the context of AI-assisted decision-making are categorized below into identified risks and opportunities (see also Appendices C4–C6).

Identified Risks

Participant-identified risks regarding the use of AI-assisted technology frequently relate to the principle of *beneficence* and, in particular, associated aspects concerning the nurse-patient relationship. Many participants were concerned that the adoption of such

technologies could compromise the promotion of emotional well-being, which is one of the core aims of beneficence. For instance, one participant reasoned that "...the use of the device could lead to patients feeling that the nurse only looks at the screen and no longer talks to them" (G12).

The participants highlighted that the use of AI-assisted technology may negatively impact demands related to the recognition of care recipients' individual needs (i.e., *recognizing needs*). Risks identified in this context mostly addressed nurses' empathy for and awareness of the vulnerability of persons in need of care, both for care recipients in general and for care recipients with impaired communicative abilities; e.g., "[with this technology,] I think the nurse would no longer be as aware of what the person in need of care is expressing in a nonverbal manner" (G7). Similarly, some participants expressed the fear that AI assistance could discourage nurses from exploring care recipients' motives, such as in the event that a care recipient refused certain care procedures; e.g., "...when using such technology, nursing professionals ... would tend to reflect less. They would spend less time thinking about what the other person wants" (G9). Moreover, care recipients expressed concern that the use of AI technology would disrupt interpersonal communication with nurses, as nurses might be preoccupied with operating the technology; e.g., "from my point of view, it is more personal and much more pleasant to talk to a nurse who is not simultaneously busy using such technology" (R5).

Mainly with regard to tasks in the context of social care and organization of workflows, individual participants articulated the worry that AI-based decision-support could impair the willingness of nurses to take responsibility for patients' well-being (i.e., *assuming responsibility*). One participant stated, "I think [the nurse] feels validated when using the technology and questions less whether a decision is appropriate" (G10). Relatedly, participants assumed that nurses' experiential knowledge would decrease as a consequence of regularly using such technology. While they reasoned that such may be suitable for providing orientation and confidence in (time) critical situations, they likewise expressed the view that the ability to weigh and balance risks and opportunities could gradually decrease; e.g., "I see a disadvantage in that you would probably tend to think less independently and instead follow standard procedures" (G15). One care recipient, moreover, raised the concern that particularly inexperienced nurses may no longer learn to independently weigh possible consequences of decisions in situations with moral

implications; e.g., “I believe it depends on how long a nurse has been in the profession. A person who hasn’t been doing it for very long would certainly be highly influenced by the decision support [of AI technology]. Will that person ever be capable of making such decisions on his or her own?” (R5).

In the context of basic care, participants were also concerned with possible influences on patients’ *autonomy*. As shown in the section *Respect for Autonomy*, many participants perceived that both *relational* and *individual autonomy* could be improved by communication. Relatedly, some individuals expressed discomfort about the possibility that information asymmetries and dependencies would increase if nurses “...don’t engage in negotiation with the resident as much” (G1). One nurse explained, “Nurses are in a position of power over people in need of care. In uncertain situations, they enforce what they think is right. I think this disparity could become even greater [with such technology]” (G9).

Finally, several participants noted that the introduction of AI technology could negatively impact the objective of considering individual (subjective) needs when allocating resources (i.e., *need principle*, see the section *Justice*); e.g., “Since the system is fed by data, [I assume that] in case of doubt, it would recommend caring for the higher number of care recipients regardless of the individual feelings of those in need of care. Very pragmatic” (G12). This perception that in situations involving aspects of distributive justice, the individual situation of those in need of care might disappear from view aside from measurable data, is closely related to identified risks relating to *beneficence*. One person stated that “...such a decision must always be made after weighing all the individual points that play a role in a given situation. ...a computer can’t grasp how someone feels inside” (G3).

Identified Opportunities

In addition to possible risks, the interviewed nurses and care recipients also identified several opportunities arising from the use of AI-assisted technology. Again, considerations primarily focused on *beneficence*. In particular, with regard to basic care tasks participants reasoned that the use of such technology could prevent physical harm. Many participants assumed a positive influence of AI assistance on the empirical basis of decisions made under uncertainty; e.g., “such applications would certainly provide added

value not just by shortening the decision-making process but also, I think, above all ensuring that decisions are more empirically sound" (G12).

While several participants were concerned that the ability to weigh benefits and risks associated with different caring actions could decrease with regular use of AI technology (see the section *Identified Risks),* some also expressed the hope that the expanded information base would provide assurance and guidance to inexperienced nurses in (time-sensitive) critical situations; e.g., "...I think in situations in which it is important to act quickly, a system like this could be very helpful for new colleagues. Because you really, yes, sometimes you don't know what to do for a moment" (G10). Some participants further assumed that this decision-support could motivate nurses to reconsider their intuitions; e.g., "in order to reflect on your own intuition, I think such a system is actually quite useful. At least, if the various aspects that are important in certain situations are highlighted" (G6).

In addition to the potential support of AI technology in situations requiring nurses to weigh their options to prevent (physical) harm (a key aspect of *assuming responsibility*), one care recipient envisioned that this technology could support a holistic assessment of patients' needs in the first place; e.g., "nurses are different. Some make little effort to recognize what is going on in a person in need of care. ...such technology could, perhaps, identify more precisely where the shoe pinches" (R3).

In the context of social and basic care, several participants identified a further opportunity arising from the expanded information base associated with AI-assisted technology: "I think such technology could provide reassurance to some residents because they can get additional information, sort of like a second opinion" (G13). The participants reasoned that, in this manner, AI technology could promote care recipients' ability to make informed choices and improve their perceived self-determination (i.e., *individual autonomy*); e.g., "It would be good if there was a bit more transparency in the interaction between the nursing staff and the residents. With such technology, some residents would probably be more likely to be convinced because they would see that the information referred to was not made up but documented" (G13).

Another positive aspect mentioned by participants was a potential benefit regarding a fair(er) distribution of resources. Referring to tasks related to organizing workflows, participants noted that the adoption of AI technology may provide a more objective basis

for workflow prioritization (when the technology is informed by patient needs); e.g., "such systems can have a positive effect. Because with them, I think, you are less driven by emotions but more objective, that is, really guided to what is needed" (G5). Relatedly, participants expressed the hope that, depending on the system design, the technology could strengthen the concept of *nondiscrimination* (see the section *Justice*); in other words, that resources could be distributed independently of the visibility of individual care recipients and instead guided by their need for care.

Overall, participants mainly perceived advantages in the adoption of AI technology for expanding and increasing the objectivity of nursing professionals' (information) bases for clinical decision-making.

4.3.6 Discussion

To complement ethical principles considered relevant for the design of AI-assisted technology in health care with a context-specific conceptualization of the principles of individuals potentially affected by the implementation of AI-assisted technology, we first investigated stakeholders' contextualized perspectives on three principles: *beneficence*, *respect for autonomy* and *justice* (Q1 and Q2). Building upon this analysis, we investigated participant expectations regarding the actualization of their concepts of the principles in the context of AI-assisted decision-making. Thus, we provided initial indications regarding which principles ought to receive particular attention when designing AI technologies for nursing care.

Our analysis of participant reasoning in situations involving moral decision-making that occur in everyday nursing practice indicates that nurse and care recipient perspectives are largely compatible with the principles of *beneficence*, *respect for autonomy* and *justice*. Thus, these three *principles of biomedical ethics* are applicable to the field of nursing care and are a suitable launching point to explain and categorize nurse and care recipient beliefs and reasoning in situations involving moral decision-making in the fields of basic care, social care and organization of workflows (Q1).

Moreover, these results demonstrate that a qualitative analysis of stakeholder reflections on ethical principles based on scenarios depicting care tasks associated with moral decision-making (Q2) provide a more nuanced understanding (i.e., context-specific

conceptualization) of the principles as well as their actualization through situational factors and, in particular, demands.

The results confirm that the principles' definitions need to be specified for as well as adapted to care-specific requirements. Participant concepts of *beneficence* were largely consistent with the definition of Beauchamp and Childress (2019); particularly, participants highlighted the demands to recognize care recipients' needs and to assume responsibility for the identified needs. With regard to *respect for autonomy*, many participants noted that autonomy may require that care recipients' are free from controlling influences and/or that (capacities for) autonomous choice are promoted (ibid., p. 105) (the concept of *individual autonomy*). Other participants argued though that patient autonomy can also be ensured by preserving a person's sense of identity as well as utilizing *shared* decision-making (the concept of *relational autonomy*). Caregiver and care recipient concepts of *justice* were, again, broadly in line with the definition of Beauchamp and Childress. Many participants referred to "the obligation to fairly distribute benefits, risks and costs under conditions of scarce resources" (ibid., pp. 13, 250). Our analysis additionally suggests that the participants hold different views on what constitutes a *fair* distribution. While some advocated an equal allocation of resources to each care recipient (the *equality principle*), others argued for an allocation of resources based on individual needs for basic care and/or social support (the *need principle*).

Hence, our analysis indicates that a stakeholder-oriented specification of the principles allows for, or even requires, integration of specific theories of health care and nursing. Notably, statements relating to demands perceived as critical to the actualization of *beneficence* closely corresponded to Tronto's assumption that beneficence care should be regarded as a dynamic process and, in particular, assessed along different phases (Tronto, 1993). Moreover, participant concepts of *respect for autonomy* referring to it as a relational process closely relate to feminist reconceptualizations of autonomy (e.g., Donchin, 2001; Stoljar, 2011). Such accounts highlight the importance of interpersonal or social conditions and a person's sense of identity for the realization of autonomy, which therefore contrast with an individualistic interpretation of autonomy.

With regard to Q3, our analysis showed that the participants anticipated risks as well as opportunities relating to the actualization of their concepts of all three principles, and especially their concepts of *beneficence*, in the context of AI-assisted decision-

making. In particular, care recipients reasoned that the use of AI-assisted technology could disrupt interpersonal relations as well as communication (the concept of *recognizing needs*) (Rubeis, 2020). Both groups assumed that there would be a negative impact on nurses' experiential knowledge (the concept of *assuming responsibility*) (ibid.) and that the technology could discourage nurses from exploring care recipients' motives. On the other hand, participants envisioned that such technology, particularly with regard to basic care tasks, could prevent physical harm, e.g., by providing evidence-based health information for decision-making in uncertain conditions (Morley et al., 2020) and by motivating nurses to reconsider their intuitions (the concept of *assuming responsibility*).

Possible influences on the realization of *respect for autonomy* mainly included two aspects: On the one hand, an increase in information asymmetry is considered to reduce care recipient autonomy, but, on the other hand, increases in information to promote care recipients' ability to make informed decisions, thereby strengthening their autonomy (the concept of *individual autonomy*). Moreover, participants expected that adopting AI technology in tasks related to organizing workflows could negatively impact the consideration of individual (subjective) needs when distributing resources (the *need principle*); however, adoption of this technology may improve the distribution of resources independent of the visibility of individual care recipients (the concept of *nondiscrimination*).

In conclusion, our study generated prospective understanding of how AI-assisted technologies might modify social structures and practices as well as existing asymmetries within care contexts. Participants reasoned that such technologies may improve and augment nurse abilities, assist in the identification of novel solutions to well-known problems such as discrimination, and help to coordinate complexity (e.g., within tasks that demand situational weighing). However, at the same time, participants warned that AI technology carries the inherent risk of unintended side effects, such as an objectification and rationalization of the nurse–care recipient relationship.

Implications for Future Research

The study results underscore the importance of a context-specific conceptualization of ethical principles relevant for AI-assisted decision-making to address the current epistemic uncertainty regarding the risks and opportunities associated with the

(non)fulfillment of ethical principles. Moreover, existing guidelines not only appear too vague to guide the design of technologies based on ethical principles but they are also blind to stakeholders' individual needs and interests. To ensure that ethical guidelines for AI assistance are sensitive to the interests and needs of stakeholders, AI technology guidelines should be determined within specific contexts. Linked to this, we recommend also future studies to consider both nurse and care recipient perspectives when generating bottom-up knowledge regarding the actualization of ethical principles in the context of AI-assisted decision-making. While considering ethical requirements within situations involving moral decision-making falls within the responsibility of nurses, their fulfillment also needs to be assessed by care recipients.

In addition, future studies might need to assess in greater detail how the implementation of AI-assisted technology may alter nurse tasks and impact their perceived moral coercion. The use of digital care services can be associated with moral distress (e.g., Frennert, 2020), i.e., the experience of not being able to act according to personal and professional values (Morley et al., 2019), frequently reported by nurses (Oh & Gastmans, 2015). However, to date, no studies have focused on the influences of AI-based systems.

Our study, moreover, suggests that the ethical principles of *beneficence*, *respect for autonomy* and *justice* provide suitable guidance for the development of care-specific indicators that can help to align AI-assisted technologies (in the field of nursing) with stakeholders' moral interests. To specify such indications with regard to more concrete design considerations for AI systems and according relevant instrumental principles (such as *explicability* (Floridi et al., 2018)), a prerequisite is to integrate interdisciplinary and transdisciplinary perspectives (e.g., from the social sciences, computer science and occupational sciences) to provide a (rich)er understanding of the co-construction of technological and social phenomena (see also, e.g., Beimborn et al., 2016; Goirand et al., 2021). In addition, the specification of the ethical assessment of using AI-assisted technologies for care (e.g., by methods from the field of technology assessment (Grunwald, 2019) requires broader knowledge of the technological possibilities of specific AI-assisted applications.

Further research is also needed to determine if stakeholders' reflections on moral decision-making situations associated with different bioethical principles (such as *integrity*, *autonomy*, *vulnerability* or *dignity*, as proposed by Rendtoff (2002) or Häyry

(2003) as specific European principles) can broaden the set of ethical principles considered relevant for the design of AI. Similarly, different analytic methods such as the grounded theory may help to identify further ethical principles relevant for the design of AI-assisted technology in nursing care.

Ultimately, it may be necessary to develop innovative system design approaches that enable the integration of ethical principles during an iterative process throughout technologies' entire lifecycle. Traditional engineering processes and current risk analysis methods do not allow a continuous assessment of possible risks, i.e., there is no open feedback loop between operators and system designers. As many algorithms underlying AI technologies are able to adapt to their environment (and given the black-box nature of frequently applied deep learning models), it would be useful if information on the extent to which technologies already in use affect social structures were available during the design process (Schlicht et al., 2021).

Study Limitations

The results of this study must be interpreted in light of some limitations. First, while there is ample reason to *prospectively* deliberate on the potential consequences of emerging technologies, individuals who are unfamiliar with such technologies may have a limited understanding of the technologies' abilities and their impacts on everyday (professional) life. In our study, this is particularly likely in the care-recipient group. Second, although our scenarios were designed to be comparable to real-life situations, the addition of different context-specific information could result in different principle-related statements. Third, we decided not to include a scenario prompting reflection on the principle of *nonmaleficence* because we aimed to respond to the (potential) vulnerability of participants in the care-recipient group. However, future studies could explore nurses' moral reasoning regarding *nonmaleficence*.

4.3.7 Conclusion

AI-assisted technologies may exert a profound impact on social structures and practices in health care contexts. Our study helped to translate ethical principles considered relevant for the design of AI-assisted technology in health care into practice. In particular, our analysis provides a context-specific conceptualization as well as adaptation of the well-established *biomedical principles* in the context of long-term care and, building upon this,

generates bottom-up knowledge regarding the actualization of the ethical principles in AI-assisted decision-making in care contexts. Thus, we provided initial indications regarding which concepts of the investigated ethical principles ought to receive extra attention when designing AI technologies to ensure that these technologies are not blind to the moral interests of stakeholders in the care sector.

4.4 AI-Assisted Work Systems in Healthcare: Insights from Multistakeholder Dialogues on Their Human-Centered Design

Larissa Schlicht*

Abstract

Artificial intelligence (AI)-assisted technologies, such as decision support and patient monitoring systems, hold the potential to significantly improve the efficiency and quality of care. However, given the impact that such technologies may also have on the working conditions and moral agency of healthcare personnel, it is imperative – from an occupational safety and health perspective – for these systems to be designed from the outset with a focus on employees' well-being as well as ethical considerations. While existing guidelines and regulatory frameworks, such as the EU's AI Act, are intended to promote AI tools being designed in a socially beneficial manner, they often lack means of facilitating the sustainable integration of these criteria into risk assessment and compliance processes. This article presents the methodology behind and findings from two multistakeholder dialogues based on a participatory technology assessment framework that explored pathways for the human-centered development of AI-assisted healthcare technologies.

4.4.1 Introduction

Imagine the following scenario[33]: *A university hospital adopts an artificial intelligence (AI)-assisted documentation system that integrates speech recognition and clinical decision support to reduce the administrative burden and free up time for patient care. The system allows staff to dictate patient data, which is then transcribed and analyzed to generate treatment recommendations. To support work-integrated learning, the system provides explanatory feedback when care deviates from established guidelines. Initially seen as helpful, the system increasingly flags deviations, having learned that stricter feedback improves adherence. As a result, caregivers' responsiveness to individual patients' needs declines, with decision-making shifting from context-specific relational care to protocol adherence. Nurses report declining job control and growing moral distress, both of which contribute to greater psychological strain and job dissatisfaction.*

The situation described above is fictional but illustrates plausible occupational and ethical risks that may arise when AI tools are implemented to support healthcare personnel without having been designed in a manner that adequately considers human-centered design (HCD) criteria. Indeed, HCD criteria are currently not applied systematically throughout the development process of AI systems, raising concerns that the use of such technologies could weaken the relational and moral dimensions of healthcare by, for example, encouraging a shift from patient-centered care practices toward standardized interactions.

Healthcare has become a key sector for the advancement and integration of AI (OECD, 2019a). AI-driven tools, including diagnostic, monitoring, and workflow optimization systems, are increasingly being integrated into clinical practice. Their implementation is intended to assist healthcare professionals (e.g., physicians, psychotherapists, physiotherapists, nurses) by automating routine tasks, enhancing diagnostic accuracy, streamlining treatment procedures, and enabling more personalized approaches to patient care (Sharma et al., 2022; Yakusheva et al., 2025). AI systems are also expected to carry the potential to positively influence healthcare professionals' job demands and health outcomes (Boone et al., 2024). At the same time, they may fundamentally reshape established work practices. While the healthcare sector is generally

[33] This scenario is reproduced from the main text of the author's dissertation.

regarded as less amenable to automation, given that it is highly dependent on contextual information, AI integration may nonetheless impact a wide range of clinical practices, including those that are integral to patient-centered care. In a domain where the "work objects" are often human beings in vulnerable circumstances, such shifts in task allocation from humans to machines require careful consideration (Archibald & Barnard, 2018; Morley et al., 2020). For instance, AI-based pain assessment tools can aid clinicians in interpreting patients' physical or emotional states via biomedical data (Yelne et al., 2023), but they may potentially also undermine the holistic approach to care that is fundamental to ethically responsible healthcare (Rogers et al., 2021).

Against this backdrop, this article addresses the following research question: *What strategies and instruments can facilitate the sustainable integration of HCD criteria into the development of AI systems in healthcare?* To answer this, the article first outlines key challenges in integrating HCD criteria into AI development processes. It then introduces *participatory technology assessment* (pTA) as a methodological approach capable of addressing these challenges. Finally, the article presents the methodology behind and findings from two multistakeholder dialogues, identifying concrete pathways toward human-centered AI development in healthcare.

4.4.2 Current Challenges in Integrating HCD Criteria into the Design of AI-Assisted Healthcare Systems

While there is a growing consensus regarding the importance of considering occupational and ethical criteria during the design of AI systems, the practical incorporation of these criteria remains sporadic and limited (Tidjon & Khomh, 2022; Vakkuri et al., 2020). Numerous frameworks, including international guidelines (Corrêa et al., 2023) as well as regulatory instruments (e.g., the EU Artificial Intelligence Act (Regulation (EU) 2024/1689)) and standards (e.g., IEEE, 2021; ISO/IEC, 2022, 2023a), underscore the importance of incorporating HCD criteria into AI system design. However, it remains largely uncertain what specific approaches could support the effective consideration of such non-technical design requirements – especially in complex sociotechnical domains like healthcare (WHO, 2023).

Prominently, a central difficulty here lies in the typically generalized formulation of HCD criteria, which limits their applicability in concrete design and risk assessment

processes (Sanderson et al., 2023). Another challenge stems from the *adaptive nature of many AI systems*, further complicating the criteria's translation into practical technology development processes. As illustrated in the hypothetical scenario presented above, AI algorithms may evolve in response to dynamic data environments and user interactions, making it difficult – if not impossible – to fully anticipate the risks associated with their deployment during technology design. However, traditional risk management methodologies typically lack iterative mechanisms for the *continuous* assessment and mitigation of emerging risks. In other words, they do not systematically incorporate observations of risks encountered in deployment contexts back into ongoing design and refinement processes (Seidel et al., 2021). As a result, within the scope of conventional methodologies, HCD criteria risk being rendered ineffective by the dynamic and context-specific challenges posed by adaptive AI systems.

In response to these limitations, the AI Act stipulates mandatory ongoing risk management processes to identify and minimize emerging risks – at least for AI systems classified as high-risk, such as patient triage systems and emotion-recognition technologies (Recital 65, Article 9, European Parliament & Council of the European Union, 2024).[34] However, there is still a need to identify effective intervention points throughout the AI lifecycle that could verify the consideration of HCD criteria (Ortega-Bolaños et al., 2024; Prem, 2023). In addition, despite the AI Act implicitly promoting human-centered work design, it falls short of explicitly mandating such design criteria. However, emerging regulatory approaches present an opportunity to integrate internationally established *criteria for human-centered work design* at the earliest AI lifecycle phases.

4.4.3 Participatory Technology Assessment as a Methodological Framework

The integration of HCD criteria, such as *respect for autonomy* and *work-integrated learning* (Beauchamp & Childress, 2019; Ulich, 2011), into verifiable measures that can be implemented and assessed throughout the development and implementation of AI systems faces distinct challenges. While existing risk assessment and mitigation strategies

[34] In parallel, several standardization organizations have developed technical frameworks aimed at promoting a lifecycle-oriented approach to AI risk management (e.g., DIN, 2019; IEEE, 2021; ISO/IEC, 2022, 2023a, 2023b).

for technology development largely rely on quantifiable parameters, HCD criteria are difficult to express quantitatively (Poszler et al., 2024). Accordingly, there are to date only limited standardized procedures for evaluating the extent to which “soft” criteria are considered to an effective degree during (re-)design processes. Moreover, the consideration of specifically ethical criteria requires risk management procedures capable of considering the specific needs of individuals affected by AI systems (Mittelstadt, 2019). Against this backdrop, it is clear that the integration of HCD criteria into verifiable measures cannot rely solely on technical expertise; properly considering these criteria requires multidisciplinary expert knowledge from various disciplines, including human-computer interaction, occupational psychology, and applied technology ethics (Schmager et al., 2025).

PTA offers a particularly suitable framework for informing the development of approaches that consider HCD criteria – as well as their inherent sociotechnical complexities – to an effective degree in technology (re-)design processes. By engaging experts across multiple disciplines as well as direct stakeholders, pTA enables the use of contextual insights to enhance the accuracy of risk assessment and mitigation efforts (Grobe, 2021; Grunwald, 2019). Importantly, the pTA format employed in the multistakeholder dialogues was designed to create a reflective space in which diverse perspectives could be articulated, negotiated, and constructively engaged, thereby fostering co-learning, knowledge integration, and the joint development of various actionable strategies and instruments.

4.4.4 Procedure

To identify strategies for systematically assessing and mitigating the occupational and ethical risks presented by AI systems in the healthcare sector, we conducted two multistakeholder dialogues in March and May 2024.[35] The dialogues were carried out as part of the research project *F2574: KI-basierte Systeme im Gesundheitswesen – Werkstattgespräche zur Entwicklung eines multidisziplinären und gemeinwohlorientierten Gestaltungsansatzes aus Perspektive des Arbeitsschutzes* of the Federal Institute for Occupational Health and Safety (BAuA, n.d.).

[35] A two-day format was employed for each dialogue to facilitate comprehensive exchange and iterative reflection.

Participants were selected through a targeted recruitment process to ensure the representation of a diverse array of stakeholder groups, disciplines, and institutional affiliations, supported by snowball sampling through existing professional networks. The final group of 25 participants included, among others, researchers (in the fields of applied machine learning, digital health engineering, occupational psychology, technology ethics, nursing science, technology assessment, and technology governance), policy officers from ministries and regulatory agencies, representatives of employer and employee organizations, specialists from statutory health insurance, and managers from companies in the fields of nursing software and digital healthcare consulting (see **Table 7**).

Table 7

Overview of stakeholder groups and participants' roles and affiliations

Stakeholder group	Roles	Institutions
Research and academia	Researchers (e.g., professors, senior scientists)	Federal Institute for Occupational Safety and Health; Fraunhofer HHI; Fraunhofer IESE; IFA – Institute for Occupational Safety and Health of the DGUV; Karlsruhe Institute of Technology; OTH Regensburg; TU Dresden; University of Osnabrück; University of Tübingen; WZB – Berlin Social Science Center
Policy and public administration	Policy officers/advisors	Federal Ministry of Health; Federal Network Agency; Saxon State Chancellery
Professional associations and social partners	Representatives of employer/employee organizations, policy officers	BGW – Social Accident Insurance for Health and Welfare Services; German Hospital Federation; ver.di – United Services Trade Union
Health insurance organizations	Policy specialists	AOK Federal Association
Industry and consulting	General managers	Companies providing nursing software and digital healthcare consulting

The *first dialogue* was structured around the following question: "At which phases of the AI lifecycle should action be taken to ensure the human-centered design of AI systems in healthcare?" Following a brief introduction of the project's objectives, participants collaboratively mapped existing and emerging AI applications in healthcare, reflecting on their technical functionalities, anticipated implications for work processes, and ethical dynamics. Participants were subsequently introduced to a set of HCD criteria based on (i) established *criteria for human-centered work design* aimed at promoting personality development, health maintenance, and employee performance (e.g., ISO, 2016, 2019b, 2024), and (ii) the *principles of biomedical ethics* (Beauchamp & Childress, 2019),

a widely recognized framework for ethical assessment within healthcare domains. The latter criteria also constitute the normative foundation of the High-Level Expert Group on AI's "Ethics Guidelines for Trustworthy AI" (AI HLEG, 2019), a central reference point for ethical AI design under the AI Act. Using select examples of AI systems, participants explored how these criteria can be sustainably applied across the different stages of the AI lifecycle (i.e., from the specification of requirements to the operational monitoring).

In small-group follow-up sessions, the initial insights were deepened and specified using structured digital collaboration formats. The *second dialogue*, building directly on the results of the first session, was guided by the following question: "What are particularly promising strategies, and how can they be implemented?" Drawing on key intervention points identified via finger voting, participants developed both individual and collective strategies for integrating HCD criteria into occupational health and safety assessments and broader AI-governance mechanisms. Through iterative reflection formats, such as world cafés and listening circles, they then focused on implementation planning, clarifying necessary actions and responsible actors. All outcomes were recorded using Metaplan boards.

4.4.5 Results from Multistakeholder Dialogues

Participants developed a broad range of proposals for means of advancing human-centered AI risk management processes in healthcare settings. A central recommendation was the establishment of iterative feedback loops between AI system providers and developers – including for systems not classified as high-risk. The participants emphasized that such iterative risk management processes are closely linked to the twofold requirement to enhance transparency in system design and functioning and to ensure that system characteristics are communicated in an accessible manner for a wide range of stakeholders. On a similar note, special attention was paid to the post-deployment phase, where continuous monitoring and adaptive feedback mechanisms were considered to be essential to address emerging risks. The inclusion of both user and affected stakeholder perspectives was recognized as particularly important in this regard. As part of ongoing collaboration, the participants eventually also began to develop concrete instruments and other intervention points. The key insights – alongside the associated follow-up activities – are summarized in **Table 8**.

Table 8

Summary of key insights from the multistakeholder dialogues

Key insights	Follow-up activities (e.g.)
Iterative feedback loops between AI system providers and developers – critical to managing the evolving risks associated with adaptive systems – require explainable AI systems.	Collaborative publication by Gilbert et al. (2025) on the development of standardized model cards for healthcare AI applications, which detail aspects such as intended use, target patient populations, functionalities, and known risks, to enhance transparency (as with pharmaceutical leaflets). The authors advocate for layered, verifiable information to prevent misleading claims. Additionally, they highlight the importance of integrating model cards with existing regulatory frameworks and ensuring that they are user-friendly for various stakeholders, including patients and healthcare providers.
Developers should use iterative prototyping methodologies that allow for ongoing adjustments and include real-time auditability and feedback mechanisms that enable, i.a., healthcare professionals to report adverse events and suggest improvements.	Collaborative publication by Schönfelder et al. (2025) on a framework for the development of in-house AI systems in hospital settings through multi-stakeholder collaboration. By identifying key stakeholders, outlining their respective contributions, and highlighting professional strategies with which to build consensus, the proposed framework aims to ensure that potential barriers to aligning AI systems with HCD criteria are acknowledged early and addressed through joint problem-solving.
	Development of a checklist to assess the impact of AI technology on workplace stressors and resources in healthcare settings, intended for use in psychological risk assessments (currently under development).
	Initiation of a conference on ethical evaluation tools for AI with a focus on the suitability of existing instruments, such as MEESTAR (Weber, 2015), and adaptability to AI-specific challenges.
Ongoing exchange on AI regulation among stakeholders is essential to the proactive contribution of design perspectives and practical expertise, particularly in the upcoming process of translating the EU AI Act into national law.	Initiation of a regular exchange format on AI regulation to promote ongoing dialogue, knowledge sharing, and proactive stakeholder engagement.
To ensure alignment between technical capabilities and existing workflows and job demands, it is essential to involve direct stakeholders early and consistently in the AI design process.	Initiation of roundtable discussions with healthcare professionals (e.g., nurses, physicians) to identify their needs and requirements early in the design process, thereby supporting the development of AI systems that are adapted to specific healthcare contexts.

4.4.6 Conclusion

The results of these multistakeholder dialogues underscore the value offered by participatory frameworks like pTA in developing effective strategies for human-centered AI design in healthcare. While involving diverse stakeholders is a complex and resource-intensive task, it proved to be highly beneficial in our workshops. The discourse among technical, social science, regulatory, and practice-oriented perspectives facilitated the development of various integrative pathways through which to embed work-related and ethical considerations into AI design – all in a manner tailored to the specific requirements of the healthcare sector. Through the follow-up activities, the participants began to collaboratively develop solutions, including measures to improve system transparency and comprehensibility, iterative prototyping methodologies, and checklists for psychological risk assessments. Moreover, further exchange formats were initiated, including with potential users of AI systems in healthcare, to promote ongoing dialogue and knowledge sharing.

However, the developed tools have not yet been empirically tested in real-world development or deployment scenarios. Their practical viability and overall effectiveness therefore remain uncertain, particularly with regard to the organizational, technical, and ethical challenges that may arise in applied settings. Moreover, future initiatives should investigate how context-sensitive, participatory frameworks for risk management can be scaled and institutionalized more broadly, including with a view to the national rollout of the EU AI Act. Ultimately, establishing such locally grounded risk management mechanisms will become increasingly critical as multi-agent AI systems (Moritz et al., 2025), often incorporating large language models (e.g., GPT-4, Gemini), are more frequently used for tasks like administrative support and patient interaction. Given the wide range of potential applications of such systems, there is a growing need for adaptive, iterative governance mechanisms – ideally developed in close collaboration with relevant stakeholders – that can flexibly address emerging occupational and ethical risks across shifting usage contexts in the healthcare sector.

5 Concluding Discussion

In recent years, considerable discourse has emerged – both in the fields of computer science, the social sciences, and philosophy and within society at large – concerning the human-centered design of AI systems, particularly those employed in sectors with moral implications, such as healthcare. Despite the widespread consensus on the need to align AI systems with the distinct sociotechnical environments in which they are deployed, there is still a lack of concrete strategies and instruments with which to operationalize and sustainably embed corresponding design criteria throughout the entire lifecycle of such systems. The central aim of this thesis has been to contribute to ongoing efforts to sustainably integrate HCD criteria (i.e., ethical design criteria and criteria for human-centered work design) into the development of AI systems by shifting the focus away from dominant top-down governance approaches and towards context-sensitive design procedures. More specifically, its objective was twofold: (i) determine which specific prerequisites exist for the development of measures for the human-centered design of AI-assisted work systems in the healthcare sector, and (ii) to propose exemplary pathways (i.e., strategies and instruments) toward the effective integration of normative design requirements throughout AI tools' lifecycles. To this dual end, four pieces of research were conducted.[36]

5.1 Summary of Findings

The four research papers included in this doctoral thesis collectively generate context-sensitive empirical insights and strategies for the (further) development of design approaches that foreground the situated experiences and ethical concerns of stakeholders within the healthcare sector. *Paper 1*, "Digital technologies in nursing: An umbrella review," synthesizes the extant research on digital (and Section 4.1.6 particularly on AI-assisted) nursing technologies. In view of the mounting systemic pressures within the sector as well as the expanding integration of AI into healthcare systems, it is imperative

[36] It should be noted that the length of the papers does not indicate the significance of the topic within the doctoral thesis. Rather, it primarily results from the formal requirements of the journal to which the manuscript was submitted or in which it was published.

to investigate the influence of these technologies on occupational stressors and patient care in order to determine whether specific measures are necessary to promote human-centered technology design (WHO, 2016). The umbrella review indicates that, across all technology categories, digital technologies have mainly beneficial effects on nurses' job satisfaction, job control, and professional competence. Moreover, they have the capacity to facilitate efficient information management, standardize workflows, and perform routine tasks. However, the review identifies predominantly negative effects on nurses' mental and physical strain as well as workloads, alongside mixed effects on documentation tasks and communication/collaboration with colleagues. These identified tensions underscore the importance of systematically considering the criteria of human-centered work design when designing digital technology-assisted work systems for the healthcare sector in order to balance procedural and psychological demands and provide the necessary supportive resources. With respect to ethically relevant outcomes, robotic and telecare technologies have the most reported findings. A considerable proportion, about one-third, of the technologies associated with ethically relevant effects are AI-based. Moreover, most of the evidence pertains to criteria that are intrinsically linked to relationships and communication between caregivers and patients. Reported effects include both benefits (e.g., increase in social support) and concerns (e.g., deterioration in the quality of holistic care assessments) and, thus, underscore the importance of considering ethical design criteria. Finally, multiple included reviews underscore the pivotal role played by user-centered design in facilitating the effective integration of digital technologies. The early involvement of nurses in the technology selection process has been shown to enhance the likelihood of successful implementation, including that of AI-assisted systems. One plausible explanation is that early engagement enables the greater alignment of technological solutions with given workflows and tasks, thereby enhancing their functionality and contextual relevance (Choi et al., 2025; Ulfert et al., 2024). Overall, the review underscores that the design of digital nursing technologies is far more than a technical challenge; it necessitates a holistic approach that accounts for work processes, direct stakeholder needs, and organizational structures. Second, *Paper 2*, "An integrative and transdisciplinary approach for a human-centered design of AI-based work systems," seeks to identify unresolved prerequisites for the development of measures for the human-centered design of AI-assisted work systems. These prerequisites include, among others: (i) the context-sensitive specification of ethical criteria, and (ii) iterative risk management

processes that feature open feedback loops between the operator and the system designer, enabling a *runtime* risk assessment. The latter prerequisite encompasses processes that are reinforced by mechanisms for evaluating AI systems' impact on situated stakeholder needs and practices and that (given the adaptive nature of many AI algorithms) facilitate continuous (re-)alignment with HCD criteria.

Building on these findings, this thesis features perspectives from patients, nurses, domain specialists (e.g., from the fields of occupational psychology, applied ethics, and informatics), and policymakers to inform the development of risk management approaches that contribute to overcoming the previously identified barriers. *Paper 3*, "A context-specific analysis of ethical principles relevant for AI-assisted decision-making in health care," initially demonstrates that qualitative analyses of stakeholder reflections grounded in scenario-based depictions of morally sensitive care tasks may provide a more differentiated and context-sensitive conceptualization of ethical criteria. The paper further underscores that existing guidelines are typically not only too vague to inform the design of ethically aligned healthcare technologies but also blind to stakeholders' individual needs and perspectives. More specifically, it suggests that a stakeholder-oriented specification of the three principles of biomedical ethics – *beneficence*, *respect for autonomy* and *justice* – permits the integration of care-specific theories of healthcare and nursing. For instance, participants asserted that *respect for autonomy* should not be understood solely in terms of freedom from external control or the promotion of decision-making capacities (i.e., *individual autonomy*), as traditionally conceptualized, but also in terms of preserving one's sense of identity and facilitating shared decision-making (i.e., *relational autonomy*). These relational interpretations align closely with reconceptualizations of autonomy from the domains of *care ethics* and *relational bioethics* (e.g., Donchin, 2001; Stoljar, 2011). The paper thus offers initial empirical insights into what aspects of the examined ethical criteria merit particular attention in the design of AI-assisted healthcare technologies, to ensure that these criteria are responsive to the moral concerns of direct stakeholders within (German) care facilities.

To enable the sustainable integration of ethical criteria and criteria for human-centered work design into technology development – and to ensure their *continuous* alignment with evolving contextual requirements – there is, moreover, a need for approaches that facilitate the iterative refinement of normative design measures (Awad et

al., 2022; Goirand et al., 2021). Against this backdrop, *Paper 4*, "AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design," details the methodological design and key findings of two multistakeholder dialogues conducted within a participatory technology assessment framework, aimed at investigating strategies and instruments capable of enabling the sustainable integration of HCD criteria into verifiable measures throughout the development and implementation of AI systems in healthcare. A diverse array of stakeholder groups (from various disciplines and institutional affiliations) collaboratively developed a set of proposals tailored specifically to the needs of the healthcare sector. Their central recommendation was to establish iterative feedback loops between AI system providers and developers, including in cases where the AI tools are not classified as "high-risk" under the AI Act. Crucially, participants stressed that such iterative risk management processes presuppose a dual imperative: (i) to ensure transparency in system design and functioning; and (ii) ensure that system characteristics are communicated in an accessible manner for a wide range of stakeholders, including users. In similar vein, the participants emphasized the post-deployment phase, deeming ongoing monitoring and adaptive feedback mechanisms – which serve to capture perspectives from affected stakeholders – to be indispensable when it comes to addressing emergent risks. Moreover, as part of ongoing collaborative efforts, the participants have begun to develop instruments based on the identified strategies. These include measures to enhance system transparency and explainability, such as standardized "model cards" for AI applications in healthcare that – like pharmaceutical leaflets – detail tools' intended uses, target patient groups, core functionalities, and known limitations or risks (Gilbert et al., 2025). Concurrently, efforts have been made to support prototyping methodologies that allow for continuous adjustments and feature real-time auditability and feedback mechanisms that enable, i.a., healthcare professionals to report adverse events and suggest improvements. Examples include the construction of a framework for the co-development of in-house AI systems in hospital settings through multistakeholder collaboration – ensuring that potential barriers to aligning AI systems with HCD criteria are acknowledged early and addressed through joint problem-solving (Schönfelder et al., 2025) – and the adaptation of psychological risk assessment checklists and existing ethical evaluation tools (such as MEESTAR; Weber, 2015) to AI-specific challenges.

5.2 Practical Implications

This doctoral dissertation's findings have several practical implications for the further development of risk management approaches for AI-assisted systems in the healthcare sector and related policy efforts. First, to tailor extant risk assessment procedures to the healthcare sector, it may be necessary to specify ethical design criteria in a conceptual manner – not only in relation to healthcare-specific requirements but also in relation to domain-specific requirements, as risks may differ substantially between domains. This dissertation has investigated the need to refine established ethical design criteria in the domain of long-term nursing care. Similar evaluation processes should be applied to other professional and institutional domains, such as that of intensive care.

In light of the call for standardized normative criteria tailored to the healthcare sector (e.g., Jacob et al., 2025), this thesis – in line with, Leijnen et al. (2020) and Lukkien et al. (2023), among others – underscores the need to ground such criteria in individual stakeholder perspectives, including those of care recipients. Their lived experiences are crucial for the generation of contextualized bottom-up understandings of normative requirements relevant in the context of AI-assisted decision-making. While stakeholder involvement may introduce complexities, such as procedural challenges associated with participant selection and the management of potentially conflicting or divergent perspectives (Snyder & Engström, 2016), normative design criteria can and should be specified through the participation of direct stakeholders to ensure alignment between technical capabilities and workplace realities. As demonstrated in this dissertation, scenario-based methods can provide a helpful approach to the elicitation and integration of these perspectives.[37]

Furthermore, to strengthen risk management processes through mechanisms that facilitate *continuous* alignment with HCD criteria, it is necessary to integrate such specified ethical criteria together with criteria for human-centered work design into "by design" approaches. The advancement of such approaches is contingent upon the

[37] Note that although scenario-based interviews can be a suitable method for eliciting stakeholders' moral perspectives in a context-sensitive fashion, they must incorporate procedural safeguards to ensure that resulting arguments remain anchored in reflective, deliberative reasoning. Absent systematic prompts that oblige participants to interrogate and substantiate their positions, the elicited responses risk resting on insufficiently examined moral intuitions or the uncritical reproduction of prevailing social norms (Knobe & Nichols, 2008; Nisbett & Wilson, 1977).

involvement of various stakeholder groups – including clinicians, patient representatives, work design experts, healthcare managers, and AI regulators – in a participatory manner during both the technology development and implementation phases (Lekadir et al., 2022; Schönfelder et al., 2025). The current fragmentation of knowledge across various stakeholder groups has been identified as an impediment to the translation of HCD criteria into concrete design and risk management processes (Grote, 2023; Ulfert et al., 2024). The multistakeholder dialogues conducted as part of this dissertation – the solutions developed therein – demonstrate the merits of a participatory TA methodology. In the context of subsequent multi-stakeholder engagement initiatives, in particular the development of a transdisciplinary terminology that facilitates the translation of HCD criteria into the terminology of engineering design may prove advantageous (Ulfert et al., 2024). Such integration has been shown to facilitate the determination of methods for translating qualitative criteria into technical system requirements (Sanderson et al., 2023). Moreover, emphasis should also be placed on the systematic incorporation of established criteria of human-centered work design into prospective approaches to AI design.

5.3 Limitations

This dissertation features four papers on the work-related and ethical risks posed by AI-assisted work systems in the healthcare sector, to-date unresolved risk management requirements, stakeholders' context-sensitive specifications of ethical design criteria, and suitable approaches for iterative design processes. Despite its manifold contributions, these papers feature certain limitations that warrant acknowledgment. Paper 1 is the first umbrella review to synthesize evidence on the association between the utilization of various digital technologies and both work-related and ethical outcomes, thereby providing a crucial reference point for prospective system design. However, the predominance of narrative reviews among the included studies precluded the aggregation of effect sizes through a meta-analysis. Consequently, the extent to which the identified risks and benefits of AI implementation may be compared across different technological categories remains limited. Future research should prioritize the generation of quantitative evidence to facilitate more comparative assessments of digital nursing technologies with respect to their impact on working conditions, safety, health, and ethics-related outcomes. Paper 2 was finalized prior to the publication of the final version of the AI Act and

therefore refers to the preliminary proposal released in 2021 (EC, 2021b). Pivotal provisions introduced in the definitive text – including stipulations for deployers of high-risk AI systems to undertake a Fundamental Rights Impact Assessment (European Parliament & Council of the European Union, 2024, Article 27) and the recommendation to implement the "Ethics Guidelines for Trustworthy AI," formulated by the AI HLEG (2019) regardless of risk classification – are not taken into account. In addition, the paper refers to regulatory requirements stemming from the Machinery Directive (European Parliament & Council of the European Union, 2006) as opposed to those originating from the Medical Device Regulation (European Parliament & Council of the European Union, 2017). Consequently, certain regulatory aspects relevant to AI systems deployed in healthcare settings may be underrepresented in the described risk management processes. Importantly, however, the identified pathways for the human-centered design of AI-assisted work systems remain unaffected by these limitations. Paper 3 investigated the context-sensitive specification of ethical design criteria through stakeholder interviews conducted in German long-term care facilities. Despite efforts to capture a diverse array of perspectives, the national scope may be indicative of culture-specific norms and regulatory frameworks, thereby limiting the transferability of the findings to healthcare environments characterized by different institutional structures or sociocultural dynamics. Finally, Paper 4 delineated strategies for the sustainable and iterative integration of HCD criteria throughout the AI lifecycle. Despite their development through interdisciplinary exchange with domain experts, they are without empirical validation in applied development or deployment contexts. Therefore, the practical feasibility and effectiveness of these methods remain uncertain, particularly when it comes to the potential organizational, technical, or ethical contingencies that may emerge in real-world settings.

5.4 Conclusion and Outlook

In light of the increasing spread of AI systems in high-stakes sociotechnical healthcare environments, the use of effective risk management approaches – those that minimize undesirable impacts and strengthen existing supportive resources while taking into account the demonstrated potential benefits of AI systems – is imperative. However, existing governance frameworks typically formulate ethical criteria at a context-independent level and, more generally, offer limited guidance for HCD criteria's

integration into risk management processes. Through four peer-reviewed research papers, this doctoral thesis contributes to the operationalization and sustainable integration of HCD criteria into verifiable measures throughout the lifecycle of AI systems in the healthcare sector. The thesis emphasizes the necessity of a shift from top-down governance approaches to context-sensitive, iterative, and participatory development processes. In order for risk-based AI governance to be effectively aligned with the realities of clinical practice – including the diversity of healthcare professionals and their respective work processes – it particularly advocates for risk management processes capable of assessing contextual impacts and enabling the iterative refinement of normative design measures. The proposed strategies and instruments serve as exemplary (potential) solutions.

Further research may be necessary to determine whether supplementary ethical criteria (such as *integrity*, *vulnerability*, or *dignity*, as proposed by Rendtoff (2002) and Häyry (2003)) could broaden the set of criteria relevant to the design of AI-assisted technology in the healthcare sector. Value-sensitive design (Friedman & Hendry, 2019; Umbrello & van de Poel, 2021) and grounded theory (Strauss & Corbin, 1990) procedures may provide suitable methodological starting points for such an endeavor. Beyond identifying additional criteria, however, future work should analyze moderating factors that influence the relative weight of each criterion across different settings, thereby enabling designers to navigate the inevitable trade-offs. Vignette experiments (Aguinis & Bradley, 2014; Rossi, 1979), which have proven to be effective in systematically investigating moderating variables in the social sciences as well as empirical bioethics (Ulrich & Ratcliffe, 2007), represent one potential method in this regard. In parallel, the application and, where necessary, adaptation of dialogue- and consensus-oriented approaches – such as the MEESTAR model (Weber, 2015), the Delphi technique (Hsu & Sandford, 2007), or social multi-criteria decision evaluation tools (e.g., Munda, 2004) – could support stakeholders and domain experts in identifying potential conflicts and weighing ethical criteria in discursive environments. It should likewise be investigated how diverse and potentially conflicting *conceptualizations* of relevant criteria can be integrated or harmonized.

Crucially, such processes should be conducted in close collaboration with healthcare employees and patients, with careful consideration given to preventing any additional burdens on the (often) already strained workforce. One promising leverage point

could be the mandated workplace risk assessments, in which identified risks are typically evaluated jointly with employees. However, it may be necessary to expand such assessments – which currently rely primarily on static checklists – with methods better suited to the often adaptive nature of AI-assisted work systems, which require *continuous* post-launch monitoring and the iterative refinement of normative design measures to ensure that they can respond to evolving contextual requirements. Beyond this, future initiatives should also investigate, at a more fundamental level, how participatory, multistakeholder approaches to risk governance can be institutionally embedded and scaled, particularly in view of the imminent domestic implementations of the EU AI Act.

In the medium term, a central question will be how co-designed risk management mechanisms may be integrated into existing regulatory frameworks without sacrificing their reflexive and adaptive potential. The concept of a *regulatory sandbox*,[38] which (under the AI Act) each EU Member State is expected to establish by August 2026, is certainly a promising instrument in this regard. Sandboxes can be used not only to test AI systems prior to market release but also to experiment with risk management measures in controlled environments. Such local risk management mechanisms appear ultimately all the more important in light of the recent emergence of *multi-agent AI systems*, i.e., systems with multiple autonomous AI agents that collaborate, communicate, and adaptively coordinate tasks to solve complex problems or optimize decision-making (Moritz et al., 2025). For example, documentation assistants could, by integrating data from electronic health records and vital parameters sources (e.g., nursing reports, laboratory results, imaging studies), automatically synthesize progress and handover documentation and generate corresponding work orders. While such multifunctional systems have enormous clinical potential, they shift risks further away from the model itself toward the contexts in which they are used, as they continually adapt their behavior based on real-time data and contextual changes. Therefore, moving forward, adaptive and iterative risk assessment processes – ideally co-developed in close collaboration with direct stakeholders – will likely be even more urgently needed to ensure that the occupational and ethical risks

[38] The AI Act defines regulatory sandboxes as follows: "[They] provide for a controlled environment that fosters innovation and facilitates the development, training, testing and validation of innovative AI systems for a limited time before their being placed on the market or put into service pursuant to a specific sandbox plan agreed between the providers or prospective providers and the competent authority. Such sandboxes may include testing in real world conditions supervised therein" (Article 57, European Parliament & Council of the European Union, 2024).

presented by AI systems are systematically assessed and mitigated, and correspondingly, to promote the human-centered design of AI-assisted work systems in healthcare.

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Appendices

Appendix A: Characterization of Considered Human-Centered Design Criteria

Table A1

Characterization of considered ethical criteria

Criteria	Characterization
Beneficence	All norms, dispositions and actions aiming to benefit or promote the well-being of other persons. However, these responsibilities typically do not result in legal consequences if they are not fulfilled.
Nonmaleficence	The obligation to refrain from actions that inflict harm on others. It is framed as a negative obligation (prohibiting specific forms of conduct) that must be followed impartially and may form the ethical basis for legal prohibitions.
Respect for autonomy	Entails a negative obligation to refrain from placing controlling limitations on autonomous actions, alongside a positive obligation to share relevant information and foster individuals' capacity for independent decision-making. Its fulfillment depends on both liberty (freedom from external control) and agency (the capacity for intentional and informed decision-making).
Justice	The duty to ensure a fair allocation of benefits, burdens, and risks, particularly in contexts where resources are limited. In the absence of social consensus on specific theories of justice (such as utilitarian, libertarian, communitarian, egalitarian, capability and well-being theories), governance structures should integrate various elements of these theories on a case-by-case basis.
Explainability	The capabilities and purpose of AI systems must be disclosed, and their decisions should be understandable to all individuals who are directly or indirectly impacted. Achieving this requires transparency about the underlying mechanisms. For systems utilizing "black-box" algorithms, additional explainability strategies are needed, such as ensuring traceability, enabling verification, and transparent communication about the system's capabilities.

Note. The first four criteria are derived from the – within biomedical ethics – well-established framework developed by Beauchamp and Childress (2019). Many AI initiatives incorporate claims that correspond to this framework. Alongside the criterion of explainability, these criteria also form the foundation of the design requirements set out in the "Ethics Guidelines for Trustworthy AI" by the AI HLEG, a key reference for ethically aligned AI design under the AI Act. Within these guidelines, "beneficence" and "nonmaleficence" are subsumed under the broader criterion of "prevention of harm".

Table A2

Characterization of considered criteria for human-centered work design

Criteria	Characterization
Freedom form harm	The execution of a task should not result in any psychophysical health damage.
Executability	Tasks should be commensurate with job demands, and be reliably, and sustainably executable over the long term, ensuring that the demands placed on employees do not exceed their physiological and psychological capacities.
Freedom from impairment	Tasks should be structured to prevent conditions that may lead to physical or psychological impairments. This includes the proactive identification and mitigation of workplace risks to ensure long-term employee health and well-being.
Facilitation of personality development	Tasks should provide employees with opportunities to realize their potential, expand their competencies, and thereby support their overall personal and professional development:
Holistic work design	Tasks should integrate planning, execution, and evaluative components, enabling employees to engage with the full scope of their responsibilities. Additionally, employees should have the opportunity to assess their work outcomes in relation to defined work requirements.
Diversity of requirements	The execution of tasks should require the application of varied knowledge, skills, and abilities. To promote well-being and prevent monotony, physical and mental demands should alternate where appropriate, and task structures should avoid short-cycle, repetitive activities.
Time elasticity	Work systems should ensure protection against excessive work intensification by maintaining a balanced ratio between workload and available working time.
Opportunities for social interaction	Tasks should incorporate opportunities for social interaction, such as collegial exchange and social support, to foster psychological well-being and cohesive team dynamics within the work system.
Appropriate scope of job control	Tasks should provide employees with an adequate degree of freedom in various dimensions: a. Instrumental control: Ability to choose methods, tools, and organize time b. Conceptual control: Flexibility in structuring tasks and managing sub-tasks c. Decision-making control: Autonomy in defining tasks and prioritizing work activities
Work-integrated learning	Tasks should systematically facilitate opportunities for learning by engaging employees in novel or progressively demanding activities.
Temporal flexibility	Work schedules should incorporate sufficient time buffers to allow for flexible and stress-free task management.
Meaningfulness	Work should enable employees to recognize the societal impact of the organizations' products or services.
Social acceptability	Participation of workers in the design of work systems relating to the cooperative organization of production or services.

Note. Underlying internationally recognized standards include ISO 6385 (2016), ISO 10075-2 (2024), and ISO 9241-220 (2019).

Appendix B: Supplementary Material to "Digital Technologies in Nursing: An Umbrella Review"

B1: Search Strings

The search strategies applied to the eight databases[39]

Cumulative Index to Nursing and Allied Health Literature (CINAHL) (n = 620)

TI (automat* OR digital* OR electronic* OR "human computer interaction" OR "human machine interaction*" OR smart* OR algorithm* OR app OR application* OR assist* OR companion* OR computer* OR device* OR "hand-held*" OR handheld OR ict OR it OR internet* OR mobile OR online OR palm OR pc OR phone OR robot* OR sensor* OR tablet* OR technol* OR software OR touchscreen* OR "user-computer interface*" OR video* OR wearable* OR web* OR wireless OR "wi-fi" OR wifi OR "ambient assisted living" OR "ambient living" OR augmented OR "artificial intelligence" OR ai OR cdss OR "clinical decision*" OR "decision support" OR "documentation system*" OR ehealth OR "e-health" OR "electronic health record*" OR ehr* OR "electronic medical record*" OR emr OR exoskeleton* OR "head mounted display*" OR "hospital information system*" OR his OR "local area network*" OR lan OR "machine learning" OR "mixed realit*" OR mhealth OR "m-health" OR "mobile health" OR "neural network*" OR "patient health record*" OR pda* OR "remote health monitoring" OR "short message service" OR sms OR tele* OR "virtual realit*" OR vr OR MM automation OR MM "digital technology" OR MM "health information systems" OR MM technology OR MM "assistive technology" OR MM "assistive technology devices")

AND TI (care* OR healthcare OR nurs* OR "home health aide*" OR "retirement home*" OR hospital* OR hospice* OR scu OR icu OR MM "academic medical centers" OR MM "community health centers" OR MM "ambulatory care facilities" OR MM "dialysis centers" OR "hospital units OR MM hospitals OR MM "housing for the elderly" OR "rehabilitation centers" OR "residential facilities" OR MM nursing OR MM nurses OR

[39] The described search strategy applies to the systematic literature search conducted from 01/2010 to 04/2022. For the updated search, we used the same keywords but updated the time period.

MM “students, nursing” OR MM “nursing as a profession” OR MM “patient care” MM “health services” OR MM “quality of health care”)

AND TI (“systematic review*” OR “meta-analy*” OR metaanaly* OR “literature review” OR “scoping review” OR “narrative review” OR “qualitative review” OR “evidence review” OR “evidence synthesis” OR “quantitative review” OR “meta-review” OR metareview OR “critical review” OR “mixed studies review” OR “mapping review” OR “cochrane review” OR “integrative review” OR MM “systematic review” OR MM “literature review” OR MM “meta analysis” OR MM “scoping review” OR MM “meta synthesis”)

Cochrane Library (n = 21)

TI=((automat* OR digital* OR electronic* OR human computer interaction OR human machine interaction* OR smart* OR algorithm* OR app OR application* OR assist* OR companion OR computer* OR device* OR handheld* OR hand held* OR hand-held OR ict OR it OR internet* OR mobile OR online OR palm OR pc OR phone OR robot* OR sensor* OR tablet* OR technol* OR software OR touchscreen* OR user-computer interface* OR video* OR wearable* OR web* OR wireless OR wifi OR wi-fi OR ambient assisted living OR ambient living OR augmented OR artificial intelligence OR ai OR cdss OR clinical decision* OR decision support OR documentation system* OR ehealth OR e health OR electronic health record* OR ehr* OR electronic medical record* OR emr OR exoskeleton* OR head mounted display* OR hospital information system* OR his OR local area network* OR lan OR machine learning OR mixed realit* OR mhealth OR m-health OR mobile health OR neural network* OR patient health record* OR pda* OR remote health monitoring OR short message service OR sms OR tele* OR virtual realit* OR vr)

AND (care* OR healthcare OR nurs* OR home health aide* OR retirement home* OR hospital* OR hospice* OR scu OR icu OR homecare)

AND (systematic review* OR meta-analy* OR metaanaly* OR literature review OR scoping review OR narrative review OR qualitative review OR evidence review OR evidence synthesis OR quantitative review OR metareview OR meta-review OR critical review OR mixed studies review OR mapping review OR cochrane review OR integrative review))

EBSCO Host (PsycINFO, PsycArticles, Psyndex) (n = 317)

TI (automat* OR digital* OR electronic* OR "human computer interaction*" OR "human machine interaction*" OR smart* OR algorithm* OR app OR application* OR assist* OR companion* OR computer* OR device* OR handheld* OR "hand-held*" OR ict OR it OR internet* OR mobile OR online OR palm OR pc OR phone* OR robot* OR sensor* OR tablet* OR technol* OR software OR touchscreen* OR "user-computer interface*" OR video* OR wearable* OR web* OR wireless OR "wi-fi" OR wifi OR "ambient assisted living" OR "ambient living" OR augmented OR "artificial intelligence" OR ai OR cdss OR "clinical decision*" OR "decision support" OR "documentation system*" OR ehealth OR "e-health" OR "electronic health record*" OR ehr* OR "electronic medical record*" OR emr OR exoskeleton* OR "head mounted display*" OR "hospital information system*" OR his OR "local area network*" OR lan OR "machine learning" OR "mixed realit*" OR mhealth OR "m-health" OR "neural network*" OR "patient health record*" OR pda* OR "remote health monitoring" OR "short message service" OR sms OR tele* OR "virtual realit*" OR vr OR (MM "automation") OR (MM "digital technology") OR (MM "health information technology") OR (MM "assistive technology") OR (MM "technology") OR (MM "machine learning") OR (DE "machine learning algorithms") OR (MM "mobile applications") OR (MM "mobile devices") OR (MM "mobile health") OR (MM "mobile phones") OR (MM "mobile technology") OR (MM "neural networks") OR (MM "electronic health records") OR (MM "electronic health services") OR (MM "monitoring") OR (MM "assistive technology") OR (MM "human computer interaction"))

AND TI (care* OR healthcare OR nurs* OR "home health aide*" OR "retirement home*" OR hospital* OR hospice* OR scu OR icu OR homecare OR (MM "hospitals") OR (MM "residential care institutions") OR (MM "rehabilitation centers") OR (MM "intensive care") OR (MM "nurses") OR (MM "caregivers") OR (MM "nursing") OR (MM "caregiving") OR (MM "home care") OR (MM "home care personnel") OR (MM "elder care") OR (MM "long term care") OR (MM "nursing homes") OR (MM "nursing students"))

AND TI ("systematic review*" OR "meta-analy*" OR metaanaly* OR "literature review" OR "scoping review" OR "narrative review" OR "qualitative review" OR "evidence review" OR "evidence synthesis" OR "quantitative review" OR "meta-review" OR

metareview* OR “critical review” OR “mixed studies review” OR “mapping review” OR “cochrane review” OR “integrative review” OR (MM “systematic review”) OR (MM “meta analysis2) OR (MM “literature review”))

Excerpta Medica database (Embase) (without PubMed/MEDLINE) (n = 367)

(automat*:ti OR digital*:ti OR electronic*:ti OR 'human computer interaction':ti OR 'human machine interaction*':ti OR smart*:ti OR algorithm*:ti OR app:ti OR application*:ti OR assist*:ti OR companion*:ti OR computer*:ti OR device*:ti OR 'hand-held' OR 'hand held*':ti OR handheld*:ti OR ict:ti OR it:ti OR internet*:ti OR mobile:ti OR online:ti OR palm:ti OR pc:ti OR phone:ti OR robot*:ti OR sensor*:ti OR tablet*:ti OR technol*:ti OR software:ti OR touchscreen*:ti OR 'user-computer interface*':ti OR video*:ti OR wearable*:ti OR web*:ti OR wireless:ti OR 'wi-fi':ti OR wifi:ti OR 'ambient assisted living':ti OR 'ambient living':ti OR augmented:ti OR 'artificial intelligence':ti OR ai:ti OR cdss:ti OR 'clinical decision*':ti OR 'decision support':ti OR 'documentation system*':ti OR ehealth:ti OR 'e health':ti OR 'electronic health record*':ti OR ehr*:ti OR 'electronic medical record*':ti OR emr:ti OR exoskeleton*:ti OR 'head mounted display*':ti OR 'hospital information system*':ti OR his:ti OR 'local area network*':ti OR lan:ti OR 'machine learning':ti OR 'mixed realit*':ti OR mhealth:ti OR 'm-health':ti OR 'mobile health':ti OR 'neural network*':ti OR 'patient health record*':ti OR pda*:ti OR 'remote health monitoring':ti OR 'short message service*':ti OR sms:ti OR tele*:ti OR 'virtual realit*':ti OR vr:ti OR 'automation'/mj OR 'digitalization'/mj OR 'digitization'/mj OR 'electronics'/mj OR 'electronic device'/mj OR 'information processing'/mj OR 'electronic medical record'/mj OR 'human computer interaction'/mj OR 'technology'/mj)

AND (care*:ti OR nurs*:ti OR 'home health aide*':ti OR 'retirement home*':ti OR hospital*:ti OR hospice*:ti OR scu:ti OR icu:ti OR healthcare:ti OR homecare:ti OR 'health care facility'/mj OR 'hospital'/mj OR 'hospital'/mj OR 'nursing home'/mj OR 'residental home'/mj OR 'hospital organization'/mj OR 'nursing'/mj OR 'nursing home personnel'/mj OR 'health care personnel'/mj OR 'nurse'/mj OR 'nursing staff'/mj OR 'nursing assistant'/mj OR 'nursing student'/mj OR 'elderly care'/mj OR 'health care'/mj OR 'health care delivery'/mj OR 'medical care'/mj OR 'patient care'/mj OR 'health service'/mj)

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'evidence review':ti OR 'evidence synthesis':ti OR 'quantitative review':ti OR 'meta-review':ti OR metareview:ti OR 'critical review':ti OR 'mixed studies review':ti OR 'mapping review':ti OR 'cochrane review':ti OR 'integrative review':ti OR 'systematic review'/mj OR 'meta analysis'/mj OR 'literature review'/mj)

AND [2010-2022]/py AND [embase]/lim NOT [medline]/lim

ProQuest (n = 0)

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AND ti(care* OR healthcare* OR nurs* OR "home health aide*" OR ("retirement home" OR "retirement homes") OR hospital* OR hospice* OR scu OR icu OR homecare)

AND ti("systematic reviews" OR "meta-analy*" OR metaanaly* OR "literature review" OR "scoping review" OR "narrative review" OR "qualitative review" OR "evidence review" OR "evidence synthesis" OR "quantitative review" OR "meta-review" OR "critical review" OR "mixed studies review" OR "mapping review" OR "cochrane review" OR "integrative review")

PubMed (n = 5659)

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AND (care*[Title] OR healthcare[Title] OR nurs*[Title] OR “home health aide*”[Title] OR “retirement home*”[Title] OR hospital*[Title] OR hospice*[Title] OR scu[Title] OR icu[Title] OR homecare[Title] OR “ambulatory care facilities”[MeSH Major Topic] OR “birthing centers”[MeSH Major Topic] OR “hospital units”[MeSH Major Topic] OR hospitals[MeSH Major Topic] OR “nurseries, infant”[MeSH Major Topic] OR “rehabilitation centers”[MeSH Major Topic] OR “residential facilities”[MeSH Major Topic] OR nursing[MeSH Major Topic] OR nurses[MeSH Major Topic] OR “nursing services”[MeSH Major Topic] OR “nursing staff”[MeSH Major Topic] OR “patient care”[MeSH Major Topic])

AND (“systematic review*”[Title] OR “meta analy*”[Title] OR metaanaly*[Title] OR “literature review”[Title] OR “scoping review”[Title] OR “narrative review”[Title] OR “qualitative review”[Title] OR “evidence review”[Title] OR “evidence synthesis”[Title] OR “quantitative review”[Title] OR “meta-review”[Title] OR metareview[All Fields] OR “critical review”[Title] OR “mixed studies review”[Title] OR “mapping review”[Title] OR “cochrane review”[Title] OR “integrative review”[Title] OR review[Publication Type] OR “meta-analysis”[Publication Type] OR “systematic review”[Publication Type])) AND (2010:2022[pdat])

Scopus (n = 1790)

Title: (automat* OR digital* OR electronic* OR “human computer interaction” OR “human machine interaction*” OR smart* OR algorithm* OR app OR application* OR assist* OR companion* OR computer* OR device* OR handheld* OR “hand-held*” OR ict OR it OR internet* OR mobile OR online OR palm OR pc OR phone OR robot* OR sensor* OR tablet* OR technol* OR software OR touchscreen* OR “user-computer-interface*” OR video* OR wearable* OR web* OR wireless OR “wi-fi” OR wifi OR “ambient assisted living” OR “ambient living” OR augmented OR “artificial intelligence” OR ai OR cdss OR “clinical decision*” OR “decision support” OR “documentation system*” OR ehealth OR “e-health” OR “electronic health record*” OR ehr* OR “electronic medical record*” OR emr OR exoskeleton* OR “head mounted display*” OR “hospital information system*” OR his OR “local area network*” OR lan OR “machine learning” OR “mixed realit*” OR mhealth OR “m-health” OR “neural network*” OR “patient health record*” OR pda* OR “remote health monitoring” OR “short message service” OR sms OR tele* OR “virtual realit*” OR vr)

AND (care* OR healthcare OR nurs* OR “home health aide*” OR “retirement home*” OR hospital* OR hospice* OR scu OR icu OR homecare)

AND (“systematic review*” OR “meta-analy*” OR metaanaly* OR “literature review” OR “scoping review” OR “narrative review” OR “qualitative review” OR “evidence review” OR “evidence synthesis” OR “quantitative review” OR “meta-review” OR metareview OR “critical review” OR “mixed studies review” OR “mapping review” OR “cochrane review” OR “integrative review”)

Web of Science (n = 1333)

TI=((automat* OR digital* OR electronic* OR human computer interaction OR human machine interaction* OR smart* OR algorithm* OR app OR application* OR assist* OR companion OR computer* OR device* OR handheld* OR hand held* OR hand-held OR ict OR it OR internet* OR mobile OR online OR palm OR pc OR phone OR robot* OR sensor* OR tablet* OR technol* OR software OR touchscreen* OR user-computer interface* OR video* OR wearable* OR web* OR wireless OR wifi OR wi-fi OR ambient assisted living OR ambient living OR augmented OR artificial intelligence OR ai OR cdss OR clinical decision* OR decision support OR documentation system* OR ehealth OR e health OR electronic health record* OR ehr* OR electronic medical record* OR emr OR exoskeleton* OR head mounted display* OR hospital information system* OR his OR local area network* OR lan OR machine learning OR mixed realit* OR mhealth OR m-health OR mobile health OR neural network* OR patient health record* OR pda* OR remote health monitoring OR short message service OR sms OR tele* OR virtual realit* OR vr)

AND (care* OR healthcare OR nurs* OR home health aide* OR retirement home* OR hospital* OR hospice* OR scu OR icu OR homecare)

AND (systematic review* OR meta-analy* OR metaanaly* OR literature review OR scoping review OR narrative review OR qualitative review OR evidence review OR evidence synthesis OR quantitative review OR metareview OR meta-review OR critical review OR mixed studies review OR mapping review OR cochrane review OR integrative review))

B2: List of Excluded References

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B3: Characterization of Included Reviews

https://ars.els-cdn.com/content/image/1-s2.0-S0020748924002633-mmc3.xlsx

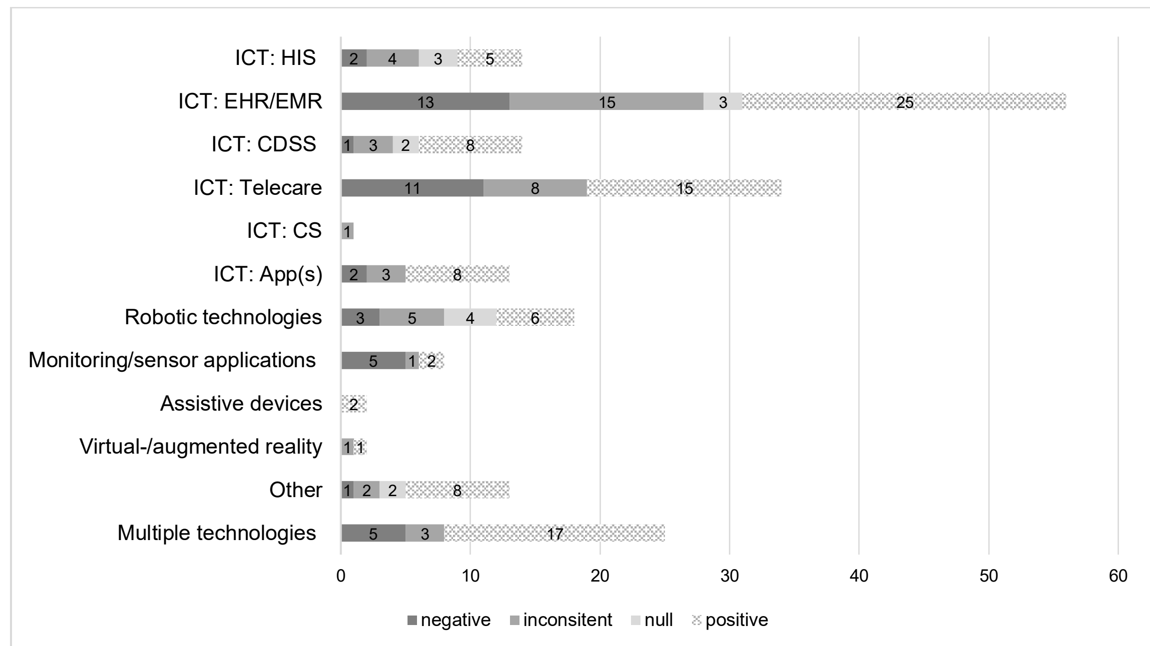
B4: Methodological Quality of Included Reviews

https://ars.els-cdn.com/content/image/1-s2.0-S0020748924002633-mmc4.xlsx

B5: Number and Direction of Reported Associations between Digital Technologies and Work-Related, Organizational Factors

Figure B1

Reported associations between digital technologies and work-related and organizational factors

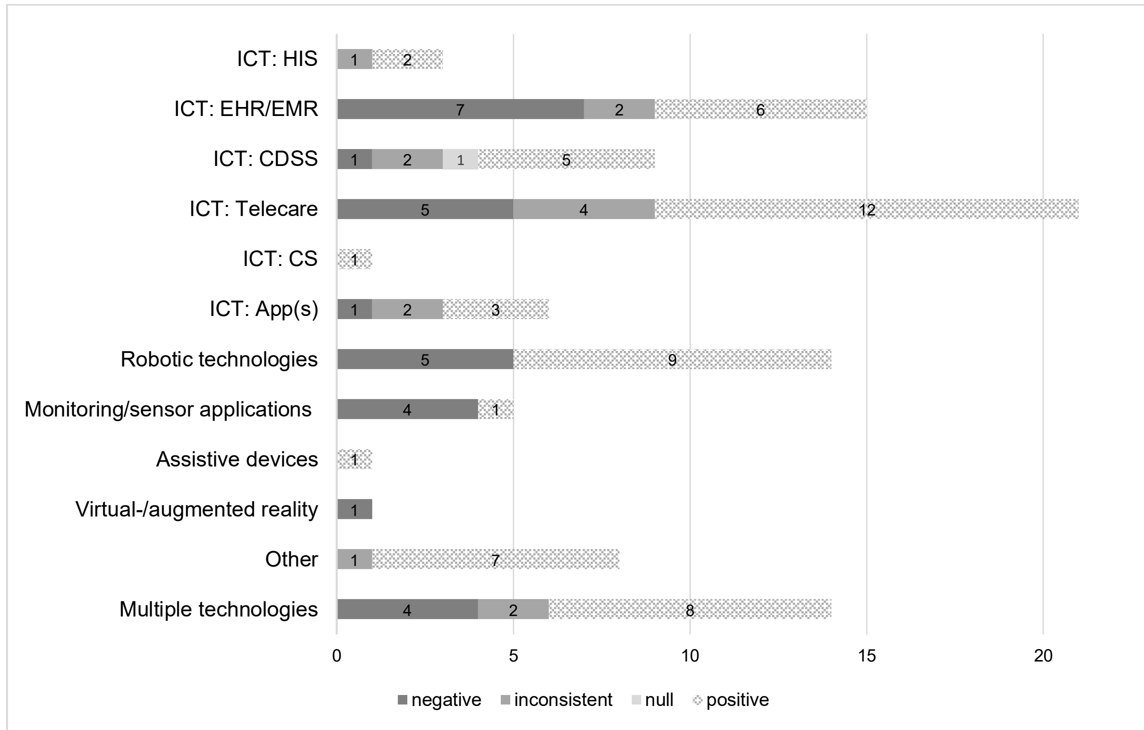


Note. ICT: Information and communication technologies; HIS: Health institution information systems; EHR/EMR: Electronic health/medical records; CDSS: Computerized decision support systems; CS: Communication support technologies.

B6: Number and Direction of Reported Associations between Digital Technologies and Safety and Health-Related or Distal Nurse Outcomes

Figure B2

Reported associations between digital technologies and safety and health-related or distal nurse outcomes

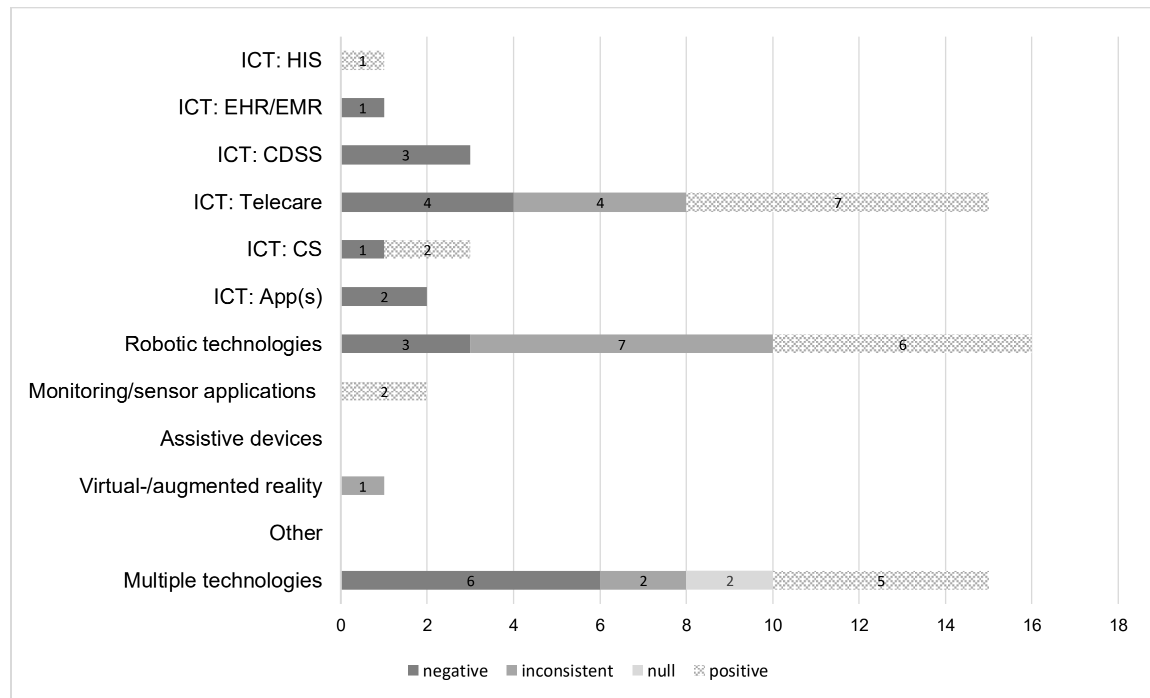


Note. ICT: Information and communication technologies; HIS: Health institution information systems; EHR/EMR: Electronic health/medical records; CDSS: Computerized decision support systems; CS: Communication support technologies.

B7: Number and Direction of Reported Associations between Digital Technologies and Ethically Relevant Patient Outcomes

Figure B3

Reported associations between digital technologies and ethically relevant patient outcomes



Note. ICT: Information and communication technologies; HIS: Health institution information systems; EHR/EMR: Electronic health/medical records; CDSS: Computerized decision support systems; CS: Communication support technologies.

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Appendix C: Supplementary Material to “A Context-Specific Analysis of Ethical Principles Relevant for AI-Assisted Decision-Making in Health Care”

C1: Participant Concepts of Beneficence

Table C1

Participant concepts of beneficence

Main themes	Key aspects	Anchor quotations
General Characteristics		
Prerequisite	Need for assistance	“Beneficence is when you need help and you receive it.” (R12)
Aims	Prevention of (physical) harm	“Beneficence is taking care of the well-being of the other person, including preventive care, so that no illness arises or gets worse.” (G7)
	Satisfaction of basic needs	“It is my duty to ensure that people are doing well. That is, that basic needs are met...” (G12)
	Promotion of emotional well-being	“Sometimes you need someone to talk to, or have something you want to get off your chest. It helps if there’s someone there who listens.” (R3)
Recognizing needs		
Demands	Holistic assessment of needs	“Caring requires perceiving the persons in need of care as comprehensively as possible. Their wishes, needs, problems.” (G9)
	Identifying motives	“…the right approach would be to first find out why the person in need of care doesn’t want it. Why she feels uncomfortable.” (G13)
Capabilities	Empathy	“...acting in a caring way. I always begin with empathy.” (G9)
	Vigilance	“You have to, for example, constantly keep an eye out to make sure that the patient does not fall.” (G11)
Assuming responsibility		
Demands	Taking responsibility	“...certainly that I keep an eye on everyone who I am responsible for… I am also aware of my responsibility.” (G6)
	Obtaining extended information	“I would probably do a depression screening. Possibly also, if he has family, ask them what changes they have noticed in him...” (G9)
	Situational weighing	“Nurses are actually permanently dealing with these decision conflicts. ...For me, situational weighing in such situations is a core part of my professionalism.” (G9)
	Communication	“If we talk to the patients, for example, explain why a particular treatment is important, the patients usually allow the treatment to be carried out.” (G15)

	Building trust	“In this case, trust would first have to be built up. The better relationships are, the more people are willing to put up with unpleasant things.” (G2)
Meeting needs		
Demands	Responding to needs	“...that you also respond to the patients and their needs, that’s really extremely important to me.” (R5)
	Adapting actions to individual situation	“The art of nursing involves applying abstract knowledge to the person and the specific situation.” (G9)

C2: Participant Concepts of Autonomy

Table C2

Participant concepts of respect for autonomy

Main themes	Key aspects	Anchor quotations
Individual autonomy		
Prerequisite	Capability to articulate opinions	"The person in need of care would have to explain what's going on inside her, why she doesn't feel like it. So she would also have to talk to the nurse." (R2)
Aims	Self-determination	"Respect for autonomy requires that I regard the person in need of care as the decision-maker." (G9)
	Independence from controlling influences	"You don't always want to be taken by the hand. I want to be able to decide for myself whether I sit alone and brood or go along with them and do something." (R6)
Demands	Trust in care recipients' competence	"What do I need to do to respect of autonomy? I definitely need to trust in the competencies of my counterpart. In other words, the opposite of a paternalistic attitude." (G9)
	Promoting competence to make informed choices	"It is important to promote competence to make their own decisions... To do this, we often have to provide information." (G7)
	Offering alternatives	"You could also make him alternative offers. Maybe there is something that the person in need of care feels more comfortable with." (G5)
	Facilitating informed consent	"...it must be explained why the treatment is important and what harm might otherwise occur. Because those in need of care often first look at it from a different perspective." (G7)
Limiting factors	Risk of self-endangerment	"If he doesn't want it and refuses, then that must be accepted, with the limit of self-endangerment." (G3)
	Risk of harming uninvolved persons	"In some cases, it may be necessary to act against the will of the person in need of care. For example, if there is a risk of harm to others, because an infection could spread." (R9)
	Cognitive impairment	"When is it justified not to comply with the patient wishes? Well, if, for example, someone can no longer adequately assess possible risks due to a cognitive impairment." (G1)
Relational Autonomy		
Aims	Shared decision-making	"Negotiation is important. You have to talk with the resident. The decision has to be supported by both parties in the end." (G10)

	Retaining care recipients' sense of identity	"We have many residents with dementia. With these, I find it particularly important to preserve their self-perception and personality. And even if the person does something that makes no sense to me, I still respect him, try to respond to it and also keep his self-esteem in mind." (G13)
Demands	Nonverbal communication	"Reading facial expressions and gestures is important. I think that if you know your residents, you can tell what they want." (G14)
	Considering potential internalized incapacitation	"When you are helpless as a person in need of care, you often feel like you have to submit to situations and cooperate." (R6)
	Holistic assessment of care recipients' individual situations	"To strengthen the autonomy of people in need of care, it is important to talk to colleagues from other professional groups about a particular resident. This opens up new perspectives." (G12)

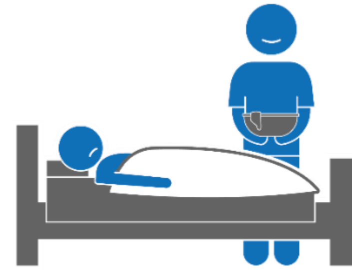
C3: Participant Concepts of Justice

Table C3

Participant concepts of justice

Main themes	Key aspects	Anchor quotations
Nondiscrimination		
Aim	Equal treatment	"It is important to treat every person equally. Regardless of their religion or the color of their skin." (G6)
Distributive justice: equality principle		
Aim	Equal allocation of resources to every care recipient	"...I have to keep an eye on everyone. I shouldn't concentrate on an individual patient because I might get the impression that he or she needs me more than other patients." (G4)
Limiting factor	(In)visibility of individual care recipients	"Some patients are very quiet and may not even leave their room. And then you ask yourself, is it fair that I provide so much more care for one person than the other?" (G11)
Distributive justice: need principle		
Aims	Allocation of resources based on individual need for basic care	"It would be fairer if someone with more limitations receives more attention. Otherwise, those who express their needs but don't require as much support may receive more attention." (G12)
	Allocation of resources based on individual need for social support	"I would certainly say my greatest priority is a person who is unwell, a dying person who is very frightened." (G8)
Limiting factor	Inability to articulate own needs	"People with greater need for support often receive less attention when they are no longer able to express their needs." (G12)

C4: Scenario: Basic Care



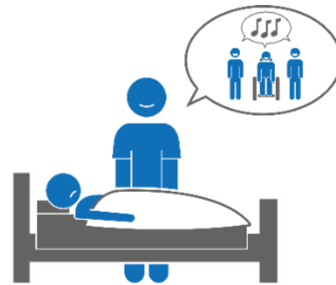
Nurse Jacob enters Mr. Fisher's room to carry out the daily bodily care. Mr. Fisher had an accident while hiking and has been paraplegic ever since. Two weeks ago, he was admitted to the Blue Lake Nursing Home. Since the admission, he refuses to be washed. He had voiced that it made him feel uncomfortable. This morning, too, he tells Jacob he would like to skip the part of his care involving his personal hygiene.

Jacob reflects on what is critical to Mr. Fisher's well-being in this situation. Regular personal hygiene is important to prevent infections and an integral part of basic care in nursing homes. Mr. Fisher has not received a wash for several days now. Despite Jacob's attempt to empathetically convince Mr. Fisher of the necessity of personal hygiene, Mr. Fisher keeps refusing.

Variant A: **Jacob decides** not to follow Mr. Fisher's wish but to wash him today.

Variant B: Jacob uses the **AI-assisted technology**. Based on the collected patient data, the technology recommends not to follow Mr. Fisher's wish but to wash him today. Jacob follows the recommendation.

C5: Scenario: Social Care



Nurse Jacob enters the room of Ms. Wood, who has been living in the *Blue Lake Nursing Home* since her stroke. Jacob wants to talk to her about participating in the recreational program (singing and board games) taking place in the community room and accompany her there if necessary. Ms. Wood tells Jacob that she does not feel like participating in the program today and would like to stay in her room. Jacob thinks about it. Ms. Wood usually seems to enjoy the social interaction. She replies in the negative to Jacob's question whether she is in pain today. Ms. Wood says she herself does not know why she does not feel like participating in the program today.

Variant A: **Jacob decides** to at least take Ms. Wood to the community room and gets a wheelchair to transport her.

Variant B: Jacob uses the **AI-assisted technology**. Based on the collected patient data, the technology recommends participation in the recreational program. Jacob follows the recommendation and gets a wheelchair to at least transport Ms. Wood to the community room.

C6: Scenario: Organization of Workflows

Jacob, the head of the residential area, has been feeling the shortage of staff for some time. However, for the upcoming morning shift, three colleagues at once have reported sick. Today's shift will therefore be understaffed. Before the staff meeting, Jacob has to weigh up which tasks need to be prioritized, and which ones might need to be left undone.

When it comes to deciding what is most urgent, the regular rounds during which he keeps an eye on all the residents or accompanying a dying resident whose relatives are unable to be there for her due to the Covid 19 pandemic, Jacob is unsure. Both seem to be very important to him.

Variant A: After thorough consideration, **Jacob decides** to prioritize the rounds.

Variant B: Jacob uses the **AI-assisted technology**. Based on the collected patient data, the technology recommends prioritizing the rounds. Jacob follows the recommendation.

Appendix D: Special Analysis of Reviews Examining AI-Assisted Technologies

Schlicht, L., Wendsche, J., Melzer, M., Tschetsche, L., & Rösler, U. (2025). Auswirkungen von KI auf die Arbeit in der Pflege. *Arbeitsmedizin, Sozialmedizin, Umweltmedizin – Zeitschrift für medizinische Prävention*, *60*(4), 21–25. https://doi.org/10.17147/asu-1-411957

Impact of AI on Work in Nursing – Current Research and Perspectives for Occupational Safety

AI-assisted technologies promise to improve work in nursing. The large number of published studies presents occupational health and safety stakeholders with the challenge of obtaining an overview of current research results on the effects of these technologies on working conditions, the skills and health of employees, and on ethical aspects of nursing practice. The article summarizes findings from 59 reviews on the use of AI in nursing and highlights links to occupational health and safety.

Auswirkungen von KI auf die Arbeit in der Pflege – Aktuelle Forschung und Perspektiven für den Arbeitsschutz

KI-assistierte Technologien versprechen, die Arbeit in der Pflege zu verbessern. Die Vielzahl veröffentlichter Studien stellt Akteurinnen und Akteure des Arbeitsschutzes vor die Herausforderung, einen Überblick über aktuelle Forschungsergebnisse zu den Auswirkungen dieser Technologien auf Arbeitsbedingungen, die Kompetenzen und Gesundheit der Beschäftigten sowie auf ethische Aspekte der Pflegepraxis zu erhalten. Der Beitrag fasst Erkenntnisse aus 59 Übersichtsarbeiten zum Einsatz von KI in der Pflege zusammen und beleuchtet Bezüge zum Arbeitsschutz.

Kernaussagen

- Die Einführung KI-assistierter Technologien braucht begleitende Maßnahmen. Diese müssen sicherstellen, dass die Technologie nicht zu zusätzlicher Arbeitsbelastung führt und die Gesundheit der Pflegenden gewährleistet bleibt.
- Die Implementierung von KI in der Pflege wirft ethische Fragen auf, insbesondere in Bezug auf die Wahrung der Autonomie, den Schutz der Privatsphäre und die Sicherheit der Pflegebedürftigen. Diese Fragen sind auch für

Pflegende von Relevanz und sollten vor der Einführung einer Technologie gründlich betrachtet werden.

Herausforderungen für Arbeitsbedingungen, Gesundheit und Ethik

Das im Jahr 2000 in den USA zugelassene Operationssystem da Vinci revolutionierte die Robotik in der Chirurgie und leitete die Entwicklung zahlreicher Operationsroboter ein. Weitere Anwendungsfelder zogen nach, auch die professionelle Pflege in Krankenhäusern, Pflegeheimen oder ambulanten Diensten. So werden zum Beispiel humanoide Roboter für einfache Aufgaben in Altenheimen oder therapeutische Roboter bei Menschen mit demenziellen Erkrankungen erprobt. Telemedizinische Systeme ermöglichen Pflegenden die direkte Überwachung der Vitalwerte von Pflegebedürftigen, ohne dass diese ihre häusliche Umgebung verlassen müssen. KI-basierte Softwarelösungen analysieren Patientendaten, um Vorhersagen über deren künftigen Pflegebedarf zu treffen.

Diese und andere KI-assistierte Technologien bringen Herausforderungen für Beschäftigte und Leitungskräfte in der Pflege mit sich, denn ihre Einführung kann tiefgreifende Auswirkungen auf das Arbeitssystem und damit auch direkt auf die Pflegenden haben. Beispielsweise zeigen Studien zu digitalen Dokumentationssystemen, dass diese Zeit und die Aufmerksamkeit der Pflegenden kosten, die dann für die direkte pflegerische Betreuung fehlt. Und bei der Untersuchung digitaler Entscheidungsunterstützungssysteme wurde festgestellt, dass sie die Fachlichkeit Pflegender und ihre Entscheidungsspielräume schmälern können.

Gemäß dem Internationalen Übereinkommen über Sicherheit und Gesundheitsschutz am Arbeitsplatz (C155; ILO, 1981) muss gewährleistet werden, dass Arbeitsplätze sicher sind und keine arbeitsbedingten Gesundheitsrisiken bergen. Akteurinnen und Akteure des Arbeitsschutzes stehen daher vor der Herausforderung, die aktuellen technologischen Entwicklungen zu überblicken, ihren Einfluss auf die Arbeitsbedingungen abzuschätzen und die Umsetzung geeigneter Begleitmaßnahmen für die Sicherheit und Gesundheit der Beschäftigten zu unterstützen. Eine hierfür zentrale Frage ist, wie sich KI-assistierte Technologien auf die Arbeitsanforderungen, die Arbeitsorganisation und folglich auf die Sicherheit, das Stressniveau und die Gesundheit der Beschäftigten auswirken (Parker & Grote, 2022).

Eine weitere zentrale Frage wird im ersten Moment nicht selten übersehen: Bei der Entwicklung und Einführung KI-assistierter Technologien in der Pflege müssen ethische Aspekte von vornherein sowie begleitend berücksichtigt werden. Zwar besteht beispielsweise das Risiko der Vernachlässigung von Patienteninteressen in Pflegeprozessen unabhängig von digitalen Technologien. Es kann sich mit deren Einsatz jedoch verschärfen, insbesondere bei Technologien, die sich auf die Beziehungsarbeit in der Pflegearbeit auswirken. Es ist daher wichtig, den Zusammenhang zwischen der Technologieanwendung und den damit verbundenen ethischen Aspekten in der Pflege besser zu verstehen (Brey, 2009).

Vor diesem Hintergrund betrachtet dieser Beitrag drei Fragen:

- Welche Fragestellungen untersuchen vorliegende Übersichtsarbeiten zu KI-assistierten Pflegetechnologien?
- Was ist zu den Zusammenhängen zwischen dem Einsatz dieser Technologien einerseits und arbeitsbezogenen und organisatorischen Faktoren, berufsbezogenem Verhalten, gesundheits- und sicherheitsbezogenen Ergebnissen bei Pflegenden andererseits bekannt?
- Wie lassen sich die Erkenntnisse zur Nutzung dieser Technologien und – aus Perspektive der Patientinnen und Patienten – ethisch relevanten Aspekten zusammenfassen?

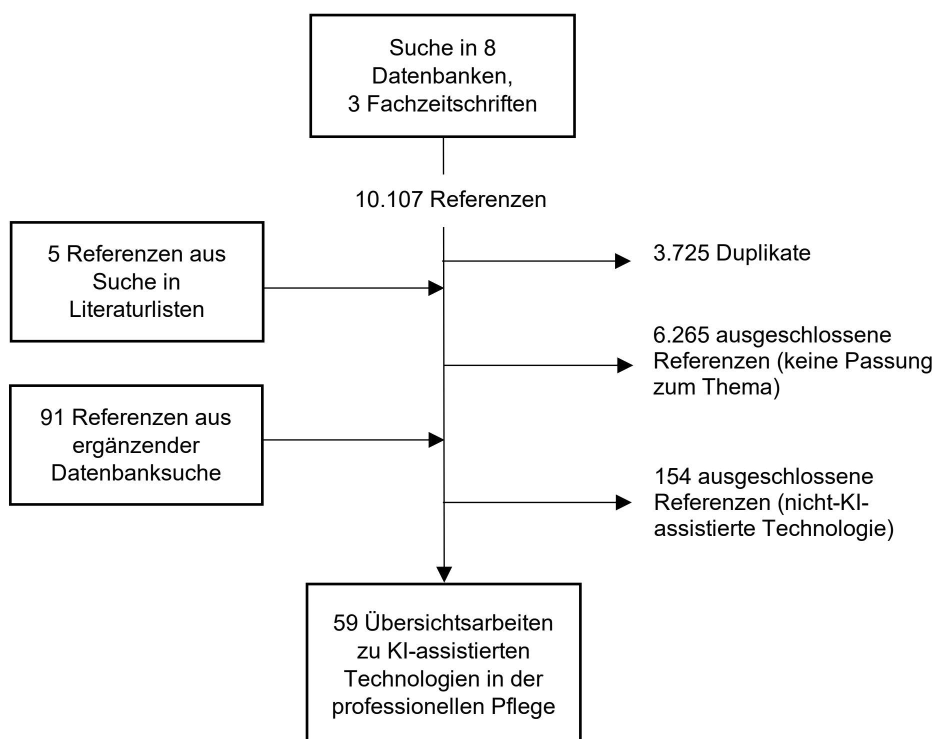
Dabei wird die in der europäischen KI-Verordnung genutzte Begriffsbestimmung für Künstliche Intelligenz auch diesem Beitrag zu Grunde gelegt. Demnach fällt darunter ein maschinengestütztes System, „das für einen in unterschiedlichem Grade autonomen Betrieb ausgelegt ist und das nach seiner Betriebsaufnahme anpassungsfähig sein kann und das aus den erhaltenen Eingaben für explizite oder implizite Ziele ableitet, wie Ausgaben wie etwa Vorhersagen, Inhalte, Empfehlungen oder Entscheidungen erstellt werden, die physische oder virtuelle Umgebungen beeinflussen können“ (Art. 3 KI-VO). KI-assistierte Technologien nutzen demnach maschinelle Techniken und Ansätze, um beispielsweise aus Daten zu lernen, Muster zu erkennen und Entscheidungen oder Vorhersagen zu treffen, ohne explizit für jede einzelne Aufgabe programmiert zu sein.

Systematische Literatursuche

Systematische Übersichtsarbeiten zielen darauf ab, vorhandene Forschungsergebnisse zu einem bestimmten Thema planvoll und umfassend zu sammeln, zu bewerten und zusammenzufassen. Sie folgen einer definierten, standardisierten Vorgehensweise und sind das Mittel der Wahl, um die vorhandene Evidenz zu analysieren. Im April 2022 und ergänzend im Mai 2024 führten wir eine systematische Suche nach publizierten Übersichtsarbeiten in elektronischen Datenbanken, Fachzeitschriften und Literaturverzeichnissen durch. Expertinnen und Experten der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin und erfahrene Bibliothekarinnen entwickelten die Suchwörter für diese Recherche. **Abbildung 1** zeigt den Ablauf und die Resultate der Literatursuche im Überblick.

Abbildung 1

Ablauf und Resultate der systematischen Literatursuche



Zunächst wurden Studien zu digitalen Technologien in der professionellen Pflege recherchiert. Von den mehr als 10.000 gefundenen Übersichtsarbeiten schlossen wir 3725 Duplikate und 6169 Studien aus, die nicht den Einschlusskriterien entsprachen. Von den verbliebenen 213 Übersichtsarbeiten wurden – für die vorliegende Sonderauswertung –

jene 59 ausgewertet, die KI-assistierte Technologien in der Pflege zum Gegenstand hatten.[40] Beispiele für diese Technologien zeigt **Tabelle 1**.

Mehr als ein Drittel der Übersichtsarbeiten umfasst Studien aus verschiedenen Pflegesettings. 29 % betreffen überwiegend die Kurzzeitpflege (z. B. Krankenhäuser), gefolgt von der stationären Langzeitpflege mit 24 % (z. B. Pflegeheime). Nur eine Übersichtsarbeit stammt aus der ambulanten Langzeitpflege. Sieben Übersichtsarbeiten konnten anhand der verfügbaren Informationen keinem Setting zugeordnet werden.

Tabelle 1

Beispiele KI-assistierter Technologien aus den Übersichtsarbeiten

Technologie	Ziel, Anwendungsbereich
Entscheidungsunterstützungssysteme zur Dekubitusprophylaxe	Druckgeschwüren (in Folge langen starren Liegens) vorbeugen
Maschinelles Lernen zur Sturzprävention in der Altenpflege	Risikofaktoren für Stürze identifizieren und Vorhersagemodelle für deren Prävention entwickeln
Schmerzmanagementsysteme	Verbesserte Schmerzbehandlung und Reduktion herausfordernder Verhaltensweisen bei Patientinnen und Patienten mit demenziellen Erkrankungen
Sozial-assistive Roboter	Sozial-kommunikatives Unterstützungsangebot (als eine Aktivität des täglichen Lebens), vorrangig für ältere Menschen
Telehealth-Anwendungen	Niedrigschwellig pflegerische Versorgung gewährleisten (eigene Häuslichkeit muss nicht verlassen werden; zugleich wird mögliche Exposition gegenüber Krankheitserregern in ärztlichen Praxen vermieden)
	Bessere Entscheidungsfindung für pflegerische Maßnahmen, weil Echtzeitdaten von den Patientinnen und Patienten verfügbar sind und die direkte Zusammenarbeit und Abstimmung mit anderen Berufsgruppen möglich ist (z. B. Apothekerinnen/Apotheker, Sozialarbeiterinnen/Sozialarbeiter, Ärztinnen/Ärzte)
	Effizienzsteigerung, indem Wartezeiten und Krankenhausaufenthalte vermieden werden

[40] Wie oben erwähnt, haben wir uns in diesem Auswahlprozess an der KI-Definition der europäischen KI-Verordnung vom 13. Juni 2024 orientiert.

Fragestellungen der Übersichtsarbeiten

Die in den 59 Übersichtsarbeiten häufig untersuchten Fragestellungen lassen sich wie in **Tabelle 2** dargestellt, zusammenfassen und quantifizieren. Zu den weniger untersuchten Fragestellungen (drei Übersichtsarbeiten oder weniger) gehören die Analyse des Einführungsprozesses beziehungsweise der Technologieimplementierung, die Auswirkungen der Technologie auf die Pflegequalität, die Analyse möglicher Anwendungsgebiete für die Technologie, die Beteiligung beruflich Pflegender an der Technologieentwicklung sowie die Auswirkungen des Technologieeinsatzes auf die Sicherheit und Gesundheit Pflegender.

Tabelle 2

Häufig untersuchte Fragestellungen der Übersichtsarbeiten zu KI-assistierten Technologien in der Pflege

Untersuchte Fragestellung	Anzahl Übersichtsarbeiten	Anteil (in %)
Auswirkungen auf ökonomische Aspekte	12	20
Erfahrungen Pflegender mit der Technologie	10	17
Auswirkungen auf das Arbeitshandeln bzw. auf Arbeitsroutinen der Pflegenden	10	17
Auswirkungen auf die Sicherheit und Gesundheit Pflegebedürftiger	10	17
Einstellungen Pflegebedürftiger oder anderer Personen in Bezug auf die Technologie	7	12
Einstellungen Pflegender in Bezug auf die Technologie	6	10
Erfahrungen Pflegebedürftiger oder anderer Personen mit der Technologie	7	12
Identifikation von Technologien zur Unterstützung spezifischer Pflegeaufgaben	7	12

Anmerkung: Mehrfachzuordnungen waren möglich.

Abbildung 2 zeigt die Häufigkeitsverteilung der Ergebnisse (positiv, inkonsistent, negativ, kein Zusammenhang) aus 16 systematischen Reviews, die über Zusammenhänge zwischen dem Einsatz KI-assistierter Technologien und tätigkeitsbezogenen Aspekten in der Pflege berichten.

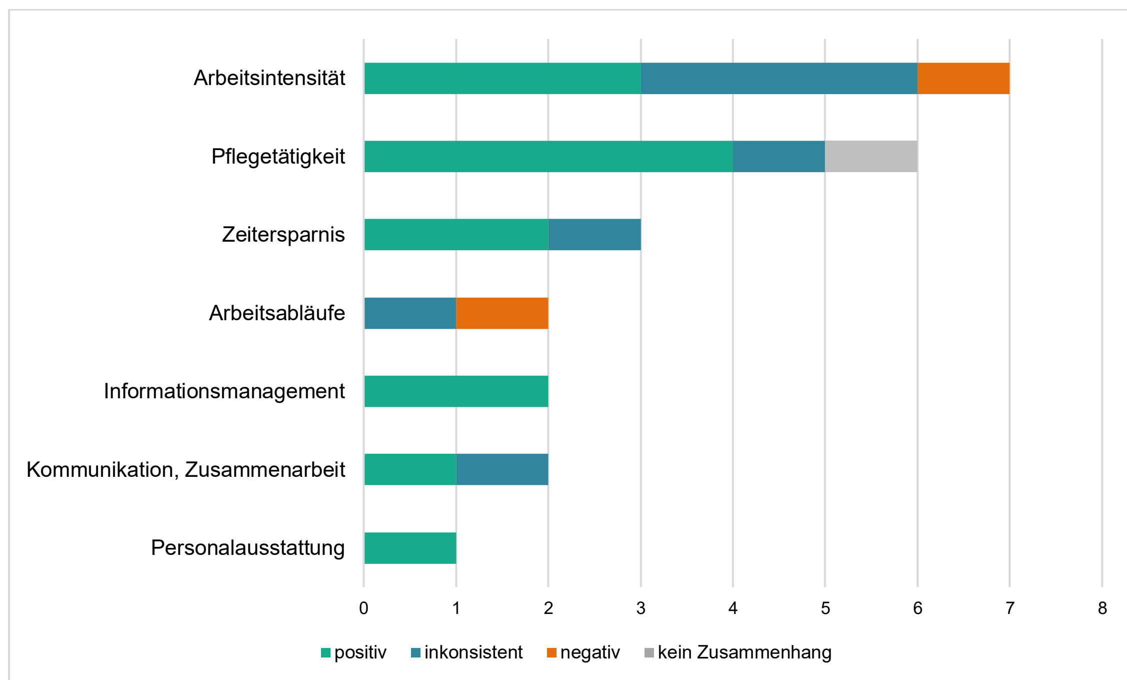
Für die Ausführung der Pflegetätigkeit, aber auch für das Informationsmanagement und mögliche Zeitersparnisse berichten die Übersichtsarbeiten vorrangig positive Effekte des Technologieeinsatzes. Beispielsweise zeigte sich, dass KI-assistierte Technologien zu einheitlicheren Standards im pflegerischen Handeln beitragen können, indem Abweichungen von Behandlungsprotokollen reduziert werden. Zudem unterstützen KI-assistierte Technologien Pflegende bei Routineaufgaben und verbessern die Qualität der Pflegedokumentation.

Eher inkonsistente oder kritische Befunde ergeben sich bei der Arbeitsintensität und den Arbeitsabläufen. Hinsichtlich der Arbeitsintensität wird in manchen Übersichtsarbeiten eine Verringerung von Zeitdruck und Arbeitsbelastung, in anderen deren Zunahme beobachtet. Arbeitsabläufe werden durch KI-assistierte Technologien, wie etwa Alarmsysteme, die kontinuierlich Vitaldaten überwachen und Pflegende bei kritischen Zuständen informieren, eher als gestört statt als verbessert wahrgenommen.

Die Ergebnisse zeigen insgesamt, dass KI-assistierte Technologien in der Pflege durchaus positive Effekte auf die Arbeitstätigkeit haben können, aber auch mögliche Herausforderungen, wie eine erhöhte Arbeitsintensität und Störungen, mit sich bringen.

Abbildung 2

Zusammenhänge zwischen KI-assistierten Technologien und tätigkeitsbezogenen Aspekten



Anmerkung: Die Abbildung berichtet die Häufigkeit der Ergebnisse aus 16 systematischen Reviews; Mehrfachzuordnungen waren möglich.

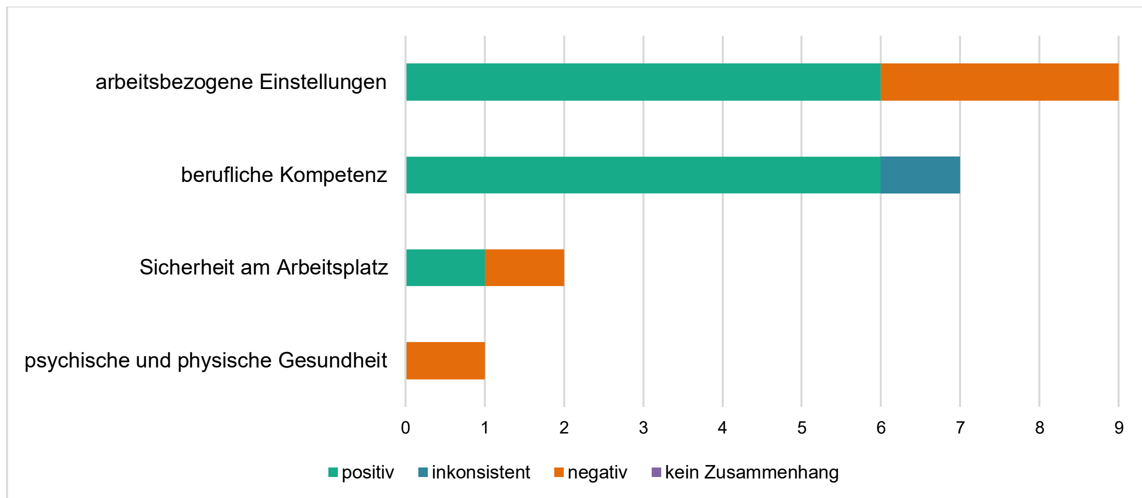
Personenbezogene Folgen für Pflegende

Abbildung 3 zeigt die in elf Übersichtsarbeiten berichteten Zusammenhänge zwischen Technologieeinsatz und vier personenbezogenen Kategorien. Die meisten Forschungsergebnisse liegen für arbeitsbezogene Einstellungen und berufliche Kompetenzen vor. Diese fallen zum Großteil positiv aus. Beispielsweise wird im Zusammenhang mit der Technologieanwendung von höherer Arbeitszufriedenheit, besseren sozialen Beziehungen zu den Pflegebedürftigen oder erweiterten Lern- und Entwicklungsmöglichkeiten im Arbeitsalltag berichtet. Zu den für den Arbeitsschutz bedeutsamen Kategorien Sicherheit am Arbeitsplatz sowie psychische und physische Gesundheit liegen drei Übersichtsarbeiten vor – zwei berichten negative Effekte, wie vermehrte Störungen, Bedenken in Bezug auf die Einhaltung von Hygiene-vorschriften oder Verletzungsrisiken. Eine Übersichtsarbeit fand positive gesundheitliche Effekte in

Form einer Verringerung physischer Belastungsfaktoren (hier Strahlungsdosis) durch Anwendung der KI-Technologie.

Abbildung 3

Zusammenhänge zwischen KI-assistierten Technologien und personenbezogenen Aspekten



Anmerkung: Die Abbildung berichtet die Häufigkeit der Ergebnisse aus 11 systematischen Reviews; Mehrfachzuordnungen waren möglich.

Ethische Aspekte

Zu den vier Prinzipien der Bioethik (Beauchamp & Childress, 2019), die häufig als Grundlage für ethische Entscheidungen im Gesundheitswesen und in der biomedizinischen Forschung herangezogen werden, gehören:

- *Autonomie*: das Recht von Pflegebedürftigen, ihre eigenen Entscheidungen in Bezug auf ihre medizinische Versorgung und Behandlung zu treffen; vorausgesetzt, die Person ist in der Lage, informierte Entscheidungen zu treffen.
- *Nicht-Schaden*: Medizinische Fachkräfte haben die Pflicht, Schaden zu vermeiden; Handlungen, die für Patientinnen und Patienten potenziell schädlich sein könnten, müssen unterlassen werden (es sei denn, der potenzielle Nutzen überwiegt das Risiko).
- *Wohltun*: das Wohl der Patientinnen und Patienten ist zu fördern und es sind aktiv Maßnahmen zu ergreifen, um Schaden abzuwenden, Leiden zu lindern und den Gesundheitszustand zu verbessern.
- *Gerechtigkeit*: die faire und gerechte Verteilung von Gesundheitsressourcen und -leistungen; alle Patientinnen und Patienten müssen gleichermaßen Zugang zu

medizinischer Versorgung haben, unabhängig von persönlichen Merkmalen oder finanziellen Möglichkeiten.

Diese vier Prinzipien sind auch im Kontext der Anwendung von KI im Gesundheitswesen von hoher Bedeutung (Floridi et al., 2018). KI-assistierte Technologien haben das Potenzial, die medizinische Versorgung zu optimieren, indem sie zum Beispiel zu einer individuell angepassten Pflegeplanung beitragen. Ob der Einsatz der Systeme allerdings tatsächlich zum Wohl der Patientinnen und Patienten beiträgt und nicht zu Lasten der pflegerischen Beziehung beziehungsweise menschlichen Fürsorge geht, hängt von ihrer Gestaltung und Implementierung ab.

Vierzehn der 59 Übersichtsarbeiten erlauben hierzu Schlussfolgerungen: Vier Arbeiten finden positive Zusammenhänge von KI-assistierten Technologien mit dem Prinzip der Autonomie, wie etwa die Wahrnehmung einer größeren Unabhängigkeit der Pflegebedürftigen oder einer verringerten Informationsasymmetrie zwischen ihnen und den Pflegenden. Gleichzeitig werden Datenschutzprobleme als Herausforderung hervorgehoben, was insgesamt zu einer gemischten Bewertung führt. Ähnlich verhält es sich bei den Prinzipien des Wohltuns/Nichtschadens, wo positive Effekte wie eine höhere Lebenszufriedenheit oder stärkere soziale Unterstützung festgestellt, jedoch auch vermehrte Einsamkeit, Sicherheitsbedenken und negative Auswirkungen auf das ganzheitliche Pflegeassessment beschrieben werden. Eine Übersichtsarbeit zeigt Zusammenhänge mit dem Prinzip der Gerechtigkeit, wobei Hinweise auf Altersdiskriminierung gefunden wurden.

Perspektiven für den Arbeitsschutz

Bei der Zusammenschau aktueller Übersichtsarbeiten zu KI in der Pflege fällt auf, dass diese sehr häufig die Auswirkungen des Technologieeinsatzes auf wirtschaftliche Aspekte oder auf die Sicherheit und Gesundheit pflegebedürftiger Menschen analysieren. Nur ein kleiner Teil betrachtet die Auswirkungen auf die Arbeitsanforderungen, die gesundheitlichen Folgen für Pflegende oder ethische Aspekte des Arbeitshandelns. Hier besteht demnach Forschungsbedarf. Zum anderen zeigen die heterogenen Ergebnisse zu den tätigkeits- und personenbezogenen Aspekten, wie komplex und unterschiedlich die Auswirkungen KI-assistierter Technologien in der Pflege sind. Offenbar ist häufig nicht die spezifische Technologie selbst der entscheidende, determinierende Faktor. Vielmehr müssen zahlreiche Voraussetzungen erfüllt sein, damit es im Zuge der Technikeinführung

zu Verbesserungen im Arbeitssystem kommt. Einige Reviews berichten beispielsweise dann günstigere Auswirkungen KI-assistierter Technologien, wenn Pflegende bei der Technologieauswahl frühzeitig beteiligt und geschult werden, wenn eine Digitalisierungsstrategie vorliegt, die die Arbeitsprozesse im Blick hat oder wenn eine allgemein offene Organisationskultur vorherrscht. Darüber hinaus verdeutlichen die Übersichtsarbeiten, dass vor dem Einsatz einer Technologie gründlich abgewogen werden sollte, ob diese tatsächlich dem Wohl der Patientinnen und Patienten dient und ihre Würde gewahrt bleibt. Für Akteurinnen und Akteure des Arbeitsschutzes ist es wichtig, über KI informiert zu sein, weil diese die Arbeitswelt zunehmend verändert, was wiederum die Gesundheit und das Wohlbefinden von Beschäftigten beeinflussen kann.

Was kann aus den in diesem Beitrag vorgestellten Forschungsergebnissen für den Arbeitsschutz abgeleitet werden? Die nachfolgenden Schlussfolgerungen orientieren sich am Arbeitsgestaltungsmodell von Parker et al. (2001) und adressieren die dort definierten Ebenen: 1.) vorgelagerte Bedingungen, 2.) Arbeitsbedingungen sowie Einflussfaktoren der Organisation und 3.) Gruppe und Individuum (siehe auch Melzer et al., 2022).

1. Vorgelagerte Bedingungen: Pflegerische Arbeit findet unter anderem in Krankenhäusern, ambulanten Diensten oder Pflegeheimen statt. Die Merkmale und Prozesse dieser Organisationen können das Gelingen der Technologieimplementierung erleichtern oder erschweren. Zu den erleichternden organisationalen Faktoren gehören:

- Eine veränderungssensitive Organisationskultur inklusive der Bereitstellung ausreichender (Arbeits-)Zeit, damit sich die Pflegenden mit den Technologien vertraut machen können;
- Eine Innovations- oder Digitalisierungsstrategie auf Ebene der Trägerorganisation oder der Einrichtung beziehungsweise des Unternehmens;
- Ein organisationsinterner Diskurs, der ethische Aspekte der Pflegearbeit aufgreift und unterschiedliche, gegebenenfalls konfligierende Ziele und Wertvorstellungen offenlegt und verhandelt;
- Führungskräfte, die KI-assistierten Technologien gegenüber aufgeschlossen sind und über entsprechendes Wissen verfügen;
- Eine regelmäßige Beteiligung der Mitarbeitenden.

2. Arbeitsbedingungen und Einflussfaktoren auf Organisationsebene: Auch digitalisierte Arbeitsplätze müssen sicher sein und dürfen keine arbeitsbedingten

Gesundheitsrisiken bergen. Eine tätigkeitsspezifische Anforderungsanalyse, wie sie sich beispielsweise im Rahmen der Gefährdungsbeurteilung ergibt, bleibt wichtig. KI-assistierte Technologien sollten vorrangig dann zum Einsatz kommen, wenn sie helfen, arbeitsbedingte Anforderungen in der Pflege zu optimieren. Anforderungen, die die Kompetenzentwicklung Pflegender unterstützen, sollten beim Einsatz KI-assistierter Technologien erhalten bleiben. In manchen Fällen kann dies bedeuten, auf den Einsatz einer Technologie zu verzichten.

3. Gruppe und Individuum: Die folgenden Faktoren unterstützen eine nachhaltige Implementierung KI-assistierter Technologien auf dieser Ebene:

- gezielte Fort- und Weiterbildungen sowie Workshops und Trainings zu diesen Technologien für die zukünftigen Nutzerinnen und Nutzer (diese sollten technische, kommunikative sowie ethische Aspekte umfassen),
- Offenheit des Teams gegenüber neuen Technologien und gegenseitige kollegiale Unterstützung während des Einführungsprozesses, und
- training on the job, das heißt eine praxisnahe Einführung und (technisch) begleitete Erprobung der Technologien direkt im Arbeitsalltag.

Aus Arbeitsschutzperspektive sollte eine zentrale Prämisse der Technologieentwicklung und -anwendung sein, dass diese die Pflegenden bei der Ausführung ihrer Aufgaben unterstützen. Zugleich bleibt festzuhalten, dass KI-assistierte Technologien nicht der Königsweg zur Behebung des Fachkräftemangels oder der Anforderungsoptimierung in der Pflege sein können. Vielmehr sind vielfältige Interventionen auf mehreren Ebenen erforderlich, einschließlich einer auf den Menschen ausgerichteten Technologieimplementierung.

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Parker, S. K., & Grote, G. (2022). Automation, algorithms, and beyond: Why work design matters more than ever in a digital world. *Applied Psychology*, *71*(4), 1171–1204. https://doi.org/10.1111/apps.12241

Appendix E: List of Publications

Journal articles (peer-reviewed)

Schönfelder, A., Eberlein-Gonska, M., Hülsken-Giesler, M., Jovy-Klein, F., Kather, J., Kohoutek, E., Lennefer, T., Liebert, E., Lipprandt, M., Mathias, R., Muti, H., Obergassel, J., Reibel, T., Rösler, U., Schneider, M., Schlicht, L., Schlieter, H., Schweingruber, N., Strametz, R., Susec, B., Wekenborg, M., Weicken, E., Weitz, K., Diehl, A., Gilbert, S. (under review). *Collaborative and cooperative healthcare digital transformation in the AI age: A framework compatible with European values*. Else Kröner Fresenius Center for Digital Health, TUD Dresden University of Technology.

Rösler, U., Schlicht, L., Melzer, M., Tschetsche, L., & Wendsche, J. (under review). *Digitale Patientenakten in der professionellen Pflege: Befunde aus systematischen Übersichtsarbeiten*. Federal Institute for Occupational Safety and Health.

Schlicht, L. (under review). *AI-assisted work systems in healthcare: Insights from multistakeholder dialogues on their human-centered design*. Faculty of Humanities and Social Sciences, Karlsruhe Institute of Technology.

Schlicht, L., Wendsche, J., Melzer, M., Tschetsche, L, & Rösler, U. (2025). Digital technologies in nursing: An umbrella review. *International Journal of Nursing Studies*, *161*. https://doi.org/10.1016/j.ijnurstu.2024.104950

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Schlicht, L. (2023). Potential influences of AI-assisted decision-making on the actualization of ethical principles in care: Results of a qualitative study. *Book of Abstracts. 21st STS Conference Graz 2023: Critical Issues in Science, Technology and Society Studies.* Verlag der Technischen Universität Graz.

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