Hans Böckler Stiftung
Mitbestimmung · Forschung · Stipendien

WORKING PAPER FORSCHUNGSFÖRDERUNG

Number 349, August 2024

Algorithms and Agency in Hospitals

Empirical insights on the impact of digital transformation on clinical work

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This Working Paper at a Glance

This whitepaper based on the "Algorithms and Agency in Hospitals" project delves into the effects of digital transformation on the work of healthcare professionals and seeks methods to represent their interests throughout this process. Two case studies were carried out in collaboration with Charité Berlin, focusing on the impact of documentation software and algorithm-based decision support tools on clinical workflows, diagnostics, patient care, and the individual's sense of agency. The results underscore the importance of sufficient resources and a user-centered approach to technology design in supporting clinicians' work. The whitepaper concludes with recommendations for clinical managers, employee groups and their representatives, as well as policymakers.

FORSCHUNGS-FÖRDERUNG

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ISSN 2509-2359

Content

Summary

In recent years, the healthcare sector has undergone a significant digital transformation. This transformation entails a profound shift in how healthcare is delivered, and often requires a reconfiguration of professional practices through the integration of digital technologies. This evolution often leads to (partial) automation and enhanced control over work processes. As a result, healthcare professionals are increasingly supported by technology in nearly every facet of their duties. Beyond basic patient care and treatment documentation, technology has become indispensable in supporting clinical decision-making.

However, in this evolving landscape, there exists a notable gap in empirical knowledge concerning the impact of technology, including algorithmic systems, on clinical workflows and human agency. Moreover, there's a compelling need to gain a deeper insight into how these changes affect the required skill sets, the variation in work intensification across different groups of employees, and the potential consequences for job satisfaction and dissatisfaction. Such understanding is crucial for the successful implementation of digital transformation in hospitals, ensuring it adheres to the principles of quality work.

In pursuit of this goal, the "Algorithms and Agency in Hospitals" research project embarked on an empirical investigation in collaboration with Charité Berlin, the largest university hospital in Europe. This endeavor comprised two distinct case studies.

The initial case study explored the deployment of a Critical Care Information System (CCIS) in the intensive care unit (ICU), focusing on usability, autonomy, workaround strategies for technological challenges, and the inclusion of users in technology design. The subsequent case study assessed the application of a clinical decision support system in the radiology department, scrutinizing the impact of partial automation on diagnostic accuracy, workflows, and healthcare professionals' sense of control over their work.

The outcomes of these case studies emphatically suggest that digital transformation in healthcare is not a peripheral task but a central strategic initiative. For digitalization efforts in hospitals to be sustainable, it's imperative to consciously allocate resources, both financial and temporal, towards crafting technologies and organizational frameworks that bolster staff well-being and elevate patient care quality. While digital technology has the potential to significantly support clinical work, its effectiveness is contingent on being designed and implemented with a keen awareness of existing practices, constraints, and demands within hospital workflows.

Certain technical control features, like visual alerts that highlight data incongruities in clinical software, lower mental strain and reduce error risks for medical staff. Nonetheless, inflexible systems that clash with clinical workflows, or unnecessarily prolong tasks and replicate efforts, become counterproductive, increasing fatigue and frustration. The steady integration of digital technologies transforms the roles and skills of healthcare professionals. These changes are welcomed by medical staff when they enhance operations and outcomes. Our research found concerns about de-skilling were not significant among healthcare professionals.

Critiques often targeted scenarios where technology exacerbates workload. Misaligned technology increases stress, dissatisfaction, and burnout risk. Thus, technology design and implementation must prioritize usability and meet the diverse needs of employee groups like physicians, nurses, and medical-technical radiology assistants (MTRAs). Establishing effective user involvement mechanisms and iterative feedback is crucial. Additionally, representing employee interests is essential for articulating staff needs. Our research, focusing on technology's impact on autonomy and assessing usability and value, contributes to hospital digitalization discussions, emphasizing material design and resource accessibility.

Our research focuses on understanding the employee experience during the digital transformation processes within hospitals, offering practical suggestions for enhancing user empowerment, tailoring technology design, and formulating strategies for the efficient allocation and management of resources. The insights derived are pertinent to clinical management, employee advocacy groups, and policymakers.

Below, we provide comprehensive accounts of the methodologies employed, the results obtained, and the recommendations put forth based on the insights from both case studies.

1. Introduction

The influence of digital transformation permeates various industries, with organizations adopting data-driven business models and weaving increasingly sophisticated technologies into employee workflows (Baptista/Wilson/Galliers 2021; Faraj/Leonardi 2022; Magistretti/Dell'Era/Petruzzeli 2019). Beyond merely reshaping industries and ecosystems (BMWi 2019), technology, especially using algorithmic systems, acts as a catalyst for societal shifts that profoundly impact the workplace (Boes/Kämpf/Ziegler 2020).

The discourse on "smart technologies" within social sciences navigates through at least two primary narratives. The first encompasses socio-political and socio-theoretical debates, often sketching dystopian outcomes and criticizing capitalism. The second narrative relies on empirical studies to investigate changes in work patterns, human-machine interactions, and the organization of work mediated by technology (Hirsch-Kreinsen 2018, S. 11), highlighting a transition marked by fading boundaries, precarious conditions, and increased individualization, with mixed effects on autonomy and workloads (Carstensen 2014).

Healthcare, especially hospital care, is deeply influenced by digital transformation, leading to enhanced data collection from treatment activities for quality management (Kruse et al. 2016; McNutt et al. 2019; Schulte et al. 2019). Intelligent software offers promising prospects for healthcare workers by aiding in examination selection, medical data analysis, and treatment identification (Dewey/Wilkens 2019).

While the digitalization of hospitals and its effects on healthcare workers have become a focal point of academic interest (e. g., Kahn et al. 2019; Kooij et al. 2022; Lebovitz/Levina/Lifshitz-Assaf 2021; Lebovitz/Lifshitz-Assaf/Levina 2022; Sergeeva/Faraj/Huysman 2020; Sergeeva et al. 2016), the rapid development of algorithms with autonomous functions calls for continuous, multidimensional research. This research is essential for understanding evolving technology practices, their impact on work, and the well-being of individuals, advocating for a human-centered digital transformation approach.

Furthermore, while technology can govern the responsible use of algorithmic systems (Datenethikkommission 2019), current frameworks often overlook involving key stakeholders in technology design and implementation, notably diverse employee groups and their representatives (Jobin/Ienca/Vayena 2019). To comprehend and navigate the implications of hospitals' digital transformation, it is essential to examine the entire socio-technical system involved, encompassing "all components of an algorithmic application, including all human actors, from the development phase

[…] to the implementation and application environment and the evaluation and correction phase" (Datenethikkommission 2019, S. 20).

The "Algorithms and Agency in Hospitals" project aims to understand the impact of digital transformation on the socio-technical hospital system, focusing on the experiences of nurses, physicians, and MTRAs. Emphasis is placed on the perspectives of different healthcare professionals and the representation of their interests to facilitate the "exchange of experiences and opinions of all actors interested in the facilitation of participation" (HBS 2017, S. 5).

The overarching objective of the project is to examine the evolving agency of actors in hospitals as technology and human work intertwine more closely. Key research questions address the effects of digital tools, like clinical documentation software and algorithmic decision support, on clinical workflows, work intensity, and workplace autonomy. Our research also examines the reciprocal influence between social practices and technology design, assessing employee groups' ability to represent their interests and participate in technology design and implementation processes.

For this purpose, two scenarios are scrutinized: 1) the use of clinical documentation software and 2) partial automation in radiological diagnostics, through empirical studies at Charité Berlin, Europe's largest university hospital, structured into two case studies. The first explores the use of a Critical Care Information System (CCIS) in the ICU, focusing on usability, agency, technology workarounds, and participatory design. The second assesses a clinical decision support system in radiology, analyzing its effects on diagnostic accuracy, workflow changes, and agency perception. We set the stage by outlining the research context before delving into the applied methods and findings.

1.1 Digital Transformation of Hospitals

Over the last two decades, hospitals have undergone a significant transformation with the swift and extensive incorporation of digital technologies. These advancements are designed to enhance the capabilities of healthcare professionals and introduce innovative methods for delivering healthcare services (Carboni et al. 2022; Iyamu et al. 2021; Sergeeva/Faraj/Huysman 2020). Examples include the implementation of telemedicine solutions (Dorsey/Topol 2020), algorithm-based decision support systems, and the transformation of paper-based health records into electronic formats.

Digitalization necessitates the formalization and standardization of work processes (Kleemann/Matuschek 2008; Staab/Prediger 2019), lead-

ing to a reconfiguration of work dynamics. This shift enables technology to exert finer control over individual tasks and workflows (Boes/Kämpf/Ziegler 2020).

The term “digital Taylorism” has been proposed to characterize the increasing utilization of work-related data for employee control purposes (Nachtwey/Staab 2015). Technology-mediated or (partially) automated workflows can limit possibilities and challenge our conception of individual agency (Schulz-Schaeffer/Funken 2008). Even when human action is not directly constrained or replaced, information systems (IS) can enforce compliance with pre-structured work processes, such as providing employees with feedback on their alignment with key objectives and standard practices.

Studies show that introducing new systems frequently correlates with increased work intensity and reduced personal autonomy, a key element influencing job satisfaction or dissatisfaction. In severe instances, this reduction in autonomy can lead to psychosomatic health problems (Meyer/Tisch/Hünefeld 2019). Contrary to expectations that technology would lessen the stress and high demands faced by healthcare professionals, an actual uptick in workload has been observed.

For instance, the introduction of CCIS, intended to support ICU practitioners (von Dincklage et al. 2019), has been identified as an additional stressor, especially when there is insufficient experience or time to use the system in accordance with standard operating procedures (Boonstra et al. 2021; Yusof 2015). The effects related to work intensification and the restriction of agency may vary among different groups of healthcare professionals, underscoring the importance of explicitly considering and contrasting various professional groups in our research project.

Hospitals feature a mix of highly specialized technical tasks, such as diagnostic activities, alongside tasks with lower levels of technical specification, such as caregiving (Bräutigam et al. 2017). Tasks related to interpersonal interactions are deemed to have a low potential for substitution as they cannot be easily delegated to technology. Some argue that while technology may not replace human work, rigid standardization could devalue the interactive, caring, and situational competences of healthcare professionals (Staab/Prediger 2019).

Additionally, digitalization and highly standardized work documentation capture only certain aspects of the expertise and work performance of healthcare professionals, as elements of emotional work, for instance, are often overlooked (Daxberger 2018).

In the healthcare sector, economization processes lead to paradoxical outcomes: they diminish and streamline the interaction between healthcare professionals and patients, yet simultaneously, they highlight patient

satisfaction as a key economic objective. However, patient satisfaction is significantly influenced by the emotional work that is now either eliminated or reduced (Giesenbauer/Glaser 2006).

The work situation of individuals is significantly influenced by the specific organization of digital work. In this context, the norms, values, and bureaucratic formalities of an organization play a crucial role in determining whether employees experience a form of digital Taylorism or a more qualification-oriented professionalization (Jacobsen 2018).

Simultaneously, the discourse must consider the impact of technology design and designability, the prevalence of social structures embedded within, and the degrees of behavioral freedom granted to users. Therefore, a socio-technical account is recommended to evaluate the distribution of work and agency between human and technical agents in digital work (Rammert 2003).

1.2 Digital Technology and Agency

Digital technologies, particularly algorithmic systems and artificial intelligence (AI), prompt new discussions on the subject of agency. In general, agency refers to “the basic component of all concepts that explore or explain who or what has or is attributed with the potential to act, or as to whose and what influence something is to be explained” (Helfferich 2012, S. 10).

In the context of workplace digitalization, the topic of agency revolves around determining who (human or machine) decides, controls, and executes the course of action. Within this framework, considerations of agency relate to the distribution of tasks and responsibilities in human-machine dyads and whether an employee’s behavioral freedom shapes the use of technology or is constrained by it.

As a general objective, technology should aim to support and complement human work and decision-making (Dewey/Wilkens 2019). Numerous studies demonstrate how digital tools can yield significant time savings and quality improvements in healthcare, including radiological diagnostics (Annarumma et al. 2019; Arbabshirani et al. 2018).

“Critical Algorithm studies” provide a critical reflection on the use of algorithmic systems and their influence on human behavior (e. g., Ziewitz 2016; Kitchin 2017). Risks associated with this include biases in algorithmic decision-making, over-reliance on potentially erroneous algorithmic outputs, and rigid control of employee behavior (Mikalef et al. 2022). However, it is emphasized that the impact of technology does not solely arise

from its features but emerges within the constitutive relationship between the human actor and technical systems (Pääkkönen et al. 2020).

Theory-related literature presents a multitude of perspectives on the relationship between technology and human agency, exploring how each influences the other. Situated between the extremes of rational choice theory and technology determinism, alternative viewpoints such as distributed agency between human and non-human entities have been deliberated (e. g., Latour 2005). In this perspective, technological artifacts encapsulate templates for action that are socially shaped and, whether intentionally or emergently, evolved (Rammert 2003). Humans are seen as agentic subjects capable of identifying and establishing meanings and uses of technology that may not have been intended by its designer.

For instance, employees may diverge from the standard practice of technology use by employing workarounds to cope with task-technology or task-resource misfits (Alter 2014; van Offenbeek et al. 2023). However, interpretations and uses of technology are not arbitrary but are framed by the degree of interpretive flexibility granted by the materiality of technology design (Carstensen 2014; Doherty/Coombs/Loan-Clarke 2006; Weigl et al. 2022).

Various alternative perspectives on the interrelationship between human and technical agency are provided, including the duality of structure (Giddens 1992), sociomateriality (Orlikowski 2000, 2007; Orlikowski/Scott 2008, 2013), and socio-technical accounts (e. g., Cecez-Kecmanovic/Kautz/Abrahall 2014; Leonardi 2011; Venters/Oborn/Barrett 2014). Each perspective carries distinct implications for whether and how a distribution of agency between human and non-human entities can be considered.

Consequently, the choice of how to conceptualize agency dynamics in human-machine (work) ensembles, while seemingly theoretical, significantly influences how we frame and investigate them. Given the current rise of increasingly autonomous and intelligent systems, including AI technologies capable of self-learning and proactive behavior, the revision of established notions of agency is warranted and is a current subject of scholarly attention (Baird/Maruping 2021; Meske/Kuss 2022).

As outlined in the subsequent sections, the technological tools investigated in our case studies lack elements of machine learning or capabilities for proactive action. Therefore, our analysis focuses less on the autonomy of AI systems. Nevertheless, even without AI elements, the intermediation of work by technology and the transfer of tasks to machines through automation significantly impact human autonomy. Consequently, our case studies emphasize the experiences of healthcare professionals as they navigate constraints, empowerment, or control by technology, along with

their capacity to influence the design and application of these technological solutions.

To establish a theoretical foundation for our case studies and to contribute to the continuous reassessment of concepts of agency, we have published a literature review as a component of this research project (Meske/Kuss 2022). The specifics of this literature study, encompassing its discoveries and conclusions, are elaborated upon in the subsequent sections.

2. Literature Study: Theorizing Agency in Socio-technical Systems

The advancement of digital technologies, including algorithmic technology and artificial intelligence, has sparked increased interest in the concept of agency. With the progressing capabilities of technical actants, fundamental questions emerge regarding the nature of agency and the entities capable of exercising it. A nuanced understanding of how agency is distributed and confined between human and technical entities is essential for comprehending the evolution of human-technology interactions and for realizing socio-technical work systems aligned with human interests and the values of good work.

Motivated by the need to reevaluate human-centric concepts of agency due to technology's increasing role in value creation and decision-making processes, we undertook an extensive review of literature on the notion of agency within Information Systems (IS) research and related areas of management and organizational studies.

Our findings reveal a conceptual and ontological incoherence in IS scholarship, with a persistent emphasis on human agency over technological agency. This hinders a differentiated analysis of agency dynamics in socio-technical systems, risking an incomplete understanding of the complex interactions between humans and technology within and across work processes. Consequently, we advocate for a rethinking of the concept of agency through a socio-technical lens, acknowledging the coexistence and intricate interplay of human and technological agencies.

Within the framework of our literature study, we scrutinized a total of 388 articles from 18 journals, adopting an inductive top-down theorizing approach (Shepherd/Sutcliffe 2011). Candidate articles were chosen based on their emphasis on developing the agency concept or employing it to explore other phenomena, such as the distribution of work between humans and machines. A research-in-progress version of the study was presented at the Conference on Information Systems 2022 (Meske/Kuss 2022). An expanded version of the research is currently under development for journal submission.

In the examined literature, we identified three broad perspectives on agency that differ, and in part, conflict concerning the constitutive elements of agency. These differences manifest in varying presuppositions of agenthood and the respective potentiality of each perspective to recognize non-human agency.

The first perspective grounds agency in entity properties such as consciousness, intentionality, or the capacity to maximize self-interest. The

second perspective views agency as expressed in entity behavior, encompassing the enactment of effects, discretionary behavior, or delegation. The third perspective describes a relational ontology of agency, which includes the aforementioned accounts of entangled human and technical agency as well as sociomaterial perspectives.

Conceptualizations falling into categories one or two often embody a narrow notion of agency, requiring specific properties or capacities for agency attribution. While providing a clear demarcation between entities with and without agency, this approach carries the risk of being overly restrictive. For instance, linking agency to the (currently) human property of consciousness does not offer a framework for considering the agency of algorithmic systems. Some works falling into perspectives one or two apply different definitions of agency to humans compared to technology.

These cases frequently imply a qualitative asymmetry between human and technical agency by grounding technical agency in the structuring properties of technology's materiality or automated action, whereas human agency is defined by the properties of reflexivity and intentionality.

On the other hand, the relational ontology underlying the third stream of literature risks being too broad and unspecific when it comes to intuitively perceived differences in the agency expression of humans compared to technical artifacts. Moreover, notions of entanglement or imbrication, which view socio-technical ensembles as constitutively inseparable, are inherently unsuited to conceptualize distributions and potential shifts between humans and technology.

In conclusion, we find that different perspectives on agency exist within our field of research, and each comes with specific shortcomings regarding their usefulness for differentially analyzing the distribution of agency in socio-technical ensembles. Our findings underscore the importance of refining existing theoretical frameworks, as highlighted in one of our project publications (Meske/Kuss 2022), to motivate a comprehensive consideration of agency conceptualizations.

3. Case Studies

3.1 Case Study 1: Critical Care Information System

The first case study delves into the utilization of a Critical Care Information System (CCIS) in the intensive care unit (ICU). A CCIS is a software system crafted to assist clinical staff in efficiently managing intricate clinical data and making data-based decisions (von Dincklage et al. 2019). Within the ICU, the CCIS is pervasive and employed in various workflows, encompassing treatment documentation, patient visits, and medication. Serving as a reliable, comprehensive repository of patient details and critical billing information, such as treatments and diagnostic procedures, the CCIS is also utilized for billing purposes, quality management, and research.

Given its central role in patient treatment and clinical administration, the accuracy and completeness of CCIS documentation are paramount. Compromised CCIS documentation poses risks to the quality of care, regulatory compliance, financial compensation, and legal safeguarding. Physicians and nurses are, therefore, required to strictly adhere to the prescribed standards for CCIS use.

CCIS are designed to assist physicians and nurses who often struggle with excessive workloads and tight time constraints. However, the inflexibility and time-consuming documentation enforced by CCIS are frequently perceived as an additional stressor by healthcare professionals (Boonstra et al. 2021; Yusof 2015). As a result, fatigue and frustration among clinical staff escalate, leading them frequently to devise workarounds to manage the challenges presented by the CCIS (Waqar/Mahmood/Ali 2023).

The initial case study delves into the impact of the CCIS on clinical workflows and the experiences of autonomy among healthcare professionals. It identifies challenges associated with system usability and examines ways to improve the CCIS's effectiveness as a clinical tool by incorporating the perspectives and interests of physicians and nurses in the technology's design and deployment.

At the examined ICU at Charité, the CCIS software "COPRA" has been in use for over a decade. The system is procured in a basic version from a commercial vendor and then customized in-house. A governance body, comprising representatives from nursing and medical services, is entrusted with the deployment and customization of CCIS. Physicians and nurses using the CCIS have the opportunity to provide feedback and sub-

mit change requests, which, upon approval by the governance body, are implemented by an internal IT developer.

Our discussions with both the IT developer and the senior physician chairing the CCIS governance revealed that internal capabilities to enhance the CCIS according to user needs are constrained by technical limitations of the basic systems, as well as time and budget constraints for customization and feature development. Adaptations relevant for billing or regulatory compliance are typically prioritized as they often stem from legal requirements.

3.1.1 Method: Usability Study and Ethnography

The first case study utilized a dual-pronged research methodology. In the initial phase, we conducted a usability study to evaluate existing user needs concerning the CCIS, the extent to which the CCIS aligns with these needs, and how technology design processes can be enhanced to create a system that optimally supports the work of clinical staff.

To address these inquiries, we conducted ten semi-structured interviews with clinical employees and two interviews with IT developers, each lasting approximately one hour. Throughout the interviews, the interviewer and interviewee collaboratively examined the CCIS, and screenshots were captured to illustrate usability issues. The interview transcripts were transcribed and coded using MAXQDA. Data from the usability study were analyzed through structured thematic content analysis following the approach of Kuckartz/Rädiker (2022).

In the second phase, we undertook an ethnographic study that included nine days of non-participatory observation, totaling 44.5 hours, complemented by 14 interviews that summed up to seven hours. Out of these interviews, ten were conducted with physicians or nurses, two with IT specialists engaged in the development and governance of the CCIS, and two with members of the hospital's staff committee who represent the interests of employees. During each observation day, we shadowed a nurse or physician throughout their shift, focusing on observing how doctors and nurses use the CCIS in their work practices and how the system guides and controls standard operating procedures.

Additionally, we paid attention to workplace characteristics in the ICU, such as time pressure and constant workflow interruptions, and their impact on CCIS utilization. Supplementary interviews with each observed individual provided deeper insights into their feelings and thoughts, allowing us to clarify observations. Field notes and interview recordings were transcribed and coded using MAXQDA. The ethnographic data were an-

alyzed through thematic analysis following the approach of Braun/Clarke (2006).

In both the usability study and the ethnography, we made a concerted effort to recruit study participants with a balanced representation of gender, occupational group, and level within the clinical hierarchy to ensure a comprehensive multi-stakeholder perspective.

Table 1: Overview of data collection Case Study 1

Tier	**Method**	**Details**
Usability Study	Qualitative, semi-structured interviews	12 interviews 4 nurses, 6 physicians, 2 IT developers
Observations	Non-participatory ethnography	9 shifts total of 44,5 hours
Supplementary Interviews	Qualitative, semi-structured interviews	14 interviews 5 nurses, 5 physicians, 2 members staff committee, 1 IT developer, 1 CCIS governance

Source: own presentation

3.1.2 Results Case Study 1

Our findings reveal that, generally, nurses and physicians do not feel an increase in work control stemming from the use of the CCIS. Rather, all participants recognized the importance of senior-level oversight as a crucial and integral aspect of the clinical hierarchy. The CCIS provides senior staff with a location-independent comprehensive view of all patient cases and workflows in the ward, assisting them in effectively monitoring their teams. A senior physician elaborates: “Of course, I review my residents’ documentation. That is my job.”

Nevertheless, both employee groups express feeling constrained and burdened by the CCIS when its design does not align with the needs of their practice. Prominent usability issues include certain documentation tasks requiring excessive clicks and, consequently, too much time. Moreover, certain pages fail to show all pertinent information, requiring users

to seek it in another system or to uncover hidden data fields. Also, the arrangement of information and functionalities is at times unclear, hindering efficient information retrieval.

User suggestions to enhance CCIS usability include integrating an extensive hospital-wide drug database to replace manual entry of all details, incorporating visual reminders such as color-coding to highlight relevant data fields, and adding an overview page displaying relevant record changes.

Additionally, participants called for making CCIS pages customizable on an individual basis and improving the logical arrangement of information, such as an alphabetic ordering of medication lists. Inadequate usability leads to frustration, heightened stress levels, decreased agency, and errors such as missed information or mistakes in medication orders and application. These feelings are exacerbated when individuals feel unable to participate in the processes of technology design and implementation. Conversely, all participants acknowledge that well-designed and integrated systems like the CCIS can simplify their work and free up time.

The examined CCIS features minimal automation, limited to functionalities such as automatic alerts, reminders, and ongoing monitoring of patients' vital signs like heart rate or pulse. Increased levels of automation, involving the system in diagnostic or treatment tasks, could significantly impact healthcare professionals' workflow. However, even at the current low level of automation, the CCIS shapes the practice of healthcare professionals through its design and predefined standards for system usage. Illustrating instances of individual agency, we observed that physicians and nurses occasionally deviate from the standards of CCIS use – a phenomenon described in the literature as workarounds (Alter 2014).

Workarounds are commonly conceptualized as users' response to solving task-technology misfits. On the one hand, workaround behavior can benefit the organization and employees by bypassing workflow obstacles. On the other hand, it can jeopardize regulatory compliance, outcome quality, and collaborative workflows (Alter 2014; Laumer/Maier/Weitzel 2017).

Particularly in safety-critical and collaboration-intensive work environments like hospitals, workarounds can be precarious. However, we noticed that it was not always misfitted technology design that led to workaround behavior. Instead, physicians and nurses frequently deviated in their CCIS use because they did not have the time, were interrupted, or had to cope with the demands of the taxing ICU work environment.

Motivated by this observation, we delved deeper into understanding how the specific characteristics of the ICU work environment shape technology utilization and, consequently, the behavioral agency of healthcare

professionals. functions in an environment characterized by substantial and interconnected resource limitations, including shortages of staff, time, and budget. Behavioral psychology informs us that such resource limitations can profoundly influence human behavior, including the utilization of technology.

In more detail, we applied the Conservation of Resources (COR) Theory (Hobfoll et al. 2018) to conceptualize the impact of overall resource availability on the use of workplace technology by employees. COR Theory posits that individuals in resource-constrained work settings may deviate from prescribed technology usage practices to optimize, compensate for, or adapt to the existing resource constraints.

Our observations revealed instances where nurses and physicians, confronted with interruptions and limited time, resorted to using paper notes during their workflows. They would later transfer this information to the CCIS, indicating retroactive documentation practices stemming from time shortages. Additionally, healthcare professionals employed online medication tools to supplement missing features in the CCIS, showcasing adaptive behaviors in response to resource constraints.

Our findings suggest that resource limitations in clinical work settings are a significant catalyst for the adoption of technology-related workaround behaviors. Workarounds, in this context, represent a proactive response to task-resource misfits that place excessive demands on healthcare professionals. However, this workaround behavior can potentially exacerbate existing resource shortages.

For example, when workarounds result in retroactive or omitted CCIS documentation, the reliability of the system as a source of accurate information diminishes. Participants mentioned that they often feel compelled to personally verify critical data, leading to a loss of time and additional workflow interruptions. Incomplete or omitted documentation also poses financial risks for the hospital, as records may lack billing-relevant information. Therefore, these workarounds can further strain budget limitations, reducing the hospital's ability to enhance IT infrastructure or hire additional staff to mitigate the workload pressures resulting from a scarcity of clinical personnel.

To prevent a cascading depletion of resources and to ensure technologies like the CCIS effectively support healthcare professionals, tackling the prevailing resource constraints in hospitals needs to be elevated to a priority at both the managerial and political levels. Practically, this means enacting strategic initiatives to secure adequate funding for technological infrastructure and encouraging cooperation among policymakers, clinical management, and practitioners. Such collaboration is crucial for creating

a regulatory framework that protects clinical resources from being undermined by economic constraints.

Additional suggestions for enhancing the usability of the CCIS and guaranteeing its contribution to value are detailed in the following sections.

3.2 Case Study 2: Radiology Decision Support System

The second case study delved into an algorithm-based support system designed to enhance diagnostic capabilities for prostate cancer in magnetic resonance imaging (MRI) radiology. Beyond assessing technology usability, acceptance, and helpfulness, the study focused on examining the system's impact on individual agency and established workflows in radiology departments. Prostate carcinoma is the most prevalent cancer among men, and the diagnostic process involves a personalized approach based on individual risk factors, alongside standard procedures such as digital rectal examination and prostate-specific antigen blood tests (Mottet et al. 2021; Naji et al. 2018; Szeliski et al. 2018).

To assess the aggressiveness of cancer lesions, biopsies are commonly performed despite being invasive and posing potential risks (Borghesi et al. 2017; Derin et al. 2020; Enzinger et al. 2023; Perán Teruel et al. 2020). These procedures are usually guided by imaging techniques, such as transrectal ultrasound or MRI. Even with imaging guidance, routine systematic 12-core biopsies are carried out alongside targeted biopsies of notable lesions. The grading system, according to the International Society of Uropathologists (ISUP), categorizes ISUP 1 lesions as non-significant and ISUP 2–5 lesions as clinically significant.

The invasive nature of current diagnostic practices prompts ongoing research to refine prostate cancer imaging and diagnostic pathways. Multi-parametric MRI, utilizing the current guidelines-based Prostate Imaging Reporting and Data System Version 2.1 and adding fractal analysis (FA) of perfusion, shows excellent diagnostic accuracy for identifying prostate cancer lesions and can be exploited for accurate tumor grade prediction (Michallek et al. 2022a, 2022b; Turkbey et al. 2019).

FA, a quantitative imaging tool, is recognized for its effectiveness in depicting perfusion in various organs, including the liver and the myocardium. It utilizes the fractal dimension as a quantitative parameter for perfusion chaos (Michallek/Dewey 2014; Michallek et al. 2022c; Michallek et al. 2022d). In the context of prostate cancer diagnosis, FA has demon-

strated its value in predicting ISUP grade groups, establishing a link between quantitative parameters and pathology.

Despite the potential of FA and AI in prostate cancer diagnosis, their clinical implementation has been limited, particularly regarding the impact on work control and agency among radiologists, radiology technicians, and urologists. Therefore, our study aimed to pilot the implementation of FA with simulated AI-supported lesion segmentation and evaluate its clinical value in enhancing non-invasive grade prediction. The study also sought to investigate the influence of FA and AI on the work control and agency of healthcare professionals, including radiographers, urologists, and radiologists, across three university hospital centers.

3.2.1 Methods: Simulation Study Radiology

The investigated system, based on FA, supports radiologists in the classification of prostate cancer using MRI images. In the typical MRI-based prostate classification process, radiologists review a sequence of tissue images and assign a score to each, indicating the likelihood of it being cancerous. The cumulative ratings across all images for a patient are then used to calculate the probability and likely location of cancerous tissue. This information guides pathologists in taking targeted tissue samples for further analysis. However, there is a desire for non-invasive diagnostic solutions to eliminate the need for invasive tissue sampling.

FA, as a method utilizing image processing to analyze blood circulation in imaged tissue, offers a solution. Cancerous tissue exhibits distinct patterns of blood flow, allowing confident diagnosis based on MRI images without invasive tissue sampling. The investigated tool automates FA, providing radiologists with MRI images where areas of unusual blood circulation – indicating a high likelihood of cancerous tissue – are marked with color indicators.

While radiologists primarily use this tool, its potential implementation as a standard for radiology diagnostics could also impact the workflows of other employee groups, such as Medical Technical Radiology Assistants (MTRAs), responsible for administering the contrast agent necessary for FA. Both employee groups were included in our assessment, and it's important to note that, at the time of the study, the investigated tool had not been implemented, hence our research approach utilized a simulation study.

Our study included 53 healthcare professionals, encompassing seven radiographers, ten urologists, and 36 radiologists from three university hospital centers. The participants were presented with prostate lesion

cases from the ProstateX challenge dataset, which included cases with International Society of Urological Pathology (ISUP) grade groups. The questionnaire consisted of three parts: I) an objective section requiring assessments of lesion significance and ISUP grades, II) a semi-objective section with Likert scale questions on FA in the diagnostic workflow, and III) a subjective part with open-ended questions.

3.2.2 Results Case Study 2

Our objective results indicate that FA significantly enhances diagnostic accuracy compared to traditional image reading. By incorporating FA into the reading process, sensitivity for identifying clinically significant prostate cancer lesions increased from 79 percent (95 percent confidence interval [CI]: 76 percent to 82 percent) to 93 percent (95 percent-CI: 91 percent to 95 percent), and specificity increased from 31 percent (95 percent-CI: 24 percent to 38 percent) to 88 percent (95 percent-CI: 82 percent to 92 percent).

Furthermore, there were no significant differences between urologists and radiologists in correctly identifying clinically significant lesions when incorporating FA (urologists 91 percent, radiologists 93 percent, $p = .502$) compared to image reading without FA (urologists 71 percent, radiologists 69 percent $p = .758$).

Semi-objective assessments, gathered through Likert scale questions, reveal positive views on the visual representation of FA and its potential to enhance diagnostic workflows. Notably, less experienced physicians, including both radiologists and urologists, appreciated the guidance provided by algorithm-supported FA.

In the subjective responses, participants provided deeper insights into the perceived impact of FA and algorithms on agency: Radiographers acknowledged the ease of performing FA without interference in their work rhythm, anticipating improved collaboration with radiologists and urologists. Urologists emphasized the importance of validating algorithm-supported FA and considered it a valuable adjunct to biopsy.

Radiologists, while cautious about the suggested ISUP grade predictions, expressed openness to algorithm-assisted quantitative imaging based on FA and appreciated the intuitive representation of perfusion pathophysiology by FA. Overall, healthcare workers viewed FA positively, anticipating improved diagnostic certainty, decision-making, and working relationships.

While acknowledging the study's limitations, including a relatively small sample size from three different centers, it represents an initial step in

comprehending the impact of algorithm-supported FA on healthcare professionals' work control and agency in prostate cancer diagnosis. The findings emphasize the clinical value and acceptance of algorithm-based FA in enhancing diagnostic workflows and supporting healthcare professionals across different expertise levels. Future research, with larger cohorts and longitudinal assessments, could further validate these findings and explore additional aspects of AI and quantitative imaging, such as FA, in clinical practice.

4. Conclusion and Recommendations for Action

This research project sought to understand how digital technology, encompassing clinical documentation software and algorithm-based decision support tools, influences the work of healthcare professionals and how their interests can be integrated into the digital transformation of hospitals.

The findings reveal a dual role for digital technologies in healthcare, serving both as supportive tools and potential sources of increased workload for healthcare professionals. In Case Study 1, clinical software systems like the Critical Care Information System (CCIS) were generally viewed positively by healthcare professionals, acting as helpful tools without inducing feelings of being controlled by or through the system. However, usability issues posed challenges, impacting workflows and contributing to heightened work intensity and frustration among clinical staff.

The study underscores the importance of user-centered design for both commercial vendors and in-house IT teams involved in customizing clinical software. This necessitates considering the specific interests and needs of diverse user groups, involving structured, iterative usability testing, and fostering a close collaboration between manufacturing companies and deploying clinics. Establishing effective feedback mechanisms is crucial to continuously monitor user needs and address usability challenges promptly.

The extensiveness of documentation requirements, as observed in systems like CCIS, emerged as a significant burden for healthcare professionals. This burden was further intensified by a lack of interoperability between different systems and technical equipment, leading to manual data management and duplicate documentation. The study emphasizes that for optimal support of clinical work and the avoidance of additional workload, digital tools must prioritize interoperability and mutual complementarity. Technical solutions, including systems like CCIS, should be developed with a comprehensive understanding of clinical workflows and a consideration of all existing technical systems within a ward.

In addition to technology design, the usability of a system is contingent on individuals' knowledge of how to use the system effectively and skillfully. Therefore, employees need sufficient training and opportunities to practice system use in low-stakes scenarios. The suitability of different training formats must be evaluated, and employees must be aware of and given the time to engage with them.

For example, in the case of the investigated CCIS, the provided self-training tutorials were perceived as overwhelming. Moreover, employees frequently did not know that the training material existed or reported having no time to engage with it during their shifts. Consequently, employees' ability to learn to use a system efficiently requires ongoing training opportunities and sufficient time and energy to engage with them.

The availability of resources also influences the extent to which clinicians use technology in accordance with prescribed practices. In alignment with psychological research on the behavioral impact of resource availabilities, our observations indicate that shortages in time, personnel, and suitable technology incentivize employees to diverge from the prescribed standards of technology use. Described as workarounds, this behavior constitutes an expression of agency, illustrating users' freedom to, to some degree, flexibly interpret the action potential offered by technological artifacts and influence practices of workplace technology use.

However, considering the critical relevance of CCIS data accuracy and completeness for clinical workflows and managerial processes, including billing and quality management, respective deviations risk a spiraling depletion of clinical resources. Besides aligning technology design with user needs, digitalization initiatives must therefore ensure that healthcare professionals have sufficient resources to employ technical tools as envisioned and prescribed. This is critical for digitalized clinical work environments in a way that sustainably improves the quality of care and employee well-being.

Case Study 2 focused on the integration of a fractal analysis (FA) and artificial intelligence (AI) support system designed to enhance prostate cancer diagnosis through MRI images. The study explored the impact of this system on diagnostic accuracy and workflows for healthcare professionals across three university hospital centers, emphasizing non-invasive grade prediction and considerations for work control and agency.

The findings revealed a substantial enhancement in diagnostic accuracy with the incorporation of FA. The inclusion of FA increased sensitivity and specificity in identifying clinically significant prostate cancer lesions. Notably, there were no significant differences between urologists and radiologists in correctly identifying significant lesions with FA, indicating its applicability across different healthcare professional groups.

Semi-objective Likert scale assessments reflected positive perceptions regarding the visual depiction of FA. Particularly, less experienced physicians, including both radiologists and urologists, appreciated the guidance provided by AI-supported FA.

Subjective insights into the impact on agency revealed varied perspectives. Radiographers acknowledged the ease of incorporating FA into their

workflow without disruption. Urologists considered AI-supported FA a valuable addition to biopsy procedures, emphasizing the need for validation. Radiologists expressed openness to AI-assisted quantitative imaging based on FA, appreciating the intuitive representation of perfusion pathophysiology. Participants anticipated several benefits, including improved collaboration among healthcare professionals and enhanced diagnostic certainty, decision-making, and working relationships.

Building on the positive outcomes, recommendations for the clinical implementation of AI-supported FA in prostate cancer diagnosis include the initiation of training programs for healthcare professionals. These programs aim to prevent misinterpretation of results and potentially negative effects on work control, such as the perceived patronization of the system. Addressing concerns or reservations expressed by radiologists and urologists regarding ISUP grade predictions through education is identified as another important aspect.

In conclusion, the results suggest that the integration of AI-supported FA holds promise for positively impacting prostate cancer diagnosis. However, the implementation should be approached with a focus on training, collaboration, and ongoing research validation to ensure its successful integration into clinical practice.

This research project illuminated the intricate dynamics between digital technologies and healthcare professionals, underscoring the importance of meticulous design, usability testing, and interoperability. These steps are crucial to ensure that such technologies truly augment, rather than impede, the work of healthcare professionals.

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ISSN 2509-2359