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Designing with Awareness: Building an Agenda for Worker and Patient Well-being

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Abstract. Awareness technologies are a core interest for CSCW: when people pay attention to each other's actions, they have less need to communicate with each other to accomplish hospitals' complex, cooperative work. In Denmark, healthcare workers (HCWs) and patients face challenges with the architectural design of new super hospitals, which are designed to optimise the care and efficiency of healthcare services. A concrete challenge is how the new design of single-patient rooms, as opposed to traditional multi-patient rooms, will change the workflows and affect the patients and HCWs. HCWs' well-being is at risk when they have to attend to more rooms and the risk of adverse events increases. Similarly, the patient's well-being is at risk when they feel lonely or neglected in a single-patient room. In this paper, we propose an agenda for awareness technologies designed around both worker and patient well-being. We examine through prototyping an awareness technology, iAware. The solution draws together insights from a long-term ethnographic study on how to responsibly design sensed environments. We identified 4 openings for supporting patients' and HCWs' mutual awareness of workflows: 1) progress of HCWs 'ward rounds'; 2) patient 'visits' by HCWs; 3) patient 'calls' and 4) patient 'mobility'. We end with concluding remarks on how sensed environments can be designed to support HCWs' and patients' well-being.

Introduction

Sensed environments are increasingly explored to support awareness at a low cost. In hospitals, sensed environments typically involve the usage of sensors for creating awareness of patient vitals (i.e., physical health). Several studies, e.g. Andersen et al. (2020), explore how sensor data (e.g., patient activity data) can support clinical decision-making by providing an alarm for heart attack risk before its occurrence. Sensors have been used to assess patients' well-being as measured by their heart rate, blood pressure, and other vital metrics. Another perspective on well-being is patients' feeling of safety. Research in this area has primarily focused on patient well-being measured as the occurrence of adverse events (patient falls, pressure ulcers, and deep vein thrombosis) (Søndergaard, 2021). Other ways to measure patients' well-being are, for example, if they feel lonely or neglected by the HCWs (ibid).

HCWs' experience of sensor tracking as 'surveillance' is also a risk and relevant consideration. Recent studies of workplace tracking show that reliable data requires workers to accept, and not actively resist or subvert, tracking (Harper et al., 1992; Gorm and Shklovski, 2016). Another study of sensor tracking in healthcare reported that sensor tracking was acceptable to HCWs only if: (1) they could influence what is tracked; (2) they knew the intentions for data tracking; and (3) they could contest and correct tracking results (Holten Møller et al., 2017). This research demonstrates that tracking in the healthcare workplace is widespread. Increasingly the questions put before researchers and designers are not whether or not such data are acceptable but rather how to help stakeholders with different interests understand their roles, rights, and responsibilities in sensed environments (Kristiansen et al., 2018).

In this paper, we propose a CSCW agenda for HCW- and patient *well-being* through the design of sensed environments. The concept of well-being is defined in many ways but overall refers to the emotional and affective aspects of care (Andersen and Fritsch, 2018). We draw on insights from a long-term ethnographic study (+5y) of how to responsibly design sensed environments (Holten Møller et al., 2017). We present empirical findings from a recent study (March 2022) identifying that: (a) there is a risk of missing or losing critical information on patients due to a practice of storing information physically in the patient room; (b) Physical documents support an overview of working tasks and patient matters, resulting in sensitive knowledge being lost or forgotten and the risk of adverse events occurring; (c) Complexity of diversity: Patients are cognitively and socially at very different stages, which must be considered in communication systems to include all patients; (d) Physical interaction between patients and HCWs is prioritised as a form of care in order to foster safety and well-being. (e) HCWs express concern about the increasing level of documentation demand and systems

to handle at the expense of physical care and face-to-face contact with patients.

Currently, in hospitals in Denmark as well as the UK and other countries, the well-being of HCWs and patients is a growing concern for researchers (Ooms et al., 2022). The British state-run National Health Service is in crisis as thousands of nurses are leaving their jobs (Ravikumarand, 2023). Poor wages during the last decade have contributed to thousands of nurses fleeing from their profession, impacting patient care and working conditions for the remaining HCWs. Millions of patients are left waiting for treatment and are unable to receive prompt emergency care (Ravikumarand, 2023). HCWs face working conditions they describe as "unsafe and unworthy" (Jensen, 2023). The situation calls for technologies designed for the well-being of HCWs and patients.

Related work

In CSCW, there is an increasing interest in how work tracking can contribute to HCWs- and patients' well-being, especially how data can support the communication and interaction between HCWs and patients, with concern for the relational complexities of the healthcare domain (Kaziunas et al., 2017; Karusala et al., 2021; Devito et al., 2019). Many have studied sensor data tracking, gathering wearable tracking data from HCWs (Neff et al., 2017; Chung et al., 2017; Holten Møller et al., 2017, 2021; Iversen et al., 2020; Stangerup et al., 2021; From-Hansen et al.). The understanding of how sensor data and architectural designs are interlinked, specifically concerning workflows and HCW acceptance of sensor technology is well documented, e.g. by Holten Møller et al. (2017).

Despite the research focus on HCW and patient interaction, in practice sensed environments largely focus on data about patient vitals as one-way information (Andersen et al., 2020). Relatively few studies in CSCW sensor data tracking studies focus on the holistic role of data to support HCWs and patients' well-being, awareness, and emotions (Tang et al., 2015) . An aspect of sensor data that explores the understanding and development of data output, focusing on qualitative 'care' data, and data that address (patient and HCW) emotional aspects. Andersen et al. (2020) and Lomborg et al. (2020) report a study of patient's well-being during a self-tracking of data related to their heart condition. Patient's well-being in CSCW is typically addressed in relation to personal tracking (Devito et al., 2019), people's capacity to deal with their health (Light et al., 2015), and politics of care (Boone et al., 2023; Lomborg et al., 2020).

Sensor data provides insights into the flow of work of HCWs (Holten Møller et al., 2021) and it has the advantage that it does not require any human interaction such as 'clicks' to produce data. Hockenhull and Cohn (2021) explore the role of dashboards in designing alternative data visions to better understand and support cooperative work. They suggest "changing dashboards from devices that focus on

matters of fact to things which can help in articulating matters of concern" (Hockenhull and Cohn, 2021). Mutual awareness between HCWs and patients is a well-known design strategy; however, more research is needed on how sensor tracking impacts work and well-being from both an HCW and patient perspective.

Mutual awareness is tricky to design and not without issues as a theoretical concept (Schmidt, 2002). The concept of awareness as introduced by Gutwin and Greenberg (2002) describes how tasks are brought to others' attention in an organisation. Awareness supports cooperation in contexts where people share a workplace or space (Dourish and Bellotti, 1992). Workspace awareness is defined as: "up-to-the-moment understanding of another person's interaction with the shared workspace." (Gutwin and Greenberg, 2002). When designing for mutual awareness, the participation of HCWs and patients is important for testing the shift of workflows in natural settings (Bossen and Foss, 2016). According to Schmidt (2002), the challenge with awareness in cooperative work is to understand how actors effortlessly detect what is going on around them and make sense of it. Awareness in cooperative work emphasises the potentially unconscious attention towards the work of others. In successful awareness, the collaborating parties support a larger goal and integrate their activities based on a deep knowledge of the environment in which they act. Successful awareness includes a key understanding of how activities are connected as well as the likeliness and potential consequence of a given situation. Hence, a situation can effortlessly make sense.

Designing for awareness is fundamentally about finding ways to convey the sense of HCW work as it unfolds (Paul and Reddy, 2010) and patients' well-being, impacting the ongoing prioritisation (Andersen et al., 2020).

Case and Method

Our research was conducted as part of a long-term ethnographic study on the architectural design of Danish super hospitals between 2015-2021, following principles of contemporary data studies research (Blomberg et al., 1993; Blomberg and Karasti, 2013). The empirical setting is primarily sensor data tracking studies of gathering wearable tracking data from HCWs (Holten Møller et al., 2017; Stangerup et al., 2021; From-Hansen et al.) The research took place at an existing hospital - to be a new acute care hospital as part of a process of modernising and building hospitals in Denmark. The hospital is a fully functional hospital of historical and architectural importance, inspired by English Pavilions with recreative gardens. The existing hospital is fully functional but to be a 'new' acute hospital in Denmark, the building will develop with integrated new buildings.

Our team was part of a project to inform hospital designers and management about workflows and the design of physical workspaces, and to study the processes around planning a future super hospital (Holten Møller et al., 2017, 2021). This

paper also draws on a recent field study - an observation and participatory workshop conducted in March 2022. This field study took place at the same hospital as our long-term ethnographic study. This hospital is an interesting case for data tracking because people are currently working there while the new super hospital is under construction. The new super hospital will transition from having multi-patient rooms to having only single-patient rooms, entailing significant change in HCW workflows (Møller and Bjørn, 2016; Møller et al., 2017). With single-patient rooms, the HCWs oversee the same number of patients but over a greater distance, which is expected to result in fewer HCW-patient interactions and an increased risk of adverse events for patients, such as falls while not being observed and feeling lonely or even forgotten.

The participation and engagement of HCWs and patients in this study is critical. That is for an ethical approach to learning how relevant stakeholders with differential power perceive intentions when capturing data on care as a basis for our research. We apply participatory design methods for "collective sensemaking" (Holten Møller et al., 2021), a type of worker contestation of datasets with the subjects of that data, for use with the results of our sensor data analysis.

We developed a concrete prototype of scenarios for supporting awareness and well-being through sensor data. The scenarios that we prototyped were informed by and identified based on a long-term ethnographic study of the mentioned future super hospital (Holten Møller et al., 2021; Møller and Bansler, 2017). Following this, a two-day observational study was conducted in March 2022, including a participatory workshop with nursing HCWs in a hospital department with experience with sensor tracking and relevant knowledge of the layout of the future single-patient rooms. We identified mutual awareness of workflows and the well-being of patients and HCWs as critical issues for the future super hospital where single-patient rooms will be the norm. We discussed this focus and the prototype with the design team of the super hospital as well as the innovation officer.

The research prototype was developed to accommodate learning from the ethnographic studies related to mutual awareness. We aimed to apply a qualitative research method that could explore the HCWs' understanding of awareness of the workflow in multi-patient rooms versus a single-patient room. We developed a research design for a participatory card sorting workshop (Nawaz, 2012) in which HCWs were invited to debate and actively reflect on their work practices. The field study in March 2022 consisted of following and observing the HCWs during their daily work activities. The HCWs were invited for an unstructured discussion over the initial sketches of iAware.

The card sorting workshop was held in the HCWs' lunchroom (March 2022), as a constant flow of HCWs would stop by for a coffee break. The workshop

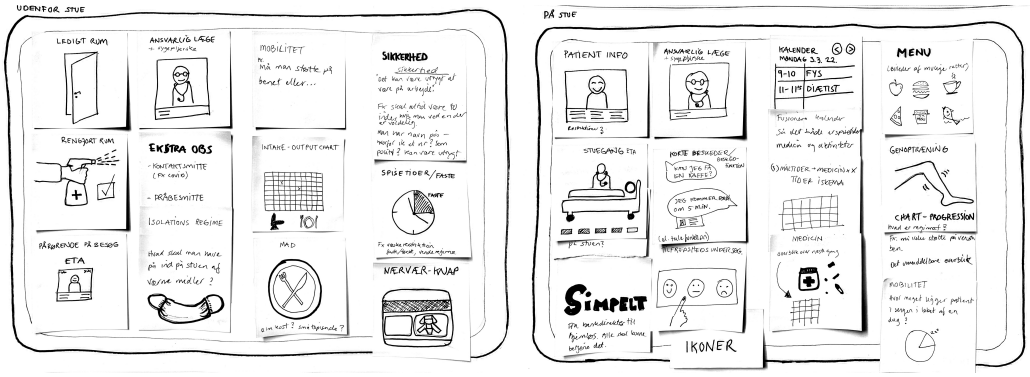

Figure 1. Designing with awareness through a participatory workshop with nursing HCWs. Cardboard sheets illustrated as a tablet dashboard - together with post-its, blank as well as predefined post-its with icons and sketches illustrating themes and situations in a hospital ward. The left-side prototype displays nursing HCWs' input for important components and topics on a dashboard outside the patient room. The right-side prototype displays the nursing HCWs' input for a dashboard inside the patient room.

consisted of two A3-sized cardboard sheets illustrated as a tablet dashboard, along with post-its both blank as well as predefined with icons and sketches illustrating themes and situations in a hospital ward (See Fig. 1). This analogue dashboard acted as an empathy probe (Mattelmäki, 2005) to engage more deeply and support conceptualisation for the HCWs. Moreover, as an exercise to invite HCWs to interact with thematic content from the previous study. When HCWs entered the room, they were all curious about the cardboard sheets and sketches on the table, which quickly enabled a dialogue between HCWs' sharing experiences and opinions about work practices and care for patients. The familiar visualisation space (Hockenhull and Cohn, 2021) of the analogue tablet dashboard led to debate amongst the HCWs. More themes were added during the ongoing discussion as HCWs entered the lunchroom during the day.

Fifteen HCWs, mainly nurses and a few physiotherapists, participated in the workshop during the two days, with some HCWs participating more than once. A broader spectrum of HCWs would have been preferable, however, in this field study, this was our resource. The next step in our research would be to engage with HCWs across professions. Drawing from Andersen et al. (2019), we propose a patient-centred approach where both patients (and their relatives) together with HCWs explore, experiment with, and evaluate (Andersen et al., 2019) divergent needs and concerns with the aim to support both HCWs and patients well-being.

Our workshops were conducted by posing unstructured questions to HCWs in relation to the material. Themes and questions, i.e., "how do you orient yourself before entering a patient room?" During the workshop, the HCWs' reflections were documented by taking ethnographic notes, sketching and illustrating post-its according to the input from HCWs, and collecting physical template papers that supported nurses during their work. The process was also captured in photographs.

Findings were thematically analysed (Bryman, 2016) to inform conceptualisation and operationalisation in future work.

Findings: Awareness of Care Workflows

Data-driven solutions for coordination and collaboration are a long-standing interest in support of hospital workers amongst researchers. In current Danish hospitals, coordination rooms located centrally in a ward support staff coordination of work across patient rooms. However, single-patient rooms in the new super hospitals will impact the workflow, in particular with regard to HCW infrastructure, coordination, and orientation. Moreover, it will also affect the awareness and overview of the hospitalised patients as well as the well-being of the patients.

In our study of the transitory process of becoming a new super hospital, we found some topics addressed by the HCWs as critical aspects of care and awareness. Namely the risk of missing critical information on patients due to the practice of keeping information artefacts in a physical way in and outside specific patient rooms. Patients with regimes such as isolation have a physical file holder containing documents next to the patient room entrance, as well as a wooden block inside the room to indicate their specific regime. These artefacts are at risk of being lost or overlooked by HCWs as well as relatives. Another topic concerns the general overview of working tasks and specific patient matters. Physical documents with handwritten notes regarding patient issues support HCWs' in keeping an overview of patients during their workday. The overview is limited and knowledge is devalued. Yet another topic surfaces from the HCWs' experience of the cognitive and social diversity of patients. The HCWs emphasise the need to include patients that are cognitively impaired and patients that can not read or understand the local language. All communication systems for patients must be intuitive and as simple as a button with a recognisable icon to support the inclusion of a diverse spectrum of individuals. HCWs point out that "contact fosters comfort and dignity," making (physical) interaction between patients and HCWs an essential aspect of care and acknowledging the patient as a holistic human being. HCWs also raise the concern of an increasingly comprehensive level of documentation demand and systems to handle at the expense of physical care and face-to-face contact with patients.

The Super Hospital as a Basis for Redesigning the Workplace

Super hospitals are designed to optimise the care and efficiency of healthcare services. New forms of data support HCWs in decision-making to ensure patients' needs are met, and to spend resources efficiently while coordinating their work across patients. In this context, sensor tracking of HCWs is considered. A concrete challenge is how the new design feature of single-patient rooms (as opposed to

traditional multi-patient rooms) will affect patients and HCWs (Møller et al., 2017). The awareness required by single-patient rooms (Søndergaard, 2021) has been shown to increase the risk of adverse events for patients, decrease patient satisfaction and mental well-being, and contribute to HCW burnout. Experiences from the first super hospitals in Denmark have shown that patients in single-patient bedrooms feel more isolated and disconnected from the staff. Given the increased distances between patients in the newly built hospitals, HCWs make fewer patient visits (ibid).

Sensed environments enable care for a broad group of patients with varying capabilities. Not all are capable of patient self-services (Nunes et al., 2015) or navigating waiting times for scheduled services (Lorenzetti and Noseworthy, 2011). In a hospital setting, HCWs shuffle and re-shuffle queues of patients in the day-to-day activities of their workflow. Both from a patient and HCW perspective, there is a need for actively exchanging information. Once a patient is admitted, the prioritisation of resources only appears to patients and their relatives when communicated explicitly (typically verbally) by the HCWs in person. For example, an HCW might explain how long the patient should expect to wait for doctors as they do their ward rounds. This implicit negotiation of patients queuing for ward rounds, cleaning, etc., is a crucial part of making the context and the provision of hospital services (Holten Møller and Bjørn, 2011; Møller and Bjørn, 2016).

Designing dashboards to support awareness and well-being

To establish an overview of workflows for coordination amongst HCWs, data can enable and support the decision-making to ensure patients' needs are met. Moreover, it can be helpful in assisting HCWs to spend resources efficiently while coordinating their work across patients. However, it is a matter of concern (Bødker et al., 2017) in sensitive settings such as healthcare.

Our ongoing study informed an iterative process of designing and prototyping data to support HCW workflows and HCW and patient well-being. The research team started working on how to operationalise the sensor data of movement, location, and interaction in a way that accommodates both the HCWs and patients according to the overall research project goal of exploring how data can be used with concern for the relational complexities that are characteristic of the healthcare domain. Sensor data could in this context be used to answer questions like: "Where is my patient?" or "When is the doctor coming to see me?

Based on the insights from our card-sorting workshop, the analogy of a window between the patient room and the ward was discussed as a metaphor for creating mutual awareness. In order to do so, and to relate the conceptualisation to a familiar setting, we applied the identified topics and relevant features to a visual board. The board depicted an interface for the HCWs - to be in the ward, and the

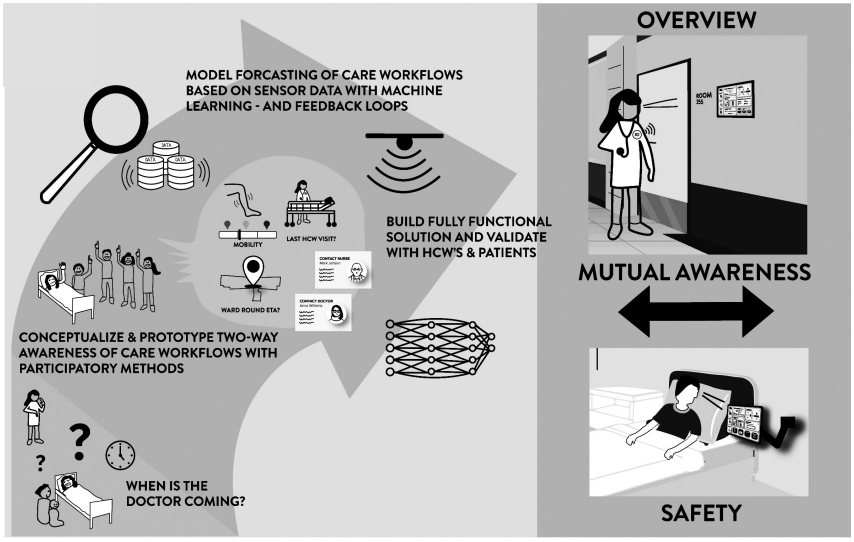

Figure 2. Designing for awareness: The figure depicts our identified topics aiming to support both patients' and HCWs' mutual awareness of workflows in the hospital ward. The concept is based on sensor data with machine learning and feedback loops..

patients - to be in the patient room.

Employing dashboards to support mutual awareness among HCWs and patients is based on the idea of using a recognisable space that the HCWs already refer to in their everyday work. iAware is not assuming the centralised information boards that are now located in coordination rooms. The familiar visualisation space (Hockenhull and Cohn, 2021) of the analogue tablet dashboard facilitates a shared understanding. While displaying relevant information on a single screen to be studied "at a glance" (Few, 2006), it draws attention to shared as well as diverging topics in what sorts of data to support team activity and coordination among HCWs. Using integrated interactive dashboards placed along the work paths of the HCWs and inside patient rooms can benefit both HCWs and patients and acknowledge the objectives as two-fold: 1) to optimise the workflow of the HCWs; and 2) to improve information exchange through mutual awareness and well-being of patients and HCWs (See Figure 2).

Movement tracking using sensor data may be used to explore complex and highly context-dependent workflows to produce new understandings of, for example, patients' needs for awareness (Kumar et al., 2020), and to redesign future workflows (Holten Møller et al., 2021). It is only recently that machine learning with sensor data has been applied in healthcare settings, and often only for specific monitoring tasks, rather than for the complex workflow that we aim to do with our concept, iAware. Sensor data have become available with the widespread use of mobile phones and wearable sensors for detecting human-building interaction in addition to the interaction between people. Prior work on machine learning in

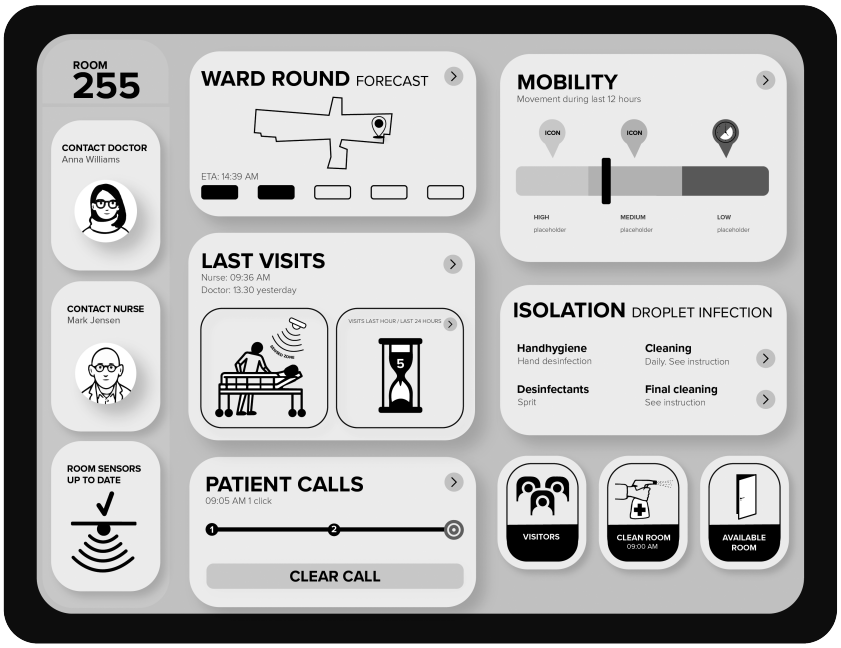

Figure 3. The figure shows awareness dashboards for HCW overview installed in the hospital ward at each patient room entrance. Data is collected from a wearable HCW beacon and sensor zones in the patient room. The dashboards replace centralised information boards in the coordination rooms and provide the HCWs with relevant GDPR-safe information they can see "at a glance" during their workflows.

hospital settings has almost solely focused on electronic patient records or vital data (Andersen et al., 2020), with scarce work on sensor data (Yu et al., 2021). In contrast, iAware will use time series analysis of sensor data to: (i) dynamically forecast and display estimated times for ward rounds in single-room wards; and (ii) gently nudge patient movement patterns based on prior data to facilitate well-being and recovery. While not necessary for iAware, both (i) and (ii) may be enriched and improved by data extracted from electronic health records (EHR), strictly keeping data in the local ward.

To facilitate knowledge management as well as support coordination of work and team awareness, dashboards as artefacts of displaying and organising data are relevant in CSCW. Following Hockenhull and Cohn (2021), studies of dashboards within CSCW have mainly focused on them as devices to investigate particular measurable goals. However, we expand to a broader holistic study of how dashboards can affect other practices in a hospital ward work setting, including both patient and HCW awareness and well-being.

Our solution iAware ensures that HCWs workflows are optimised by implementing dashboards along their work paths, i.e., they do not have to walk back to the centralised coordination room to switch off alarms or find information

about their patients. The HCWs will receive relevant information when they need it during their workflows. To address the probability that the nearest HCW may be occupied with other duties, we point out that this study is exploratory and still in the early phase. We look to Bossen and Foss (2016) suggestion for work tracking; this solution enables the porters to view and assign themselves tasks via a smartphone. The display of worker status and assignment of tasks, where the worker can influence their tasks seems relevant to study further in our context.

iAware, includes: 1. predictive ward round forecasts to inform HCWs in their workflow on ward round progression and to minimise patient calls; 2. patient movement analyses (timely mobility and fall prevention); 3. smart nurse rounding registrations (timely patient visits); 4. automated registrations of cleaned and available rooms. (See Figure 3)

Finally, to capture both movement, location and interaction activity, we note every combination of room number and contact with a specific employee category. Sensor data will be automatically analysed by state-of-the-art machine learning (ML) (Berthold et al., 2009; Bishop and Nasrabadi, 2006) algorithms that will be adapted and refactored to provide two distinct, actionable outcomes: (1) Real-time(RT) categorisation of current workflow situations (e.g., the concentration of HCW for communication such as a caregiver relaying information to a head nurse); and (2) forecasting and prediction of caregiving and clinical events (e.g., patients needing urgent care due to activity patterns of HCWs in prior hours), which HCWs can use for resource planning or medical intervention.

Concluding remarks

In our study of the transitory process of becoming a new super hospital, we find that the shift from multi-patient rooms to single-patient rooms will affect and change the workflows of HCWs significantly. The HCWs have to oversee the same number of patients placed in several rooms over a greater distance. This results in fewer HCW-patient interactions and an increased risk of adverse events, such as falls while not being observed and feeling lonely or even forgotten. The transition will affect both patients and HCWs.

We designed a concept for mutual awareness between HCWs and patients of care workflows and a research prototype for engaging sensor data with the inital perspective of the nursing HCWs in a natural setting. The resulting sensor data will contain time, location, movement, and interaction information about proximity between beacons and sensors.

This paper makes two primary contributions. First, it uses empirical data based on 5+ years of ethnographic studies to provide an understanding of how to responsibly design sensed environments, building an agenda for worker and patient

well-being. Moreover, we present empirical findings from a recent study (March 2022) identifying that: (a) there is a risk of missing or losing critical information on patients due to a practice of storing information physically in the patient room; (b) Physical documents support an overview of working tasks and patient matters, resulting in sensitive knowledge being lost or forgotten and the risk of adverse events occurring; (c) Complexity of diversity: Patients are cognitively and socially at very different stages, which must be considered in communication systems to include all patients; (d) Physical interaction between patients and HCWs is prioritised as a form of care in order to foster safety and well-being. (e) HCWs express concern about the increasing level of documentation demand and systems to handle at the expense of physical care and face-to-face contact with patients.

Second, we propose a concept for mutual awareness of care workflows and a research prototype for engaging sensor data with the perspectives of the HCWs, patients, and their relatives in a natural setting. We identify four opportunities for supporting patients' and HCWs' mutual awareness of workflows: (1) progress of 'ward rounds'; (2) patient 'visits'; (3) patient 'calls'; and (4) patient 'mobility'. The concept optimises the workflow of the HCWs by implementing dashboards along their work paths, i.e., they do not have to walk back to the centralised coordination room to switch off alarms or find information about their patients. The HCWs will receive relevant information when they need it during their workflows, and the HCW closest to the patient will get notified instead of interrupting all HCWs with generic patient alarms/calls in the entire ward. The suggested solution includes: 1. Predictive ward round forecasts, 2. Patient movement analyses (timely mobility and fall prevention), 3. Smart nurse rounding registrations (timely patient visits), 4. Automated registrations of cleaned and available rooms.

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