Accounting for the Invisible Work of Hospital Orderlies: Designing for Local and Global Coordination

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ABSTRACT
The cooperative, invisible non-clinical work of hospital orderlies is often overlooked. It consists foremost of transferring patients between hospital departments. As the overall efficiency of the hospital is highly dependent on the coordination of the work of orderlies, this study investigates the coordination changes in orderlies' work practices in connection to the implementation of a workflow application at the hospital. By applying a mixed methods approach (both qualitative and quantitative studies), this paper calls for attention to the changes in orderlies' coordination activities while moving from a manual and centralized form to a semi-automatic and decentralized approach after the introduction of the workflow application. We highlight a set of cross-boundary (spatial and organizational) information-sharing breakdowns and the challenges of orderlies in maintaining local and global coordination. We also present design recommendations for future design of coordination tools to support orderlies' work practices.

Author Keywords
Orderlies; coordination; invisible work; non-clinical work.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
The understanding and representation of work practices as a resource to inform system design is an important concern among the HCI and CSCW communities. Although these communities have primarily focused on studying the formal work practices of the more specialized workplace environments (e.g., [6, 8, 46]), there is a growing concern and interest (e.g., [1, 12]) to study the work of the "less skilled or less powerful" [28] individuals, often relegated as invisible—yet essential—work [41] to "those who benefit from it" [45, p. 58]. Invisible work includes situations where the result of the work is visible but the person doing the work is somehow invisible as in the case of design work [28], domestic work (e.g., cleaning) and other kinds of service work [41]. There are also situations in which the person performing the work is quite visible but some of the work is "functionally invisible" [41, p. 20] or taken for granted. The work (e.g., registering appointments, monitoring patients, taking medication) performed by secretaries, nurses, patients, families, and "on-call" service workers, are examples of work that often remains in the background [28, 41, 48]. Making this work more visible [45], through technology [37, 42], can support the practices of invisible workers and enforce its contribution.

The hospital is a good example of a complex environment where visible and invisible work practices take place to sustain a transparent hospital workflow and the continuity of patient care [51]. At the hospital, care activities are spatially [6] and temporally [35] arranged, performed, coordinated and negotiated between highly heterogeneous elements and individuals including patients, clinicians, non-clinical personnel and their resources [2, 12, 21, 44]. Instead of focusing on the more stationary work of secretaries and registration assistants, which is often limited to specific hospital department work arrangements [12, 29], we seek to understand the invisible work performed by a particular group of non-clinical personnel such as the orderlies, which is a critical component of hospital work practices. We examine the dynamics of the cooperative work practices of orderlies from a large university hospital, over a period of 18 months of study—before and after the introduction of a CSCW workflow application that require intra- and inter-departmental coordination [2]. In the following, we present the related work and our user studies. We then report on findings that extends earlier work [2, 42] by highlighting a set of dynamic changes, workarounds and cross-boundary information sharing breakdowns and contingencies in orderlies' work practices. Based on our findings, we provide a set of recommendations to account for the orderlies' work practices in the design of CSCW systems to enhance their coordination and the overall organizational workflow.

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RELATED WORK

In this section we describe the different forms of visible and invisible work that take place at the hospital, the existing strategies to support their coordination as well as a brief overview of technology that supports these work practices.

On the Visibility and Invisibility of Hospital Work

The main focus of clinical work relates to ensuring the continuity of patient care [51] while managing the patient's care trajectories [43] often aiming for a more stable or improved health status. At the hospital, patients receive medical treatment from diverse and specialized clinical personnel (e.g., gynecologist, cardiologists) who are organized and distributed in several departments often following a basic division of labor according to specific skill sets, professions, resources and treatment goals [11]. While the work of the doctors is highly visible, as they are in charge of performing diagnosis and prescribing treatments [5, 7, 11], the nurses' work is often taken for granted [41] even though they are quite visible performing care-related activities (e.g., connecting monitoring devices, comforting or looking after patients) [11, 44, 49]. Similarly, patients themselves also play an important role in the care trajectory while receiving and following treatments [44], but their care activities are often relegated as invisible [48]. Patients perform self-care activities not only across multiple hospital departments [34, 44] but also beyond the hospital, moving into their everyday settings and routines [16].

Besides the clinicians and the patient, hospital work practices also include all the operational and maintenance work performed by non-clinical personnel such as secretaries, service workers (orderlies) and social workers [2, 12, 29]. For instance, secretaries not only perform basic tasks such as transcribing the doctor's progress notes, or communicating with patients [12, 49], but they also engage in more complex tasks that require more specialized skills and knowledge ranging from coding and booking treatments [12] to more clinical-related work such as examining the patient's condition, and interpreting clinical information [24]. In addition, Abraham and Reddy [1, 2] describe the important role of orderlies in the coordination of patient transfers between different clinical departments. Orderlies perform diverse service (e.g., transporting patients, delivering goods) and emergency (e.g., perform cardiopulmonary resuscitation) tasks that often require high mobility (on foot or vehicles) and ad-hoc coordination [42].

Strategies to Support Hospital Cooperative Work

The cooperative work at the hospital requires a proper configuration of highly heterogeneous actors (e.g., clinical and non-clinical personnel, patients), resources (e.g., supplies, medication, equipment), diverse knowledge, times and places to perform work practices within and across clinical departments [18]. To accomplish such work requires an ongoing alignment of actions among all the different elements and entities that are necessary to cooperate, which is what Strauss [43] has described as articulation work that relates to all the planning and coordination of who, what, when, where, and how to perform care practices. One particular strategy relies on existing hospital plans, procedures, standards and classification schemes [6, 22, 47] that are used as coordination mechanisms or infrastructural arrangements, necessary to support the negotiation of heterogeneous networks [47]. Furthermore, the complex interrelation of heterogeneous actors and networks [7, 18] constitute different hospital information infrastructures [17].

Because work needs to be prioritized, scheduled and negotiated according to the spatial [6] and temporal [5, 35] dimensions of the hospital information infrastructure, another strategy relies on the use of cognitive artifacts (e.g., doctor's progress notes [3], whiteboards [50], handover sheets [40]) to support clinical [36] and non-clinical [12, 24, 49] work practices. Certain cognitive artifacts such as work and booking schedules or whiteboards act as coordination mechanisms [39] and boundary objects [26], supporting the prioritization of tasks while also providing an overview of the situation at hand. For instance, whiteboards support the communication and coordination of inter- and intra clinical personnel by providing a local overview and awareness of activities (e.g., patient's location, procedures). While providing an overview can promote a fair distribution of tasks and the anticipation of resource availability (e.g., personnel, time) [5, 31] and pre-handling work [5], these strategies might not be sufficient to support the coordination of distributed work practices and different kind of additional informal and more formal agreements and activities (e.g., calling, booking) take place across departments to accomplish intra- and inter-departmental negotiations [5, 31, 44].

Technology to Support Hospital Work

Hospitals have shifted away from paper-based cognitive artifacts, e.g., patient records, to electronic versions to increase and support the coordination of the clinical work practices [32, 49] as well as the non-clinical work practices performed by secretaries or registration assistants [12, 24, 29]. This shift has increased the visibility of work practices making them more *"inspectable and manageable"* [7, p. 90]. Besides electronic patient records, mobile technology has also been introduced to improve both the information delivery and the efficiency of healthcare professionals' work practices [38, 40]. Mobile technology has also been used to support the articulation work of secretaries and nurses regarding, e.g., booking tasks [5] or patient responsibility handover [25]. Recently, technology for supporting work practices of orderlies have been investigated through a bed-board tracking system [2], and a mobile phone based task booking system [42].

Although recent efforts have investigated the use of technology by non-clinicians, most healthcare IT systems [19] have not accounted and overlooked the important role of orderlies as part of the whole information infrastructure. Any delays, errors or breakdowns of routines in orderlies'

work practices not only affect the overall hospital organization efficiency (allocation of time and resources), but can also result in detrimental health situations for the patient and cause stress and frustration among the clinical and non-clinical personnel [1, 2]. As such, there is a need to understand orderlies' cooperative work practices with other members of the information infrastructure. Based on an initial characterization of orderlies' work [2, 42], we further describe the local (within) and global (across departments) work practices, beyond patient-transfers [4], and changes in orderlies workflow after the introduction of technology.

USER STUDIES

Our work integrates qualitative and quantitative studies as well as an investigation of the technological challenges in connection with a pilot implementation and deployment of a mobile workflow application, PLogistics (PLog), which supports orderlies' work and the logistical hospital work.

Research Setting: Major Regional University Hospital

Our studies took place in a major university with ca. 3000 employees that are distributed on 18 clinical departments (e.g., X-ray, Emergency, Cardiology). The hospital receives roughly 300,000 outpatient visits yearly and has a capacity of 450 hospitalized patients. The hospital also has a service department with a total of 60 employees, of which 24 to 28 of these are orderlies working during regular hours and 13 to 4 working during the evening and the night shifts, respectively. The clinical departments are spatially distributed in many interconnected buildings with different layouts for surgical wards and laboratories, including three tall buildings with seven or more floors.

Context: Implementation of a Workflow Application

The two main functionalities of PLog are the provision of: an overview of all currently unassigned tasks from the different hospital departments, and an overview of all orderlies' current location together with the specific tasks they have been assigned to or currently performing. An additional interface was implemented to complement the departments' EMR system to facilitate the task registration process for healthcare professionals across the different departments. Currently, PLog is developed and maintained by an external software consultancy company.

Study Design and Data Collection

To get an in-depth understanding of the research setting, we adopted a mixed-methods case study approach [33]. We selected the case of examining the work practice of orderlies due to the availability of resources and facilities [33] in the hospital. For instance, the individual organizational setting of this hospital enables us to get an in-depth understanding of the local (intra-departmental) and global (inter-departmental) organization practices and of the changes in the coordination of hospital service tasks. In particular, the availability of PLog (as part of the ongoing evaluation process) enabled us to better understand the influence of technology in practice and how it affected the hospital's cooperative work arrangements. Overall, our study consisted of an initial exploratory phase followed by three intervention-related phases combining observations, semi-structured interviews and questionnaires (see Table 1). All questionnaires consisted of open questions and statements on a 5-point Likert-type.

	Qualitative data		**Quantitative data**
	Interviews	**Observation**	**Questionnaires**
Pre-intervention	23 orderlies	20 hours	Same 23 orderlies
Pilot-study	23 orderlies 3 clinicians 2 managers	18 hours	Same 23 orderlies 36 clinicians
	Interview	**Observation**	**System log**
Post-intervention	6 orderlies	22 hours	146,664 tasks

Table 1: An overview of the methods applied in this paper

Initial Exploratory phase

In this phase, a workshop was conducted with two designers, three software developers, five orderlies, two nurse assistants, one orderly manager and one researcher. During the workshop, the software company in charge of implementing the application shared insights as part of their own empirical studies of hospital work practices[1] (including orderlies' practices). These insights concerned for example the registration process for two-man tasks and how to inform orderlies about their colleagues' locations and tasks.

Pre-Intervention: Existing Work Practices

After the exploratory phase, a total of 20 hours of observations were conducted to understand the orderlies' work practices (prior the introduction of PLog) during the day-shift period (7 AM to 4 PM). The focus was on tracking orderlies' tasks (e.g., scheduling and assignation of tasks to orderlies by the coordinator), incidents within and across departments, the resources they used as well as the actors involved. We also gave questionnaires to 23 orderlies that touched upon aspects regarding the overview of tasks (e.g., "*I have a good overview of the daily tasks*"), and the coordination of tasks (e.g., "*It is easy to handover and redistribute tasks*"). We also conducted semi-structured interviews with the same participants to further investigate: a) the orderlies' handover tasks, b) the overview of tasks, co-worker status, and how orderlies utilize such overviews, and c) the orderlies' prioritization mechanisms.

Pilot Study Phase

The pilot study focused on: a) how technology supports existing practices and orderlies' task coordination; b) the emergent changes of these practices, and c) the new practices and workarounds due to the introduction of PLog.

[1] We were granted access to the software company's internal notes on hospital work practices.

A month after deployment, we undertook observations, applied questionnaires and semi-structured interviews to get insights into work practices changes. Questions touched upon the same aspects as in the previous phase, including the challenges of using PLog and how it supported and affected the orderlies' task coordination. Clinicians that order tasks were also included through questionnaires and semi-structured interviews to explore the benefits and issues of using PLog, answering questions regarding the work practices such as "*It is easy to order an orderly?*" or "*It is easier than before to give correct information?*" We also conducted semi-structured interviews with two orderly managers to discuss the prioritization of tasks.

Post-Intervention: Work Practices After Deployment

Last, we conducted semi-structured interviews and observations of orderlies' work during a post-intervention phase (see Table 1). Observations and interviews focused on the changes in work practices and both the new practices and issues that emerged after the introduction of PLog. We also conducted a workshop to get feedback from prototypes that address some of the issues that emerged after deployment. We also collected quantitative data from the PLog application of all tasks registered over a time period of 248 days including relevant task information (e.g., departments involved, task type, time). All task information was anonymized before the data was available for analysis.

Most interviews from all phases were recorded and later transcribed for analysis. We were requested not to record interviews with orderlies that took place near departments where patient sensitive information could be recorded. We collected extensive notes from these latter interviews.

Data Analysis

An inductive content analysis [14] was performed to identify the most relevant themes from our diverse studies. We performed two rounds of analysis moving back and forth through our two different datasets: the empirical data collected before and after the introduction of technology. These rounds were conducted by the first two authors with computer science and Participatory Design backgrounds and follow the thematic analysis guidelines [14]. Particularly during the second round of analysis, we combined the qualitative data with quantitative data coming from questionnaires and from the PLog application to triangulate and support the emerging themes. Themes emerged related to either a particular challenge or aspect of orderlies' work practices coming from the observations and/or as the most frequently discussed and emphasized topics by the participants. In the next sections, we present the emerging themes regarding existing work practices of orderlies before and after the introduction of the PLog.

ORDERLIES' WORK PRACTICES BEFORE PLOGISTICS

The work of orderlies has often been taken for granted by healthcare professionals as a large part of this work is invisible and thus relegated to the "background" [41]. In this section, we present our first round of analysis and describe the work of orderlies before introducing PLog.

Action and Interactional Processes

The work of orderlies, as part of the hospital information infrastructure, can be characterized by a collection of action and interactional processes (see Figure 1) among several heterogeneous actors (clinical personnel, task requester, task coordinator), and resources to get their work done. In the following, we describe the diverse elements and entities involved in orderlies' work practices.

Articulating Tasks – Clinicians

As part of the patient examination process, clinical personnel might require additional information and elements to perform their work such as obtaining x-rays, blood samples or any additional test. For such work, clinicians require the assistance of orderlies (e.g., see (1) in Figure 1a), to continue with the care process. When needed, clinicians articulate and delegate these specific tasks to the orderlies. Examples of these service tasks from our studies are delivering food, preparing beds, throwing away trash and any patient-related tasks, such as rounds of mobilization of patients to prevent bedsores. After a task is articulated, the task management flow starts locating relevant resources and an available orderly to perform it.

Booking Tasks – The Requester

We have observed that the nurse assistants and nurses are usually the ones responsible for requesting specific tasks or booking tasks to obtain the necessary resources to enable the continuity of work. Occasionally the physicians also book tasks depending on the specific department and the context of the requested task. We use the term *task requester* to refer to the clinical personnel that request or book a task based on the information registered when the clinician articulates a task. In particular, our studies show two different ways in which a task is requested. In Figure 1a, a more explicit way is shown in which the task requester calls the orderlies' coordinator to request a specific task with the following information: type of task (e.g., patient transport, mobilization, collect blood tests), the name of the departments involved (e.g., Oncology, Cardiology), as well as the patient's name, if necessary. In this particular moment, a type of care transition, which is often overlooked, takes place between the clinical personnel and the orderlies (including the coordinator) that we have termed *clinicians-orderlies handoffs*. Our studies highlight the reiterated clinicians-orderlies handoffs as illustrated in Figure 1a, characterized by information moving back and forth between clinical personnel and orderlies when new tasks are booked that go beyond transporting patients. Furthermore, we have also observed situations in which the coordinator is not contacted by the task requester, and instead the requester directly approaches a particular orderly to request a specific task, e.g., when an orderly just walks by the clinical department. This case shows an example of a verbal clinicians-orderlies handoff where a face-to-face request takes place between the task requester

and an orderly. All the needed information is verbally given to the orderly to perform the requested task. After the task is done, the orderly informs the coordinator about the task.

In addition, we also observed that certain clinical personnel use cognitive artifacts (e.g., department's schedules) as coordination mechanisms to support resourcing activities (e.g., booking task) and get a sense of local task awareness. For instance, the task requesters associated to the medical laboratories and Operation Department book the task mainly considering their own schedules. Although most of the tasks are requested when needed and according to the situation at hand (e.g., right before a surgery) due to the department's dynamic schedules, we have also observed few departments anticipating tasks with a fixed schedule, e.g., when performing surgery, and also some tasks that could be pre-booked following the department's plan and pre-established procedures. In this case, the requester notifies the coordinator every time there is a change in the schedule regarding the pre-booked tasks.

Coordinating Tasks – The Orderlies Coordinator

The orderlies' coordinator plays an important role in the coordination of work practices as he or she is the one who decides and prioritizes what, when, and where the tasks, received from all the department's requesters, should be performed. Our studies show how the coordinator centrally manages the coordination of tasks, with consciously planning and prioritizing tasks, before assigning them to the orderlies. While assigning the priority of tasks is an important aspect of the coordinators' work to ensure the patient flow throughout the different hospital departments, we have observed that the decision-making process regarding this prioritization is challenging, as not all tasks are equally critical. The orderlies' coordinator prioritizes tasks according to several factors, including: the departments involved; the type of task; and the different levels of interdependencies (e.g., information, role, artifacts [2]). For instance, patient transports to an operation receive high priority because of the number of allocated staff needed for the surgery, and the status of the involved patient. Furthermore, we observed that prioritizing tasks exhibits a dual nature of articulation work when the coordinator needs to perform local work arrangements (within a specific department) and global work arrangements (across different departments). For instance, the coordinator reported the need to be locally and globally aware of the different internal needs and requests from and across departments while assigning regular tasks (around 30 during weekdays and 45 on weekends) to the orderlies before they show up in the morning. Furthermore, the physical layout of the hospital also influences the coordinator's work as the coordinator is physically located in the orderlies' station next to the orderlies' coffee room, to be aware of the available orderlies in case a task is available and that no orderly is calling and asking for tasks. When assigning tasks, the coordinator hands over information verbally either face-to face in the coffee room or over a DECT phone (as part of the hospital information infrastructure) if the coordinator receives a call, or waits until locating the next available orderly.

To get a sense of local and global awareness of the orderlies' location and the task status, the coordinator might call each orderly to check on the progress and possibly assign a new task if there is a new high priority task that needs to be executed right away. In contrast to the centralized coordination during the day shift, our participants reported that the coordination during the night shift is managed directly by the orderlies by calling a phone chain, which redirects the call to a particular orderly's phone in a round-robin scheduling. This assignment requires an explicit communication with the orderlies, who might not always be able to answer the phone.

Performing The Requested Tasks - Orderlies

After receiving the task request with the necessary information (e.g., departments, task description, patient's name) via their DECT phone, the orderlies are the ones performing the actual tasks moving back and forth within and across different departments. At the beginning of every task, the orderly might write down on paper the tasks and the related information such as the patient's name and the department(s) involved to keep track of the tasks and support back tracking. When the task involves patients, the orderly double checks if the received information from the coordinator is correct upon arrival, and often asks for more information if necessary. Then, the orderly notifies the

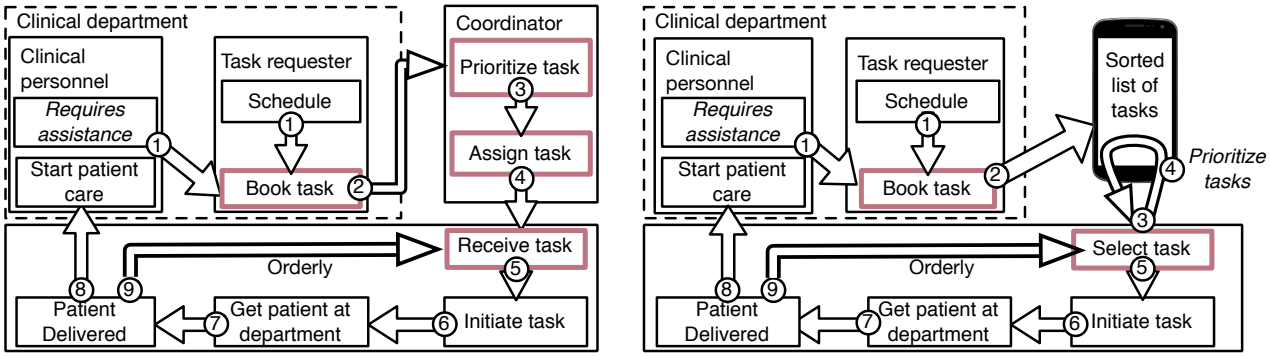

Figure 1: The ordering task flow for non-emergency tasks during the daily shift (7am to 4pm): (a) before PLog; (b) after the intervention. Red boxes highlight the changed practices.

clinical personnel of any changes, e.g., he or she will verbally notify the staff every time he or she either leaves or arrives with the patient for a patient transport. This notification is done to ensure that the clinical personnel is aware of the current status and location of the patient. At the end of every task, the orderly calls and notifies the coordinator, and probably acquires a new task. If there are no available tasks, the orderly would return to the coffee room and wait for the next task. This is an example of a void task as no task is performed during this period. A second type of void task occurs when orderlies move from department A to B without any assigned tasks.

Emergency tasks

In the case of emergency tasks, we observed that about four orderlies are designated for these tasks as they also carry an additional DECT-phone, which the clinicians can contact directly. When receiving an emergency task, the designated orderlies would rush to the department if they are available or they hand over either their current tasks or the new emergency task to an available orderly, e.g., by calling to the coffee room or the coordinator.

Cross-Boundary Information Sharing Breakdowns

We observed several process interdependencies that challenge the orderlies' task workflow and thus the whole efficiency of the patient-care process. For instance, we noticed that information interdependencies also take place during the clinicians-orderlies' handoffs when, for example, the clinical personnel forgets to specify relevant details while articulating the tasks. We found that orderlies' tasks often require certain equipment such as a lift for moving patients. However, it often happens that orderlies discover that they need certain equipment when arriving at the department, which was not specified beforehand. Another example from our observations is related to the specific characteristics of the patient's conditions: when a patient is isolated or has hip-related issues, the task might require certain protective linen or more than one orderly to mobilize a patient. In addition, our studies show situations in which a patient has been discharged, the operation has been rescheduled, or the clinical personnel already have performed the task, before the orderly arrives at the department without informing the coordinator or the orderly. Although clinicians could call the coordinator and ask for the progress (e.g., the waiting time[2]) or for the name of the assigned orderly in order to contact him, there is no other mechanism for them to become aware of the progress.

Furthermore, our studies show a task interdependency that takes place during the transfer of patients across different departments as illustrated by the following observation:

> When the orderly arrived at the X-ray department and started placing the patient into a position for the scan, the doctor from the X-ray Department checked the EMR system to get information about the kind of scan that the patient required. After retrieving the information about the type of scan, the doctor became aware of the fact that the requested scan was a CAT scan and required a contrast agent to be consumed two hours prior to the scan. So the doctor called the dispatching department to confirm whether the patient has ingested the agent, which was not the case. After discussing with the dispatching department whether another scan could be used, the final answer was no, and the orderly needed to transport the patient back to the dispatching department and two hours later to transport the patient back to the X-ray department.

The orderly assigned to this patient transfer waited for the clinicians to discuss and solve this issue caused by a task that was not completed before the clinician-orderly handoff started. In the end, the scan was postponed and scheduled two hours after the patient consumed the agent. A similar issue often takes place when the clinicians have not prepared the patient, e.g., where they will only initiate the preparation when the orderly arrives for a patient transport. In this case, the orderly needs to find a nurse first and then wait for the patient preparation and patient-related instructions as shown by the following observation:

> Early in the morning one of the orderly's first tasks was to transport a patient to the X-ray Department. When the orderly arrived at the specified room there was no nurse present. The orderly searched in the proximity of the room for a nurse, but was unsuccessful and had to wait for the nurse to show up. Approximately eight minutes later, the nurse showed up, and it turned out that she had been at a morning meeting.

In general, we observed that the clinician-orderly coordination is often a one-way coordination, i.e., the clinician requests a task for the orderly to perform. However, we also observed situations in which the orderlies' information has influenced the clinicians' work:

> As an orderly just finished a task, a nurse passed by and asked: "Can you transport the patient in the next room to get an X-ray scan?" Another orderly overhears the handover and said: "I've just transported him out of the hospital—he wanted to smoke".

After this conversation, the nurse rescheduled her plan and requested for another patient transport to an x-ray scan.

Resourcing Challenges

Since the orderly team is a shared resource across all departments, they are constantly prioritizing which task should be finished first by each orderly. An example of this issue of competing resources takes place when the nurses anticipate, that there is a long waiting time for the orderlies based on earlier tasks, and purposefully adjust the task time to an earlier time to ensure that there is less waiting time. Clinicians usually block out some extra time in case of unexpected situations and we refer to this time as buffer task time. The following excerpt shows an example of this:

> Orderly: So sometimes, when we are super busy and it feels like we are getting nowhere with our work, it happens that we arrive at a department, but the patient is not ready for the transport because the surgery is way later, but the nurse

[2] Waiting time is the difference between the actual finish time of the task, and the requested time to finish.

> booked the task ahead because she was afraid of waiting for us for too long and that the operation could have been delayed.

The buffer task time given by the clinicians subsequently affects the orderlies' task coordination by giving a higher priority to such tasks than to others that have a correct but later time. The buffer task time will overrule other tasks and be assigned to an orderly earlier than expected. Furthermore, the clinicians also bypassed the coordinator and the associated waiting time, when they verbally contacted the orderlies passing by and directly requested them to perform another task without informing the coordinator. An example of these situations is when the clinicians are busy and need a patient to get transported right away. Waiting time also occurs when the orderly shows up before the actual time and has to wait for the clinical staff to appear or return to the task later. We refer to this waiting time as inter-task time.

WORK PRACTICES AFTER INTRODUCING PLOGISTICS

In this section, we summarize our initial assessment of the impact caused by PLog on the coordination of orderlies' work practices as it moved from a centralized (see Figure 1a) to a more decentralized coordination (Figure 1b). In particular, our studies help us to get an understanding of the spatial and temporal dimensions as well as the emergent changes in the hospital information infrastructure.

Insights into the Spatial and Temporal Dimensions

Our quantitative data collected by the PLog made it possible to estimate the number of tasks that orderlies have performed every day. At the hospital, an average of 590 tasks per day took place across all departments including transportation (64%), bed delivery (10.23%) and pickup (unclean) beds (9.25%), mobilization (9.56%) and other (7.96%) tasks. Furthermore, the data from PLog shows that the X-ray Department was the most frequent location of tasks (μ=151.2 tasks), followed by the Emergency (μ=70.2 tasks), Oncology (μ=28.7 tasks), Recovery (μ=25.4 tasks), Service (μ=32.3 task) and Cardiology (μ=25.1 tasks) departments. Apart from getting insights into the spatial nature of work, PLog also enables the exploration of the temporality of orderlies' work. Figure 2 shows the distribution of tasks based on the data collected from PLog. In particular, it shows the tasks of six deparments with the highest workload and the time they are requested for. First, we see that the major load of tasks for the orderlies occurs from 10 a.m. to 11 a.m., and again from 1 p.m. to 2 p.m. We see that some of the departments, for instance the X-ray Department (light turquoise color) has a high variance of task frequency, i.e. spikes that indicate a sudden load of requests. Whereas other departments, for instance the Oncology (light red) and Cardiology (light blue) departments show more stabile rhythms, i.e. less spikes. This shows the highly diverse nature of the departments' rhythms, which directly impacts the orderlies' work.

The Dynamic Changes in the Information Infrastructure

Our qualitative studies during the pilot and post-intervention phases help us to understand how the introduction of the technology involved a complex change of existing work practices (described in the previous section) by changing or creating new practices. Figure 1b shows how the diverse elements and entities that constitute the new infrastructure arrangement handle the task coordination across several workgroups through different action and interactional processes. Because the articulation of tasks performed by the clinical personnel is comparatively unchanged (see Figure 1), we will instead start by describing the additional processes.

Consulting Task Status – Clinicians

After the introduction of PLog, it is now possible for the clinical personnel to follow the progress of their articulated tasks by consulting a desktop application placed in each department. Through this application, the clinical personnel can get status information about all booked tasks for the specific department. This information includes whether an orderly has been assigned to the tasks, as well as status of the task, e.g., started or finished. According to the questionnaires, the ability to track the progress of a task is appreciated (μ=3.6) by the clinicians. Furthermore, PLog creates a new work practice for clinicians that turned out to be beneficial as stated by a nurse:

> I use the overview of the orderlies a lot in my work. Before, we were used to often walking around and wondering: Is the orderly on his way? Have they [the orderlies] forgotten my task? It [PLog's task overview] is very useful because we can plan our work and don't have to think about the tasks.

Changes In Booking Tasks – The Requester

In contrast to the previous action of calling to book a task, an immediate effect is that the task requester (nurse, nurse assistant and sometimes a doctor) has to move and locate the desktop computer in each department's administration room to book the task using PLog. In principle, our studies show that the task requester is now enabled to book tasks ahead of time based on each department's schedule. In addition, we have observed how PLog assists in minimizing issues caused by incomplete information. For instance, the task requester has to explicitly enter the information regarding the specific room where the patient is, as well as any other relevant information required (e.g., any equipment that is necessary to complete the task). According to the responses of questionnaires, the task requesters agreed that the process of ordering a task is easy (μ=4.3), and that it is easier to hand over correct information than before (μ=3.4), and that there are fewer misunderstandings (μ=3.6). Although PLog facilitates the booking task, we have also noticed situations in which a task requester would contact an orderly passing by the department to request a task, rather than booking through the system as shown by the following observation:

> As an orderly is on his way with a patient, he walks by a nurse who asks him whether he could, on the way back, transport

another patient. The orderly says: "Sure, what's the task about?" and the nurse hands over the information. However, the orderly cannot find the task in the task overview and realizes that the nurse has yet not created the task. The orderly then goes back and asks the nurse to create the task but the nurse responds: "Is that really necessary?" Then the orderly explains that the tasks need to be documented so in case he gets delayed and another co-worker can take over.

Changes in Coordination: The Application Task List

One immediate effect of the introduction of PLog was the movement from a centralized (see Figure 1a) to a more decentralized (see Figure 1b) coordination process. While the coordinator played a key role in deciding who handles which task, where and when, the role of the coordinator almost faded away after the introduction of PLog. During the pilot study, an optional coordinator was in charge of monitoring the task flow and manually overrode tasks in case of inefficient schedules. As PLog was deployed at one department at the time, the departments that were not part of the study were still calling the previous coordinator who would manually enter the task into the system.

Instead of a coordinator explicitly handling the coordination of tasks, the coordination has been redistributed between the application and the orderlies. Rather than receiving the task from the coordinator as illustrated by Figure 1a, now the orderlies are the ones that need to explicitly prioritize, decide and select a task available through the PLog's task overview, and then book it when they start to walk to the specific department (see Figure 1b). Furthermore, the sorted task list of PLog includes an implicit prioritization of tasks according to the requesting time. The task appears as booked until the orderly arrives at the specific department, patient or equipment related to the booked task. To start the task the orderly presses 'start', and presses 'finish' whenever they finish the task. If the task overview does not show any available tasks, the orderlies go back to the coffee room and wait before checking again for a task. In addition, a large display has been placed in the coffee room to provide an overview of all the tasks that are not finished and make the orderlies aware of the progress. However, the overview provided by the display is restricted to the last hour and the next two hours ahead, in an attempt to focus on the current and relevant tasks.

Although our studies show that the role of the coordinator became more optional, and there is no designated coordinator at the hospital at this moment, one of the orderlies' managers during the interview described how he may step in and starts manually coordinating the tasks in case of a sudden surge in tasks. Furthermore, the orderlies report that they now have a good overview of which tasks are important (μ=4.4) compared to before PLog (μ=3.7), and they have a better overview of which task to start next (μ=4.0), in contrast to before PLog (μ=2.7).

Prioritizing Tasks

Ensuring a more efficient prioritization and scheduling process requires an awareness of the overall flow and task distribution to assess the busiest areas at the hospital, and enabling an ad-hoc task planning. For example, orderlies' planning focuses on minimizing the distance walked between tasks, referred to as inter-task time, as these empty tours also imply wasting time that could have been used on other tasks. We observed how orderlies consult both the task overview and the colleague overview from PLog, almost in parallel when performing a task. This enables the orderlies to assess which parts of the hospital are the most active and best covered by the orderlies. By looking at the co-workers' task progress, i.e., checking the route between the involved departments and the current position, an orderly can infer the other orderlies' task progress. The task progress can be used to estimate whether a colleague will be finished with a task soon, thus providing a better match for a task. The orderlies also reported in the questionnaires that having a good overview of their colleagues is more important now (μ=3.7) than before introducing PLog (μ=3), while they also agree that their overview of their nearest colleague is better now (μ=3.3) than before PLog (μ=1.6).

In addition to the PLog application running on a smartphone, the orderlies still carry up to two DECT phones, one for regular communication and another for emergency situations (e.g., cardiac arrest) as the smartphone does not support the current DECT infrastructure. Some of the emergency tasks (e.g. emergency transports) are handled and prioritized by PLog by displaying the tasks in the top and highlighting them in the task overview. PLog also notifies the orderly of a new emergency task through a different sound from other tasks.

Orderlies' Workarounds After Introducing PLogistics

After the introduction of PLog into the hospital information infrastructure, our studies also identified a number of local

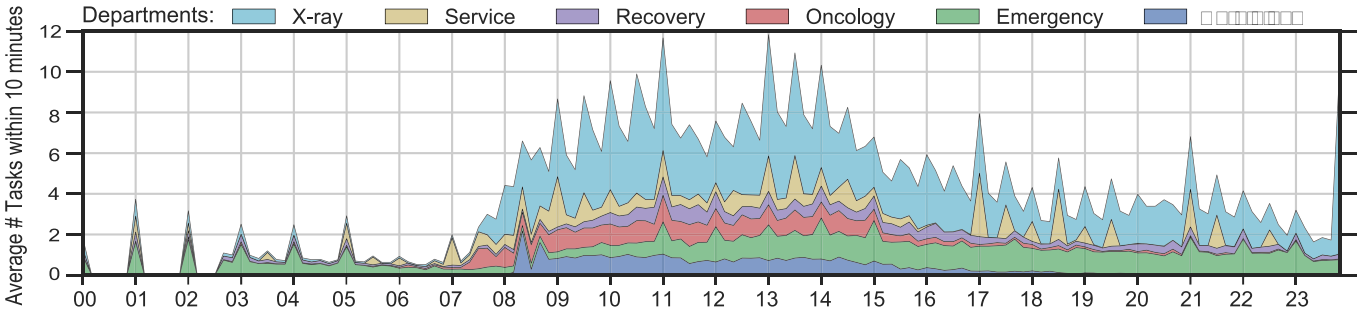

Figure 2: Visualization of the temporality of all orderlies' task flow for the six most work-loaded departments

adjustments, and workarounds to compensate any misalignments in orderlies' work practices.

New Explicit Communication

When the explicit coordination previously performed by the coordinator was delegated to PLog and the orderlies, a few issues emerged during the pilot study as the scheduling task and flow became less efficient than the previous coordination process. To overcome these issues, PLog was modified to enable orderlies to book more than one task at a time in order to increase the task flow and decrease the number of void tasks. However, it was challenging for the orderlies to schedule ahead due to the dynamic nature of the task (e.g., ad-hoc changes may imply that the orderly might be delayed in the next task). As this information is not visible, any pre-booked task might also hinder any co-worker from taking over the task if necessary. At the end, it was beneficial to enable orderlies to book only one task, and to enable them to book the next one once they are close to finishing the former, so orderlies can be aware of the assigned tasks and the available tasks.

We observed another issue when the same task required more than one orderly at approximately the same time. The coordinator previously handled this by calling the orderlies until identifying two available orderlies. Requiring two orderlies is challenging, as one orderly often has to wait for a second one to book the task and show up, before starting the task. To overcome this issue, we have observed how an orderly who has been waiting would often start calling his or her co-workers starting with the available or soon to be available ones. In some cases, two orderlies would agree while being at the coffee room or an orderly would stop by the coffee room to look for an available orderly to verbally agree to do the task together. If a co-worker has already booked that task but has not yet shown up, the other orderly will try to infer the arrival time by looking at the position displayed in PLog or explicitly calling the co-worker and ask for his or her estimated arrival time.

Workarounds Preventing Non-Efficient Schedules

Inferring co-worker's task progress could be helpful when booking the next tasks. However, an orderly's inference can be wrong, which means that orderlies are less efficient in scheduling tasks, e.g., an orderly can book a task just before a co-worker who is closer to the department, as illustrated by the following:

> At the Emergency Department one of the nurses walks by and asks Orderly A whether he has time to do a task just created by her. As Orderly A is just finishing up he marks his task finished in PLog and scrolls through the list of tasks in the PLog's task overview. When Orderly A is about to book it, Orderly B books the task, which prevents Orderly A from booking it also. Then Orderly A scrolls through the colleague overview, finds Orderly B who had booked the task before A, and could see that B is farther away from the task than A (since he is already at the Emergency Department). Then A calls B and asks him to cancel the booking. This allows Orderly A to find the task in the overview again, and book it, this time without interference from colleagues.

By calling Orderly B and asking him to hand over the task, Orderly A prevents Orderly B from having a void task (empty tour), and Orderly B can then choose a more efficient task. In other cases, when an orderly has finished a task he or she might stay around the same department for a short time and wait for the creation of a new task (inter-task time). Our studies highlight that this often happens if the orderly anticipates a new task, e.g., when transporting a patient to an examination, as the patient or another one will often need a transport back to the ward. In this case the orderly will check the task overview and as soon as possible book a task in order to prevent co-workers from booking it.

DISCUSSION

The findings show how the introduction of a new technology into the existing hospital information infrastructure affected different elements, entities and practices of the hospital. Here, we discuss three tensions resulting from the complex workflow and dynamics of orderlies' work practices: local vs. global overview, centralized vs. decentralized coordination, and local vs. global coordination. We also discuss the implications of how supporting local and global coordination of work practices of orderlies could provide opportunities for the development of future CSCW systems beyond the hospital.

Maintaining Local and Global Overview

The orderlies perform tasks across more than 30 operation centers (departments) [21], accessing and keeping track of a vast array of information to coordinate and complete their work, and avoid cross-boundary breakdowns. Although PLog facilitated the coordination and registration of tasks, it added new work for the orderlies. To prioritize and select a task by themselves, orderlies not only need to be aware of each department's rhythms and schedules but also locally keep an eye on their colleagues and the progress of the assigned tasks, which was previously handled by one person. However, the task schedules and the spatial and work arrangements of each department make it difficult for the orderlies to get a sense of the whole situation. Although some of the task information is available and visible in the task booking display, our studies show that the number of tasks can be quite high during the day shift and thus getting an overview gets complex. Orderlies should become aware that, e.g., most tasks need to be finished between 10 and 11 am, and less tasks are performed from 11 a.m. to 1 p.m. and increase again from 1 to 2 p.m. In Figure 2, one can see that the Cardiology Department has more tasks from 8-9 a.m., and later has a stabile flow of around 1 task every 10 minutes until 2.30 p.m. as it closes around 3 p.m. In addition to the local and global arrangements, the anticipation of new tasks by each department has to be considered when orderlies are close by.

Our findings suggest that *CSCW systems that support orderlies' work practices should be designed to not only*

document and support the booking of a specific task, but also provide and visualize a local and global overview of the distribution and status of tasks to sustain the task informational order across departmental boundaries. The informational order [43, 44] refers to all the aspects of the task information flow across departments (e.g., who is the sender and the receiver, type of information interchanged, such as instructions, patient's name, additional equipment and resources). Sustaining the task informational order implies an automated update of the recently articulated tasks, the assignation of tasks, the status information of every task across different departments and if possible the assigned buffer time. Supporting informational order is something often outspoken as a concern in the related work of this paper for the case of work practices of orderlies. For instance, prior work has investigated how context-awareness systems can be used as a priority mechanism to support awareness in hospital contexts, focusing on clinicians [4]. Similarly, orderlies need to be socially, spatially and temporally aware [4] of previous, current and future tasks which imposes challenges in regards to visualizing contextual clues for the orderlies. In particular, enabling the orderlies to become aware of the better places to perform a task according to the collected contextual information, might improve the dynamic and spatial distribution of tasks. However, there should be a trade-off between providing both a local and global overview, as it is necessary to balance the amount of information displayed to avoid information overload and sustain a seamless workflow performance. When a touch-based interaction is not possible due to the probability of causing interruptions to the practice at hand or the limited screen-size of a mobile phone, hands or eye free interaction could provide different channels to provide additional information to the orderlies.

From Centralized to a more Decentralized Coordination

Our study shows how certain existing work practices changed and other emerged after the introduction of PLog removing the role of the coordinator by delegating the coordination to PLog and the orderlies. As such the coordination of orderlies' work practices moved from a manual and centralized process to a semi-automatic and more decentralized process in which orderlies act as a mobile human agent [21]. In the more decentralized coordination, the prioritization is shared implicitly by PLog through the sorted list task interface and explicitly by the orderlies while proactively selecting a specific task using the different overviews. This implies that orderlies do not only interact with PLog but also become a proactive actor in the information infrastructure. Here, PLog provides a sorted task list to help the orderlies to get sense of the articulated tasks, however, the list is only sorted by due time and fails to consider other spatial and social dimensions. Here, a context-aware prioritization of tasks could be advantageous to reduce the number of void tasks as well as to facilitate the orderlies' anticipation of task and scheduling work [5]. Although the delegation of coordination takes advantage of the proactivity of orderlies and, in principle, helps them with planning and scheduling, it also has some side effects as the orderlies performed workarounds [15] and bypassed PLog to compensate situated misalignments (e.g., inefficient booking) in the information infrastructure [23]. For instance, the data collected by PLog can now facilitate the identification of opportunistic behavior when orderlies decide not to sign up for unpopular tasks, which in turn can provoke a delay on performing those tasks and thus decrease the overall efficiency of the hospital work. Indeed, more visibility of the orderlies' work might also increase the opportunities for surveillance [41]. At the organizational level, this might be beneficial as PLog makes the orderlies' work more visible, manageable and ready for inspection similar to making the work of healthcare professional visible [7, p. 90]. This in turn might increase the identification of possible void tasks (e.g., empty tours) that can put at risk the efficiency of orderlies. However, at the personnel level, this might be detrimental for the wellbeing of the orderlies and their personal preferences that now became more explicit and visible as they are the ones who decide which task to book and perform, in contrast to the centralized coordination.

Our findings suggest that *CSCW systems that support orderlies' work practices should be designed to make orderlies play an active role in the task management routines by balancing the visibility of their work practices as well as providing them with local and global awareness thereby taking advantage of the local and global overviews.* This calls attention to an important aspect of CSCW systems, the negotiation of visibility [41] which takes into account the orderlies' work practices and their personal preferences. As suggested by Star and Strauss [41], the invisibility of work could also be positive as in the case of certain workarounds. For instance, the inter-task time that takes place as part of the anticipation of tasks by an orderly (e.g., when transporting a patient between different departments) could be considered a case of a positive workaround that could be beneficial for the overall information infrastructure. To avoid misalignments, in the new infrastructure, a, particular attention should be given not only to reconcile inter-departmental differences but also intra-departmental differences due to the distributed nature of the orderlies' work practices. This might promote coordination by avoidance [27] to prevent the interference of other colleagues during the self-prioritization and selection of tasks.

Supporting Local and Global Coordination

Our study shows how the clinicians-orderlies handoff takes place among different personnel, artifacts and departments. The desktop application in each department could be an example of a common information space [11] that facilitate information sharing, also providing clinicians with a sense of local and global awareness. Besides the overview obtained by PLog, the clinicians across different departments do not get to participate together in the

articulation and prioritization of tasks, as a result of a reconfiguration of coordination. The coordination becomes even more challenging when different process interdependencies take place due to the departments' competing goals, resources and clinical and non-clinical teams [2]. On the one hand, this might in some cases imply that a more collaborative resource prioritization process across departments is needed [2], aiming for more efficient patient flows since the clinical and non-clinical staff could participate in taking their individual schedules into account. However, having the clinical personnel as an active actor in prioritizing tasks has been a concern throughout the whole implementation of PLog. As presented earlier the opportunistic behaviors of clinical personnel introduced buffer task times, but a more active role in task prioritization could introduce over-assessments of their own tasks. Moreover, introducing contextual clues, like visualizing the overall waiting time, could provoke new opportunistic behaviors. As the main focus of the clinical personnel is the patient care, it might be counterproductive to expect them to actively participate in the logistics of the service work. In this case, getting a global awareness of the hospital service work in addition to the awareness of clinical work may be too challenging for task requesters.

Our findings suggest that *CSCW systems that support orderlies' work practices should be designed to sustain the local and global coordination, the redistribution of awareness, and the negotiative work between clinical personnel and orderlies supported by the local and global overviews.* The negotiative work [44] refers to all the activities including informal and more formal agreements that take place across departments between clinical and non-clinical personnel to accomplish a successful negotiation. Here the overviews play an important role to provide both orderlies and clinical personnel with a local and global awareness as orderlies move back and forth across several departments. While the desktop application overview acted as an articulation space [10] supporting the intra- and inter- departmental coordination, PLog overviews served as a useful boundary object [26], providing a broader overview of tasks and resources across departments, enabling a local and global coordination between clinicians and orderlies and facilitating a common understanding of the practices using the information infrastructure.

Beyond Hospital Work Coordination

Our findings come from a case study in a specific hospital, but they may be transferable to other complex environments and scenarios, where prioritization, scheduling and anticipating work are essential to support the coordination of work practices such as software companies, print industry, airport and metro control centers [8, 9]. Indeed, the challenges and interdependences presented above relate to the third level of articulation of work [44] with planning, scheduling and execution of actual activities. Our findings not only show how orderlies' work practices changed but also how those of clinicians changed after the introduction of PLog. A particular strategy that could be found in other complex environment apart from the hospital is the creation of a buffer time in production lines to prevent unexpected situations [30]. Buffer times are usually created by professional workers according to past experiences [20]. As presented above, buffer time was allocated according to nurse's experiences with a predefined fixed-size. A predefined fixed-size of buffer time imposes challenges in settings where the work is not prioritized according to the time or the order [13, 30]. For instance, prioritization in the print industry would consider the complexity of the activity and how much time is required to perform a task [13]. Although making the buffer time more visible could support the coordination of work practices, future work should consider discovering the specific particularities of each domain. Furthermore, implementing and visualizing an adjustable buffer time could be beneficial (e.g., when additional time is needed to complete a task) to support the performance and coordination of work practices.

CONCLUSION

This paper discusses the importance of the often-considered invisible but legitimate work performed by orderlies as proactive actors in hospital information infrastructures. While few studies investigate the work practices of orderlies, these have mostly focused on providing a description of work practices or usability tests without exploring the dynamic changes in practices and in the overall workflow of the hospital. In contrast, we describe the existing work practices of orderlies and the involved actors and artifacts, part of a large-scale hospital information infrastructure, before and after the introduction of a new technology that support the tasks coordination across hospital departments. To our knowledge, this is the first study of technology in use that further investigates orderlies' work practices and their dynamic changes. Our findings suggest that it is necessary to generate a more complete understanding of orderlies' work practices and account for the challenges, tensions, arrangements and workarounds discussed in this paper as fundamental knowledge to support CSCW system design. Based on our findings, we provide a set of design recommendations that include: a) supporting the local and global overviews to sustain the task informational order across departmental boundaries, b) sustaining orderlies proactive role while balancing the visibility of their work practices, and c) sustaining the redistribution of awareness and negotiative work between clinicians and orderlies. These recommendations might help clinicians, orderlies as well as technology designers to account for the distributed and invisible—yet essential—work of hospital orderlies.

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