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# Visible but Unseen? A Workplace Study of Blood-Test Icons on Electronic Emergency-Department Whiteboard

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## ABSTRACT

Studies have shown that whiteboards support much cooperative work by for example strengthening awareness, improving communication, and reducing mental workload. In line with these predominantly positive findings, an emergency department (ED) turned to its whiteboard to improve the coordination of its work with blood tests. We investigate this use of the whiteboard through observations and informal interviews in the ED and analyze the ability of the whiteboard to support coordination and awareness in the work with blood tests. Our findings show limitations in the ability of the whiteboard to support awareness in a setting where the users are (locally) mobile, specifically in regard to information that requires continuous monitoring. We do however also find that the whiteboard safeguarded the work with blood tests against some risks by making blood-test information socially visible.

## Author Keywords

Electronic whiteboards; Healthcare; Blood tests.

## ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work.

## General Terms

Human Factors.

## INTRODUCTION

Whiteboards support the coordination of much cooperative work by making information visible to collaborating actors and thereby facilitating awareness, communication, and joint scheduling [8, 27, 31, 34]. In emergency departments (EDs), electronic whiteboards are replacing dry-erase whiteboards, and studies show that the electronic whiteboards may strengthen the clinicians' overview of their work [17], improve their communication [33], and reduce their mental workload [12]. In line with these predominantly positive findings, an ED at a medium-sized hospital in

Region Zealand, Denmark, turned to the vendor of their electronic whiteboards with the request to have icons showing the status of the blood tests added to the whiteboard. With this integration of the whiteboard and the laboratory system, the whiteboard was expected to improve awareness of the status of blood tests, shorten the response time to available blood-test results, and ensure that ED clinicians acknowledged having seen the results. Our study, conducted when the icons had been in use for about six months, shows however that the whiteboard icons did not have the intended effect.

On the basis of observations and informal interviews, we find that except during a few work procedures the blood-test information visualized on the whiteboard remained largely unseen by the ED clinicians. We consider this finding interesting because it speaks against the majority of whiteboard studies, which conclude that whiteboards serve an important coordinative function in much cooperative work [1, 2, 5, 8, 15, 22, 31, 33, 34]. By studying the coordination of blood-test results, our intention is therefore to contribute to a better understanding of the ability of the whiteboard to support coordination and thus to derive at some implications for the design and use of electronic whiteboards for supporting awareness and coordination. To understand the coordination of blood-test results in the ED, we focus on how clinicians attend to blood-test results and the technologies they use for this purpose. The focus on blood-test results is important, since studies show that between 1% and 75% of test results lack follow-up, with impacts ranging from no negative effect to patient death [11].

The work in the ED is conducted in cooperation with other departments in the hospital. For example, physicians from the medical department (MD) work some of their shifts in the ED and are responsible for the clinical part of the treatment of patients with medical problems. The MD physicians constitute the majority of physicians working in the ED and are highly dependent upon blood-test results in diagnosing and treating patients. In our observations in the ED, we focused on these physicians.

In the ED, electronic whiteboards were introduced in May 2011. The whiteboards are mounted on the wall in central locations in the ED. The basic layout of the whiteboards is a row for each patient, with columns displaying selected information about the patient, such as triage level, room, chief complaint, responsible nurse, responsible physician, and

**Figure 1: The electronic whiteboard.**

current treatment activity (see Figure 1). The clinicians can interact with the system by tapping the wall-mounted touchscreens and by mouse and keyboard. A study conducted before the whiteboard was extended with blood-test icons showed that it was an important coordinative artifact in the ED [16].

The functionality of showing icons that visualize the blood-test process was added to the whiteboard in April 2012. The icons show the status of each patient's blood tests by means of color-coding. A blood test goes through four steps: ordered (blue), taken (yellow), results available (green, red, or red and flashing), and acknowledged (grey). The icon is green when results are within the normal range and red when results are abnormal. If a result is critically abnormal, the red icon flashes. Prior to the introduction of the blood-test icons, the clinicians in the ED used the laboratory system to look up information about blood tests. Information about blood tests can still be accessed in this way. The whiteboard icons aim to increase the clinicians' awareness of the status of blood tests by making information that the clinicians otherwise have to look up in the laboratory system readily available by means of visual cues. The ED is the only department with a whiteboard that shows blood-test icons. In the rest of the hospital, the laboratory system is the only way to access information about blood tests.

**RELATED WORK**
In the following, we account for related work on the role of whiteboards in supporting the coordination of cooperative work and highlight challenges in the work with blood tests.

**The Role of Whiteboards in Supporting Coordination**
Multiple studies have found that whiteboards support coordination and have emphasized different ways in which whiteboards provide this support [5, 8, 33, 34]. Some stud-

ies focus on the role of whiteboards when users meet to coordinate their activities. These studies, for example, find that large whiteboards promote collective reading and interpretation during clinical activities such as nursing handovers because they provide shared access to relevant information [8, 23]. Similarly, Whittaker and Schwarz [31] argue that the public visibility of the whiteboard they studied promoted individual and collaborative behaviors that improved the participants' joint scheduling and negotiation of how to balance the workload in their projects. Scupelli et al. [22] extend these findings by emphasizing the importance of the physical setting to the success of whiteboards in supporting ad hoc meetings. Whiteboards appear especially successful when they provide for at-a-glance reading in passing the whiteboard or provide a space in front of the whiteboard for users to confer with their colleagues [34].

Whiteboards also support asynchronous coordination, for example by bringing together information that was previously distributed across multiple people and places [12, 33]. Bjørn and Hertzum [8] argue that this bringing together of information on the whiteboard integrates information relevant to different staff groups. One of the characteristics of work in, for example, EDs is that it is difficult to plan activities according to a schedule. Therefore, ED clinicians have to synchronize their activities in an ongoing, ad hoc manner. Without a preset schedule to tell them what to do next, the clinicians rely on continually working out how to mesh their interdependent activities. To succeed in this articulation work [20], the clinicians need to maintain an overview of the current state of affairs in the ED. The transition from dry-erase to electronic whiteboards in EDs appears to improve the clinicians' overview of their work because information can be made available on distributed electronic whiteboards without the need for repeated manual entry [1], because electronic whiteboards can be interfaced with other

clinical systems and automatically show information about, for example, laboratory tests [2], and because electronic whiteboards may, as a result, be accompanied by more patient-focused work practices [23]. In a systematic review of electronic ED whiteboards, Rasmussen [19] found that whiteboards had affected the work in EDs at multiple levels, but that the results were of a mixed and somewhat inconclusive nature. He therefore called for more research targeting the effects of implementing electronic whiteboards, for example studies of interface design and integration with other clinical systems. This call is similar to that of Hertzum and Simonsen [15] who contend that valuable lessons about the design and use of whiteboards can be acquired by extending the functionality of whiteboards and then studying the impact of their implementation on clinical work. Our study can contribute in such a manner.

The concept of overview is often linked with that of awareness [4, 18]. Though awareness has been studied extensively within the field of CSCW [13, 21], it still appears to be a challenge to describe the process of *arriving* at the state of overview. For example, Bossen and Jensen [9] found that although the studied physicians had an opinion about what information they needed to have confidence in their overview of their work, it was difficult for them to explain how they got, maintained, and interrelated this information. Bossen and Jensen [9] conclude that the process of achieving an overview should be viewed as an "actively pursued, reflective understanding of one or more patients' situation." Whiteboards may support clinicians in pursuing this understanding by making readily available information that otherwise has to be searched [5]. It is, however, a limitation of wall-mounted whiteboards that they "may go unnoticed if they are located off the beaten track" [22: 1778]. That is, whiteboards must be attended in order for the whiteboard information to support users in their work. While this statement is self-evident, it is not self-evident that whiteboards will be attended with sufficient consistency in a dynamic ED environment in which clinicians are locally mobile and may be away from the coordination centers of the ED for extended periods of time. This could suggest limitations in the types of information a whiteboard can be used to broadcast. Such limitations have however not been a focal point in existing studies, which instead have tended to document positive effects of whiteboards on cooperative work. The exceptions from this tendency are mainly studies finding that the shift from dry-erase to electronic whiteboards comes at a cost [7, 29].

### Working with Blood Tests

Hawkins [14] reports evidence suggesting that the most error-prone parts of the blood-test process are before and after the blood test is in the laboratory for analysis. This evidence indicates that improvement efforts should target the patient departments that order the tests and receive the test results. According to Callen et al. [11] failure to follow up on test results is a critical issue. In an ED setting the

reasons for such failures include the multiple people involved in the blood-test process and the complexity of aligning this process with patient trajectories [28]. The ED is a particularly challenging setting due to its high patient throughput, team-based care, unpredictable numbers of acute patients with urgent problems, and lack of continuous relationships between patients and clinicians [11, 32].

Physicians value to be alerted when new test results are available [6]. In continuation of this finding, systems that rely on clinicians to 'pull' information from the system are not sufficient [11], partly because critical results are overlooked and partly because clinicians waste time accessing the system in vain before the results are available. The alternative approach of 'pushing' information to physicians by means of alerts does, however, not ensure consistent follow-up on test results [25]. Physicians who receive a large number of alerts may, for example, experience alert fatigue and stop reacting promptly to alerts [24]. The diligence required of clinicians in order for them to attend quickly and consistently to new test results is also strained by the finding that the number of tests ordered differs considerably across clinicians, suggesting that much diagnostic testing may be unnecessary and warrant neither alerts nor the attention of clinicians [32].

### METHOD

The present study was approved by the management of the ED and MD. The observed and interviewed clinicians were individually informed about the study and orally consented to take part.

### Departments

The ED received 40-45,000 patients a year and consisted of a total of 21 patient rooms divided onto a fast-track area for walk-in patients, two acute areas for patients arriving by ambulance, and a long-term area. The ED employed 120 nurses and 13 full-time physicians. In addition to the full-time physicians, a number of physicians from other departments, in particular the MD, worked part of their shifts in the ED. Physicians from the MD were responsible for the clinical treatment of ED patients with medical problems but the ED retained responsibility for the overall organization of work in the ED.

The MD consisted of four wards and a number of outpatient clinics. We focused on the ward for respiratory medicine, the ward for cardiac medicine, and the ward for gastroenterological medicine.

### Procedure

We conducted an ethnographic study in which the blood-test processes in the ED and MD were investigated by means of observation and informal interviews. The observations consisted of shadowing mainly medical physicians in the ED and in the MD for periods of a couple of hours at a time as they went about their work. Shadowing the medical physicians in different contexts allowed for the observer to

get an overall understanding of the physicians' evolving tasks and a more specific understanding of how the work with blood tests was integrated into their clinical work and to what extent the whiteboard and, specifically, the icons supported these activities. The shadowed physicians also consented to answering questions about the work they were performing, thereby explaining individual activities, clarifying relations among activities, and offering informed opinions. To increase our understanding of the work with blood tests in the ED, we similarly shadowed a number of other clinicians. The observations in the ED consisted of shadowing three junior physicians (i.e., residents) working full-time in the ED and two nurses. In addition, we also observed three instances of a practice the clinicians referred to as timeouts. During a timeout, which lasts 10-15 minutes, the clinicians gather around the whiteboard to discuss the admitted patients. In total, the observations of medical physicians and the other clinicians in the ED amounted to 19 hours, spread across the day shift. In addition, informal interviews were conducted with one chief physician, two surgical physicians working their shift in the ED, two nurses, two laboratory technicians, a coordinating nurse, a triage nurse, and a secretary. These informal interviews mainly served the purpose of elaborating upon the observations and verifying our findings.

To increase our understanding of the medical physicians' work, we performed supplementary observations in the MD. These observations amounted to 9 hours in total and took place during the ward rounds and during a practice we will refer to as the end-of-shift check, where senior physicians before ending their shifts checked for blood tests lacking follow-up. We chose these observation periods in the MD because most follow-up on blood tests took place during these periods.

All observations and interviews were conducted by the first author and documented in real time in detailed notes. In our analysis, we first read through our data from the observations and interviews and divided them into initial categories. These categories included issues to do with maintaining an overview, the frequent interruptions, and understanding when and for what purposes the whiteboard icons were used. The overall theme that emerged from the analysis concerned the activities for which clinicians needed to be aware of blood-test information and the extent to which the whiteboard icons supported this awareness. In the following section, we therefore structure our results according to the identified activities and describe to what extent the whiteboard and the icons in particular supported the clinicians' coordination and awareness of the information of blood tests.

## RESULTS

### Using the Whiteboard to Gain an Overview
When the physicians from the MD worked in the ED, they were working together with clinicians from other depart-ments in the aim to treat and care for acute patients. Some of these clinicians were permanent ED staff (nurses and physicians), while others, like the physicians from the MD, represented the specialty of their base department. The physicians from the MD thus had to collaborate with a multitude of other clinicians, who were responsible for various tasks in the patients' trajectory through the hospital. This entailed considerable coordination in order for them to gain an overview of who was responsible for which patients, at what time, and to know when to perform the tasks for which they were responsible. The two examples that follow show how they used the electronic whiteboard as their main artifact in gaining this overview.

When patients arrived to the ED, they were assessed by a triage nurse in order to determine the priority of their treatment based on the acuteness of their condition. In addition to this assessment, the triage nurse also assessed which resources to call upon, typically, whether the patient should be examined by a medical or a surgical physician. After completing her/his assessment, the triage nurse updated the patient's information on the whiteboard with a label indicating, whether the patient was 'surgical' or 'medical'. From this point the whiteboard displayed the patient as the responsibility of either the physicians from the MD or the physicians from the surgical department. Whereas the organization of work in the ED thus aimed at distinguishing between a medical and a surgical track for the patients, it was however clear that in practice these tracks were interwoven in several ways. Physicians from different hospital entities were dependent upon the same resources (nurses, equipment, specialists, beds etc.) and even though they were present in the ED as representatives for a specific specialty, they shared responsibilities for several activities in the ED.

One of these activities was the supervision of junior physicians. Before choosing their medical specialty, junior physicians take their basic clinical training (in Danish: KBU) at different departments. In the ED, the junior physicians can get medical experience while working under the supervision of senior physicians. The junior physicians received this training by performing an initial examination of the less acute patients and documenting this examination in the patient record. When the junior physician finished this task, s/he updated the patient's information on the whiteboard to indicate that the patient was ready to be examined by a senior physician. While the junior physicians typically performed this initial examination on their own, we did however observe several cases, where the junior physicians sought senior physicians to ask for their advice on how to interpret results and observations. When the physicians from the MD worked in the ED, they also participated in this activity of supervising the junior physicians. In one of our observations, a medical physician was going back and forth between four or five patients, and then suddenly went looking for a junior physician, because he had noticed that another patient's pulse was critically high and he wanted to

make sure that the responsible junior physician was taking care of it. Our field notes read: *"He goes searching for the responsible junior physician and finds her as she is leaving the conference room. They sit down and start talking about the patient, what symptoms to look for and how to treat them."*

The ED is thus a setting, where many activities take place simultaneously. The medical physicians used the whiteboard as their main artifact for navigating among these activities and maintaining an overview of which patients to examine next. When they approached the whiteboard, they stated that they were mainly looking for two things: which patients were medical, and whether the junior physician had completed the initial examination.

### Approaching the Whiteboard in Between Patients

The medical physicians' primary activity in the ED is to treat and stabilize medical patients and in this process their main goal is to arrive at a conclusion about whether the patients are well enough to be discharged or they need to be transferred to other departments for further treatment. When the physicians in our observations approached the whiteboard, it was primarily when they had reached such a decision and therefore needed an overview of which patient to examine next. Like in the following example, where a physician approached the whiteboard after having devised a plan for a patient: *"The physician explains that he uses the whiteboard to see which patients have been labeled as medical patients. For two of these patients he can see that they are still being examined by the junior physicians. He will not see to them until the junior physicians have finished their examination."* He then changed the status for another patient on the whiteboard to indicate that he was taking responsibility for this patient, wrote the patient's social security number in a little notebook, and sat down by a computer to prepare for the examination. He then accessed the patient's record in the electronic patient record (EPR) system and read previous notes about the patient's condition and medical history. In this process he also accessed the laboratory system through a menu in the EPR system to check for new blood-test results.

This observation was verified by similar observations of other medical physicians. The physicians approached the whiteboard in between patients to gain an overview of what to do next, but we never saw them approach the whiteboard with the sole purpose of attending the blood-test icons. Rather, they chose to sit down to prepare for the examination and in this process they accessed the laboratory system to check for and evaluate blood-test results. One of the medical physicians in our observation stated that because a great deal of her time was used on coordination with nurses, medical students, junior physicians, other departments, transferals and so forth, she felt that she was struggling to complete the treatment of her patients and reach a decision about whether to discharge or transfer them. Her struggle to maintain a focus on the treatment of individual patients also affected how she managed the blood-test results and what technology she chose to use for this purpose. She explained that to her it would seem like just another interruption, if she had to regularly approach the whiteboard to keep an eye on the icons: *"When I sit down, I check for test results"*. Constantly monitoring the icons on the whiteboard was seen as an interruption to her primary activity of finishing the treatment of patients. She therefore integrated the evaluation of blood-test results with the treatment of the individual patients, that is by attending to blood-test results while she prepared for her examination of the patient.

### Activities that Require Immediate Attention

Though the medical physicians in most cases strived to align their evaluation of blood-test results with their preparation for the examination of individual patients, there were two activities that required them to perform an immediate evaluation of blood-test results: to follow-up on critical results and to secure free beds for arriving patients.

In the case of critical results, the icon on the whiteboard flashes to indicate that the results require immediate attention. However, it was clear that the clinicians did not monitor the whiteboard closely for flashing icons. In one of our observations, we asked a clinician about who was responsible for attending to an icon that had been flashing for a while. One of the nurses replied that it was primarily the nurses, who noticed the flashing icons, but they would then try to find the responsible physician. In an interview, a nurse however stated that a flashing icon did not always require immediate attention: *"A flashing icon is not necessarily life threatening. Sometimes it is just one of the values in the test that is slightly off. So we do not always react promptly. We know that the laboratory will call us on the phone, if the results are critical."* They therefore relied more on the procedure that the laboratory in these cases is required to phone the ED to inform them about the results. It is primarily nurses in the ED, who receive these calls, whereafter they forward the information to the right physician.

Whereas the medical physicians were highly engaged in the treatment of medical patients, they also had to engage in the activity of securing the flow of patients through the ED. This activity was about managing the flow of patients through the ED and securing free beds for the unpredictable numbers of patients that would be arriving. Because the physicians prioritized the treatment of the most acute patients, less acute patients would sometimes be waiting and thereby occupying a bed, until the physician had time to complete the examination and reach a decision about the patient. In one of our observations, one of the admitting nurses even stated: *"That is the problem with less acute patients. If the patient had been more critical, the physicians would have more focus on the patient."* In several of our observations, we observed how the medical physician would inform the nurses that a patient could be discharged, if the results of a laboratory test came back normal. Be-

cause the nurses were aware that the physicians often awaited the results of blood tests before reaching a decision about what should happen to the patient, they saw the arrival of new test results as an opportunity to notify the physicians and thereby get the physician to attend to these patients. When the nurses approached the whiteboards to update information about patients, we observed how they also used these opportunities to attend to the blood-test icons and then inform the physicians about available blood-test results.

Thus, in the case of critical results or if the flow in the ED was under pressure, the medical physician had to be interrupted to perform an immediate evaluation of blood-test results. It was however clear that the whiteboard was not sufficient in calling the physicians' attention to critical results. Even though there were clinicians in the proximity of the whiteboard, who could see the flashing icons, they would rather rely on having the laboratory calling the nurses, when the results were of such a nature that they warranted the physicians' prompt attention. When the patient flow was under pressure, the physicians relied on having the nurses inform them of the availability of results about less-critical patients, who in most cases could be discharged from the ED. Notably, in both of these cases, the clinicians reported that it was most likely the nurses, who would notice the changing colors of the icons.

**Using the Whiteboard at Timeouts**

Whereas most of the coordination in the ED happened continually and in an ad hoc manner, we did observe one scheduled practice (the timeouts), where the clinicians met to discuss the overall status of the department. Timeouts were held up to four times a day and lasted 10-15 minutes. During a timeout the  clinicians met by the whiteboard (see Figure 2) and walked through the patients in the ED. If at all possible, medical and surgical physicians had to suspend their treatment of their patients to participate in the timeout. The ED nurses and the junior physicians also participated. As the following excerpt from our observations illustrates the clinicians, in walking through the patients, repeatedly made reference to the whiteboard information. *"Two physicians are standing in front of the whiteboard. One of them, the chief physician, asks, if everyone is ready. He then starts to talk about the first patient on the whiteboard (the top row); they are waiting for blood-test results. If they come back normal, the patient can be discharged. He then points to the second row and mentions the name of the next patient. Another physician takes over and informs the others of his treatment of the patient. The chief physician offers advice about what can be done."* During another timeout, the chief physician on two occasions tapped on the blood-test icons on the whiteboard. This action prompted the opening of a pop-up window displaying the values of the blood-test results, thereby opening up to a collective evaluation of the results. This activity also provided an opportunity for junior physicians to seek advice on how to inter-



**Figure 2: Timeout in front of the whiteboard.**

pret test results and for senior physicians to provide advice on additional possibilities to consider. We also observed how the chief physician delegated relevant tasks to the junior physicians, and the more experienced physicians offered them advice on how to perform these tasks.

The timeout was the only incident, where we observed physicians actually tapping on icons to view blood-test results. A junior physician explained that apart from during timeouts she would not use the whiteboard to evaluate tests, because she did not want to disturb others that wanted to look at the whiteboard and because she saw her individual evaluation of the results as a task that should be performed on a personal computer. Outside of the timeouts the physicians only made changes to the whiteboard, when they updated the whiteboard with information about their own activities. They never used the whiteboard to look up additional information about blood-test results but, instead, used a personal computer to look up such information in the laboratory system.

**Negotiating the Clinical Relevance of Acknowledgement**

In the studied hospital, it was a formal requirement that all tests should be acknowledged. This requirement had been introduced to prevent that blood-test results were missed or neglected. One of the aims of introducing icons on the ED whiteboard was to increase the physicians' awareness of
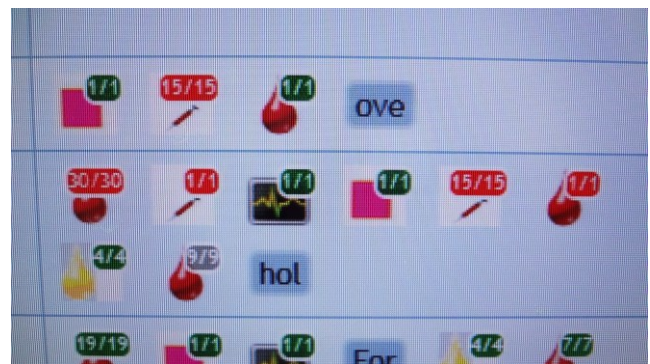


**Figure 3: Whiteboard icons with colors indicating their status.**

blood-test results that needed to be acknowledged. A red or green icon indicated that the blood-test results had not yet been acknowledged, a grey icon that the results had been acknowledged (see Figure 3). During our observations it was however apparent that the physicians were confronted with several challenges in regard to integrating the requirement to acknowledge blood-test results with the clinical activity of evaluating the test results.

Though test results were evaluated during timeouts, they were never acknowledged during this practice. There were at least two reasons for this. First, while the whiteboard provided for evaluating blood-test results, it was not possible to acknowledge test results on the whiteboard. Second, a chief physician in the ED stated that timeouts were primarily a collaborative activity, and the acknowledgement of test results should be performed by individual physicians in the course of treating individual patients. We observed several instances of medical physicians acknowledging results in the laboratory system while they were sitting by the computer and preparing for examining their patients, but they clearly did not acknowledge all test results. The observed physicians provided several explanations for omitting to acknowledge test results. In one of our observations, a physician stated that she would not acknowledge the results, because some of the multiple values in the test were still missing. In another, a lesser-experienced physician stated that he would not acknowledge a test result, because he was concerned that if he did then a more experienced physician would not examine the results. In both of these cases, the physicians appeared unwilling to comply with the requirement to acknowledge test results, because it clashed with their primary activity of ensuring competent treatment of the patients.

In the Medical Department, the management had implemented a practice (the end-of-shift check), where the senior physicians, before ending their shifts, took turns to acknowledge the blood-test results that had not been acknowledged during the ward rounds. However, several medical physicians in our study stated that they felt that the acknowledgement of blood-test results mostly served managerial purposes. This was also recognized by the head of the Medical Department, who during an initial meeting with us stated: *"It is not the acknowledgement that is important to the clinicians. Rather, their concern is to perform a proper evaluation, which can then lead to a better treatment of the patients."*

When a patient leaves the ED, the information about the patient disappears from the whiteboard and there is, consequently, no visual reminder to help the physicians remember to acknowledge blood-test results. At the time of our study, the ED had not implemented any practice to ensure any form of follow-up on blood-test results for patients that had left the ED. If the ED physicians do not follow up on these test results, the requirement to follow up on and acknowledge them is propagated to the physicians in the

receiving department. In one of our observations at the Medical Department, we observed how the blood-test results that had been ordered by the ED had not been acknowledged: *"The medical physician accesses the patient's blood tests. Some of the tests have not been acknowledged – including some from the ED. 'This happens frequently!' the physician says."* This finding points to challenges in managing the blood-test results of patients that are transferred to other departments, and emphasizes that these challenges have not been managed simply by providing the physicians with access to the blood-test results of transferred patients.

## DISCUSSION
The aim of the ED in introducing the blood-test icons on the whiteboard was to improve the ED clinicians' awareness of the status of blood tests, shorten their response time to available blood-test results, and ensure that they acknowledged having seen the results. While related work generally finds that whiteboards succeed in supporting awareness and coordination, the present study has shown that the blood-test icons on the studied whiteboard were rarely attended by the physicians.

### The Whiteboard Is Not Continuously Monitored
To improve the ED physicians' awareness of the status of blood tests and shorten their response time to available results, the physicians must continuously monitor the whiteboard. Continuous monitoring is, however, at odds with ED work.

First, ED physicians are locally mobile and, thus, away from the centrally located whiteboard for considerable periods of time to attend their patients. In accordance with previous studies [22, 34] we find that the whiteboard supports the clinicians in gaining an at-a-glance overview when they pass by the whiteboard, but such ad hoc scanning of the whiteboard is very different from continuous monitoring. Without continuous monitoring the changed status of a blood test will not be noticed until a clinician passes by and attends the whiteboard, not even if the icon is flashing.

Second, ED clinicians face many interruptions and, consequently, work to receive interruptions when they disrupt the least. Previous work shows that ED clinicians are interrupted as much as an average of 15 times an hour [26], often with the result that they fail to return to the interrupted task or hasten to complete it to compensate for the time 'lost' in interruption [30]. We find that the physicians seek to attend to one patient at a time; that is, to complete their current examination of a patient before they turn to the next patient. To do so they do not attend to blood-test icons for their other patients until they have completed their current patient and need to decide whom to attend next. Attending to the blood-test icons in between patients is consistent with studies suggesting that the cost of being interrupted is lower at the boundary between tasks than in the middle of a task [3]. However, this strategy means deliberately avoiding a con-

tinuous monitoring of the whiteboard and, thereby, postponing the response to available blood-test results.

Third, in an ED setting many blood tests have become irrelevant before their results arrive because the patient's condition has changed or the physicians' understanding of it has evolved. For example, Torkilsheyggi et al. [28] report that predefined sets of blood tests are ordered by the admitting ED nurse. While that practice aims to avoid delays waiting for test results, it also means that the tests are ordered before a physician has assessed which tests are needed to diagnose the patient, thereby risking that many of the tests are irrelevant. When general experience, or concrete knowledge about a specific patient, shows that blood-test results have often been superseded by other developments when they arrive, physicians become less preoccupied with remaining minutely aware of the status of blood tests. This reinforces the strategy of attending to the blood-test icons in between patients rather than doing it continuously.

Fourth, to see the actual blood-test results the physicians need to tap on the icons to open a pop-up window. The physicians are however reluctant to perform such interactions at the whiteboard because they perceive it as occupying, though only briefly, an artifact intended for shared use with information relevant only to their individual needs. Therefore, the physicians normally look up the actual blood-test results by accessing the laboratory system from a desktop computer rather than via the icons on the wall-mounted whiteboard. This practice contributes further to making the whiteboard less important to how the physicians attend to blood tests.

**The Status of Blood Tests Becomes Socially Visible**
While the physicians do not continuously monitor the whiteboard for changes in the status of blood tests, the icons have made the status of blood tests socially visible. In the laboratory system, information about blood tests is only visible to the physician looking it up for a specified patient. On the whiteboard, the status of all blood tests is visible to all clinicians. We emphasize three implications of this social visibility.

First, the arrival of test results has become visible to the nurses. This visibility has affected the interactions between the activities of treating the patients and of maintaining the flow of patients through the ED. When the nurses need to free beds in the ED to make room for new patients, they keep an eye on the arrival of blood-test results. Upon their arrival a nurse alerts the physician responsible for the patient to the possibility – and need – of completing the treatment of the patient and freeing the bed. This use of the blood-test icons illustrates that the whiteboard serves and meshes a multiplicity of practices [8]. In addition to supporting the nurses in maintaining the flow of patients through the ED, the nurses' alertness to the blood-test icons in these situations also supports the physicians in their strategy of restricting their own attention to the blood-test

icons to the periods in between patients. When this strategy conflicts with the activity of maintaining the flow, the nurses will alert the physicians of new blood-test results.

Second, the blood-test information is routinely attended at the timeouts during which the physicians suspend patient treatment to walk through the currently admitted patients. The timeouts is one of very few standard procedures that involve the ED physicians as a group, and it evolves around the content of the whiteboard. The introduction of the blood-test icons has made blood tests more prominent during the timeouts, and in this collaborative context the physicians make frequent use of the possibility to tap on an icon to see details about the results of the test. This way, the blood-test icons have changed the timeouts from a discussion based on one physician's reading (ahead of the timeout) of the blood tests toward one of collective reading and interpretation by the physicians at the timeout. Simonsen and Hertzum [23] have previously reported a similar effect of a large, shared display on nursing shift handovers.

Third, while it might be expected that the social visibility of unacknowledged blood tests would increase the physicians' impetus to acknowledge having seen test results, this has not happened. One explanation for the absence of such an effect is that it is, at present, not possible to acknowledge test results on the whiteboard. Other explanations include that the physicians may act on test results without acknowledging having seen the results, thereby reducing the acknowledgement to a formal requirement of importance to quality management but not to the physicians' primary activity of patient treatment. This explanation is reinforced by the procedure that the laboratory must phone the ED whenever a blood test yields critically abnormal results. Receiving this information consistently on the phone makes it even safer for the physicians not to monitor the whiteboard continuously and not to worry a lot about unacknowledged blood tests. A supplementary explanation for the many blood tests that remain unacknowledged may be that patients disappear from the whiteboard when they leave the ED. Because most patients are only in the ED for a few hours, unacknowledged blood tests tend to disappear from view quite quickly. In the MD, where patients stay longer and their condition evolves more slowly, the end-of-shift check provides a procedure for avoiding unacknowledged blood-test results. Notably, the medical physicians' care in attending to the acknowledgement of test results in the MD did not transfer to their shifts in the ED.

**Implications for the Design and Use of Whiteboards**
Our study has five implications that extend previous work on the design and use of whiteboards for supporting awareness and coordination. First, whiteboards do not seem to be effective at supporting continual awareness of time-critical information in settings where participants are locally mobile. Rather, whiteboards appear useful for supporting information needs that are periodic, such as between patients (for physicians) and when beds need to be cleared (for

nurses). This distinguishes settings like EDs from settings with the characteristics of a control room, in which people can be expected to monitor whiteboards near continuously.

Second, whiteboards are perceived as shared artifacts and should build on this perception by aiming to enhance cooperative practices such as timeouts. In contrast, users should not be expected to perform individual tasks at the whiteboard, unless they are trivial and very brief. The primary type of individual use appears to be at-a-glance reading.

Third, by making information socially visible, whiteboards can serve to create safeguards against individual persons' oversights as well as opportunities for coordination of seemingly conflicting activities. While it may be tempting in the planning of future design initiatives to consider sending blood-test information directly to the physician responsible for the specific patient (e.g., by text messages on a smartphone), it must be considered that such an approach does not make information socially visible and necessitates replacements of the practices that rely on this visibility.

Fourth, by making information socially visible whiteboards support ad hoc coordination well but the social visibility is likely insufficient to foster consistent compliance with formal requirements, especially if the visibility is transient. The MD illustrates that the consistent acknowledgement of having seen blood-test results is dependent on enforced procedures and does not require a whiteboard.

Fifth, it might seem banal to point out that even if a whiteboard makes information visible, it cannot be taken for granted that clinicians will see the information. It appears, however, that the effect expected from the blood-test icons presupposes that the clinicians continuously monitor the whiteboard. This misunderstanding could, probably, have been avoided if the design of the icons had been informed by an ethnographic study of the work in the ED. Although it is an often-made point in CSCW studies that technologies are designed without taking work practices into account [10], our study suggests that it is a point still worth making.

## CONCLUSION
In the studied ED, blood-test icons were introduced on the whiteboard to improve awareness of the evolving status of blood tests, shorten response time to available results, and ensure that clinicians acknowledged having seen the results. However, the physicians did not attend appreciably to the icons, except at timeouts and in between patients. The main reasons were that continuously monitoring the whiteboard for changes in the status of blood tests was incompatible with the physicians' local mobility and the high number of interruptions they already experienced. As a result, the icons had little effect on the work activities performed by the physicians individually. Instead, the social visibility of the blood-test information on the whiteboard facilitated coordination between clinicians who were otherwise engaged in seemingly separate activities. It, for example, improved the timeouts by providing for collective reading of

test results, thereby incorporating the supervision of junior physicians better in the activity of patient treatment. It also facilitated the coordination between patient treatment and the activity of maintaining the flow of patients through the ED. In spite of the social visibility of the icons many blood tests remained unacknowledged.

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