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Work-Practice Changes Associated with an Electronic Emergency-Department Whiteboard

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Abstract. Electronic whiteboards are introduced at emergency departments (EDs) to improve work practices. This study investigates whether the time physicians and nurses at an ED spend in patient rooms versus at the control desk increases after the introduction of an electronic whiteboard. After using this whiteboard for four months nurses, but not physicians, spend more of their time with the patients. With the electronic whiteboard, nurses spend 28% of their time in patient rooms and physicians 20%. Importantly, the changes facilitated by the electronic whiteboard are also dependent on implementation issues, existing work practices, and the clinicians' experience. Another change in the work practices is distributed access to whiteboard information from the computers in patient rooms. A decrease in the mental workload of the coordinating nurse was envisaged but has not emerged. Achieving more changes appears to require an increase in whiteboard functionality and a firmer grip on the implementation process.

Keywords: electronic whiteboard, emergency department, time with patients, work-practice changes

1 Introduction

Emergency departments (EDs) receive large numbers of acute patients with diverse health complaints and for brief periods of time. This makes it a continual and demanding activity to maintain an overview of the status of the patients, including the logistic management of the allocation of rooms and clinicians to patients[1-3]. A central tool in maintaining this overview is the ED whiteboard, which increasingly is an electronic rather than a dry-erase whiteboard[4-9]. Compared to dry-erase whiteboards, electronic whiteboards offer possibilities for integrating whiteboard information with information from other electronic records, for broadcasting information to multiple whiteboards without repeated manual data entry, and for keeping whiteboard information for later use when it is erased from the whiteboard. To benefit from these possibilities the introduction of electronic ED whiteboards must be accompanied by changes in work practices, yet current research is inconclusive with regard to the work-practice changes associated with electronic ED whiteboards[10].

This study investigates whether the introduction of electronic whiteboards at one ED has enabled physicians and nurses to spend more of their time with the patients. Such a change in work practices is motivated by a concern that healthcare clinicians spend an increasing amount of their time on paperwork and other activities that reduce the time they have available for the treatment and care of patients. This is experienced as wasteful, stressful, and dissatisfying[11, 12]. Spending more time with the patients may improve treatment and care [13], because the clinicians get more opportunities for noticing and reacting to details and changes in the patient's condition, improve clinician satisfaction[14], because they presently experience their time with patients as insufficient and decreasing, and improve patient satisfaction[15], because their treatment becomes more visible to

patients and there are more occasions for them to feel heard. Also, in our Danish setting policymakers call for turning 'cold hands' (i.e., time and attention spent away from the patients) into 'warm hands' (i.e., time spent with the patients).

We measured the ED clinicians' distribution of their time by tracking how they moved around the ED before the introduction of the electronic whiteboards and after the electronic whiteboards had been in full-scale use at the ED for four months. To assess the extent to which a change in clinician time in patient rooms was associated with the electronic whiteboards we also measured the use of the whiteboards on the computer in the patient rooms. A complementary aim of introducing the electronic whiteboards was to decrease the mental workload of the coordinating nurse, who is in charge of dynamically assigning and re-assigning ED clinicians to the patients who most urgently need treatment and of maintaining the flow of patients through the ED so that patients receive treatment and leave at about the same rate as new patients arrive. The coordinating nurse is crucial to the effective, efficient, and safe operation of an ED and uses the whiteboard more than any other ED clinician. We measured the subjective mental workload of the coordinating nurse.

The electronic whiteboard deployed at the ED largely mimics dry-erase whiteboards in content and surface structure and thereby resembles those in other studies of electronic ED whiteboards[1, 4-9, 16, 17]. While the electronic whiteboard is gradually being extended with automatically updated fields of information, it was at the time of this study largely a manually updated, standalone system. When a patient is announced for arrival at the ED by ambulance, the coordinating nurse enters preliminary patient information on the whiteboard. Walk-in patients that arrive in the waiting room are received and announced by the secretaries. Upon patient arrival the coordinating nurse allocates a room and a nurse to the patient, and enters this information on the whiteboard. The nurse's first activity is to triage the patient to determine the urgency of the patient's complaint. Selected triage information is entered on the whiteboard, including the triage level and any tests ordered. This information triggers the next sequence of actions, which includes that the coordinating nurse allocates a physician to the patient. Often, physicians will monitor the whiteboard to align their examination of a patient with the arrival of test results. The secretaries regularly monitor the whiteboard for patients for whom records must be finalized. Whereas all ED staff use the whiteboard to maintain an overview, keep track of their patients' progress toward discharge, and help determine their next move, most whiteboard updates are made by nurses, particularly by the coordinating nurse.

Previous studies of electronic whiteboards report multiple positive effects on work practices, including that electronic whiteboards improve ED clinicians' overview of their work and make information available where and when needed[7], improve communication and save time when searching for information[18], make work more efficient[6], and improve patient satisfaction[5]. However, studies also report that electronic ED whiteboards have a negative impact on workflow and communication[17], are used less and contain more inaccuracies than dry-erase whiteboards[8], contain less information relevant to the coordination of patient treatment[4], and move ED work away from a collaborative effort and more toward functioning as individuals[9]. In addition to these mixed results, physicians and nurses experience electronic whiteboards differently[7, 18], as do nurses and clerks[19]. Previous studies have not investigated whether electronic ED whiteboards affect the amount of time clinicians spend with the patients[10].

2 Method

To investigate the work-practice changes associated with the introduction of the electronic whiteboard we conducted a before/after study. The study was approved by the management of the ED and by the healthcare region's department for quality and development.

2.1 The emergency department

The ED was a 10-bed department at a medium-sized hospital in Region Zealand, one of Denmark's five healthcare regions. The ED comprised an acute area with approximately 15000 patient

admissions a year and a fast-track area, which treated almost twice as many less urgent walk-in patients. The electronic whiteboard focused on the admitted patients and, thereby, on the acute area. By default this area had five beds but in periods with many acute patients the acute area was dynamically extended into the fast-track area. Patients arrived at the ED from outside the hospital, received initial treatment and a diagnose, and were either transferred to another department for full treatment or, mainly in case of fast-track patients, discharged. The ED staff included 25 physicians and 35 nurses. In addition to these two staff groups, which were directly involved in our measurements, the ED was staffed with laboratory technicians, secretaries, and management.

2.2 The electronic whiteboard

The electronic whiteboard, developed by Imatis (www.imatis.com), gives one row of information for each patient, including information such as time of arrival, room, patient name, age, triage level, problem, attending physician, attending nurse, and next action, see Figure 1. The whiteboard is permanently displayed on two wall-mounted, 52-inch touch screens at the control desk (i.e., in the location where the dry-erase whiteboard used to be), see Figure 2. Information on this whiteboard is entered via the touch-screen interface or via mouse and keyboard. To change whiteboard information, clinicians first log on to the whiteboard by briefly holding a personal token onto a sensor. Another wall-mounted touch screen in the physicians' work area, which is next to the control desk, also permanently displays the electronic whiteboard. In addition, the electronic whiteboard can be accessed on any computer at the ED, specifically on the computers located in each of the patient rooms.

2.3 Procedure and measurements

After the study had been approved we held a workshop with representatives of the physicians, nurses, secretaries, and management of the ED. At this workshop, the purpose of the measurements was discussed and details about their practical administration were refined. There was general agreement about the relevance of the measurements.

The study involved two measurement periods, each lasting four weeks. The first measurement period (November 2010) was before the electronic whiteboard was introduced, the second (May 2011) after it had been in full-scale use for four months. We considered four months sufficient because previous research has found that new work practices stabilize after a rather brief period of experimentation[20]. Prior to each measurement period we informed about the study through the weekly electronic newsletter received by all ED staff. All physicians and nurses also received a description of the study on paper and an informed-consent form concerning their participation in the measurements. During the first days of each measurement period we were present at the physicians' and nurses' morning meetings to introduce the measurements and answer questions about the study. In addition to the measurements described below, we observed work at the ED. The main focus of the observations was the control desk and its dry-erase (before measurements) or electronic (after measurements) whiteboard. We did not observe work in the patient rooms. The observations provided a background understanding of ED work and opportunities for exploring how the clinicians used and experienced the electronic whiteboard. After the second measurement period we interviewed two physicians, four nurses, and three management representatives about how the electronic whiteboard had changed work at the ED and about the reasons for these changes and for the other results of the measurements. The interviews were audio-recorded and lasted 30-45 minutes.

The measurements were the same during the two measurement periods. They comprised:

The location of the physicians and nurses was tracked with an ultrasound positioning system from Sonitor (www.sonitor.com). Each physician and nurse who agreed to be tracked wore a tag that emitted a unique ultrasound signal every 20 seconds. To avoid that the clinicians forgot to wear their tag it had a strip for attaching it to their staff card or another object they always carried. The clinicians initially got their tag from a box containing tags with blue and green strips. Physicians were requested to pick a tag with a blue strip, nurses to pick a tag with a green strip. Thus, we knew for each tag whether it was carried by a physician or a nurse, but it remained unknown which person

carried which tag. Receivers were set up in the ten patient rooms and at the control desk and calibrated so that the signal from a tag was only picked up when the clinician with the tag was in the patient room or in the close vicinity of the control desk. Outside of these locations, the clinicians' whereabouts were not tracked.

The use of the computer in the patient rooms was logged continuously by a tailor-made program. We distinguished between using the computers for five applications: (1) *The electronic whiteboard*, which provided overview information about the patient in the room as well as about the other patients currently admitted or announced to arrive at the ED. (2) *The electronic patient record*, which comprised modules for the ED clinicians to record information about the patient's current admission and look up information about previous admissions. (3) *Test results and images*, which provided access to the results of tests and other examinations ordered by ED clinicians from other departments. (4) *Treatment instructions*, which described the procedures prescribed for patients with a specified problem or presumed diagnose. (5) *Other*, which comprised all remaining applications, such as retrieval of information about the effects of medication. Apart from links from the electronic patient record to test results and images, the five applications were not interlinked. The logs contained no information about who used the computers.

Mental workload was measured for the coordinating nurse, a primary user of the electronic whiteboard, by means of the NASA task load index (TLX)[21]. TLX consists of the six subscales mental demand, physical demand, temporal demand, effort, performance, and frustration, each rated on a scale from 'low' (0) to 'high' (100) in increments of five, except performance for which the anchors are 'good' (0) and 'bad' (100). The coordinating nurse made TLX ratings four times during each day shift: in the morning shortly after the start of the shift, before lunch, after lunch, and near the end of the shift. We selected these four situations because they represented important points at which the coordinating nurse needed to ascertain her or his overview of the patients and ensure that the whiteboard was updated. At any one time the role of coordinating nurse was held by one nurse. The nurses took turns in this role and normally had it for half a shift or an entire shift at a time. We introduced the nurses to TLX on their morning meetings at the beginning of each measurement period, and we sometimes repeated the introduction for the coordinating nurse as part of our observations at the ED.

Finally, we extracted data about the number of admissions, the age of patients, and their triage level from the nursing records. This was done manually for the full four weeks of each measurement period. These data were used as control variables.

2.4 Data pre-processing

Before the statistical analyses, the data from the tracking of the clinicians' location and their use of the computers in the patient rooms were pre-processed because such data are noisy.

For the tracking of the clinicians' location, some of the signals emitted from the tags were lost, even when the clinicians were in the vicinity of a receiver. We allowed up to two minutes between consecutive trackings of a tag. If consecutive trackings were more than two minutes apart, we treated the first two minutes as time spent at the location and the remaining time as unaccounted for. Time unaccounted for included, for example, lunch, breaks, meetings, and work tasks away from the ED. To include a day's tracking of a tag in our analysis, we required that the clinician with the tag had been tracked by a receiver at least 100 times and that less than 50% of the duration of the clinician's shift was unaccounted for by the tracking data. This excluded 34% of the tracked shifts, during which the positioning system failed to track the clinicians consistently or the clinicians were away from the patient rooms and control desk for the majority of their shift.

For the clinicians' use of the computers in the patient rooms, the active application, if any, was logged continuously but it cannot be concluded that the user continuously attended to the application. We aimed to account for this in two ways. First, if the same application window remained active for an unbroken period of more than 10 minutes followed by the onset of the screen saver, we assumed the application was unattended during the last 8 minutes of the period and discarded them. We chose

8 minutes as an approximation of the period of non-use that triggers screen-saver onset. Second, if an application window still remained active for an unbroken period of more than 15 minutes, we recorded only the first 15 minutes as application use.

3 Results

The main independent variable in the following analyses is the measurement period (before, after). We also analyze interactions between measurement period and two time-of-day variables: work shift (day, evening, night) for the tracking of the clinicians' location and time of day (morning, before lunch, after lunch, afternoon) for the coordinating nurse's mental workload. Finally, the division between acute and fast-track patient rooms is explored in some of the analyses. In all analyses statistical significance was set at the level of 0.05.

3.1 Control variables

A total of 2177 patients were admitted during the two measurement periods. Table 1 shows the average number of admissions a day, the average patient age, and the patients' average triage level. A triage level was present for 62% of the patients in terms of a number from 1 (life-threatening) to 5 (normal). We found no difference between the before and after measurements for any of admissions a day, $F(1, 54) = 0.33$, $p = 0.6$, patient age, $F(1, 2145) = 0.10$, $p = 0.7$, and triage level, $F(1, 1349) = 0.06$, $p = 0.8$. With no differences for these control variables, we assume that the patient populations were similar during the two measurement periods. The number of staff was the same during the two measurement periods.

3.2 Time spent in patient rooms versus at the control desk

During the before measurements, 23 (92%) physicians and 34 (97%) nurses wore tags; during the after measurements, the numbers were 20 (80%) physicians and 30 (86%) nurses. The data included in the analysis comprised 316 physician shifts with an average duration of 8.70 hours ($SD = 5.24$) and 347 nurse shifts with an average duration of 6.67 hours ($SD = 1.81$). We initially distinguished between rooms permanently used for acute patients and rooms mainly used for fast-track patients but got essentially the same results for both types of patient room and, therefore, collapsed them.

Tables 2 and 3 show the percentage of their time the physicians and nurses spent in patient rooms, at the control desk, and in other locations. For the physicians, there was no difference between the before and after measurements in percentage of time spent in patient rooms, $F(1, 314) = 1.25$, $p = 0.3$, but significant differences for percentage of time spent at the control desk, $F(1, 314) = 8.20$, $p < 0.01$, and for 'other' time, $F(1, 314) = 29.24$, $p < 0.001$. With the electronic whiteboard, the physicians spent a larger part of their time at the control desk and a smaller part in locations other than patient rooms and the control desk. For the nurses, we found significant differences between the before and after measurements in percentage of time spent in patient rooms, $F(1, 345) = 19.69$, $p < 0.001$, and at the control desk, $F(1, 345) = 8.14$, $p < 0.01$, but no difference in the percentage of 'other' time, $F(1, 345) = 0.92$, $p = 0.3$. With the electronic whiteboard, the nurses spent more of their time in patient rooms and less of their time at the control desk. The increase in time spent in patient rooms was 11 percentage points, corresponding to about 44 minutes per nurse shift.

The percentage of time spent in patient rooms differed significantly across shifts for both physicians, $F(2, 313) = 8.11$, $p < 0.001$, and nurses, $F(2, 344) = 3.46$, $p < 0.05$. These differences across shifts did, however, not interact with measurement period (both ps > 0.1). There were no differences across shifts in percentage of time at the control desk and in 'other' locations (all ps > 0.06). But, for the percentage of time the nurses spent at the control desk there was a significant interaction between measurement period and shift, $F(2, 344) = 3.74$, $p < 0.05$. The decrease in the percentage of nurse time spent at the control desk from before to after the introduction of electronic whiteboards was 16 percentage points during day shifts but only 5 and 4 percentage points during evening and night shifts, respectively.

3.3 Computer use in patient rooms

To relate the time spent in patient rooms to the whiteboards, we logged the use of the computers in the ten patient rooms. For the before measurements, the data from six patient rooms were, unfortunately, lost due to a software upgrade. The analysis of before/after effects was therefore restricted to the four patient rooms for which we had recordings from both measurement periods, a total of 211 room days. Table 4 shows the average number of minutes a day during which five applications were active on the computers in these four patient rooms. There was a significant difference between the before and after measurements in the total duration of computer use, $F(1, 209) = 5.49$, $p < 0.05$, with more use after the introduction of electronic whiteboards. This increase was mainly due to the electronic whiteboard which was the only one of the five applications for which there, unsurprisingly, was a significant difference between the before and after measurements, $F(1, 209) = 101.78$, $p < 0.001$. Specifically, the use of neither test results and images nor treatment instructions differed between the before and after measurements, Fs(1, 209) = 0.23, 0.47, respectively (both ps > 0.4).

We note that the overall pattern of computer use in all ten patient rooms after the introduction of the electronic whiteboards was largely similar to the pattern in the four rooms included in Table 4, except that test results and images were accessed substantially more (M = 7.9 minutes, SD = 19.8).

For the after measurements we also analyzed whether the use of the electronic whiteboard differed across shifts. All ten patient rooms were included in this analysis, a total of 280 room days. The use of the electronic whiteboard differed significantly across shifts, $F(2, 81) = 9.22$, $p < 0.001$. Bonferroni-adjusted pair-wise comparisons showed that the averages of 91.4 (SD = 51.2) and 73.6 (SD = 38.0) minutes of whiteboard use (for all patient rooms combined) during day and evening shifts, respectively, were significantly more than the average of 44.0 (SD = 34.0) minutes during night shifts. The electronic whiteboards were accessed an average of 7.91 times a day in each of the rooms used for acute patients and an average of 1.20 times a day in each of the rooms used mainly for fast-track patients.

3.4 Mental workload of coordinating nurse

The coordinating nurses rated their mental workload 147 times, corresponding to a response rate of 92%. Table 5 shows the average mental workload ratings for the six TLX subscales. A multivariate analysis of the six subscales showed no difference between the before and after measurements in overall mental workload, Wilks' $\lambda = 0.92$, $F(6, 134) = 1.88$, $p = 0.09$. As this p-value approached significance we note that power was 0.68 and we thus cannot rule out that a decrease in mental workload was masked by insufficient sample size. Analyses of the individual subscales showed a significant difference for physical demand, $F(1,145) = 4.36$, $p < 0.05$, with lower physical demands after the introduction of the electronic whiteboard. For mental demand, temporal demand, effort, performance, and frustration there were no differences between the before and after measurements, Fs(1, 145) = 0.97, 1.05, 0.70, 0.13, 1.19, respectively (all ps > 0.2).

The coordinating nurse's mental workload differed significantly with time of day, Wilks' $\lambda = 0.79$, $F(18, 379.5) = 1.85$, $p < 0.05$. Unsurprisingly, mental workload displayed an increasing trend from the TLX ratings in the morning through to those in the afternoon. There was, however, no interaction between measurement period and time of day for overall mental workload, Wilks' $\lambda = 0.88$, $F(18, 379.5) = 0.99$, $p = 0.5$. Similarly, there were no interactions between measurement period and time of day for any of the six individual TLX subscales (all ps > 0.4).

3.5 Perceived effects of the electronic whiteboard

Most of the interviewed clinicians agreed that the electronic whiteboard provided an improved overview. Indeed, the clinicians' primary use of the electronic whiteboard was to gain and maintain an overview, especially in busy periods and in between patients. The interviewees made statements such as "*It gives a brilliant overview*", "*More people have an overview now*", and "*It provides a good overview of the announced patients [i.e., those who are on their way but have not yet arrived]*".

However, one physician complained that the ordering of the patients was illogical on the whiteboard in that the more important patients – those in the patient rooms – were the less visually prominent, thereby detracting from the overview. The whiteboard was also considered to provide "*better protection against errors*" due to legible writing and to be "*rather easy to use*" though many interactions were perceived to require too many clicks.

With respect to changes in work practices a nurse noted that "*It was our hope that the whiteboard would be used from the patient rooms to see whether you were needed in other places or you could stay a bit longer in the patient room and complete your care of the patient extra well.*" This use of the electronic whiteboard related to the clinicians' need for preparing for new patients by completing their current patients and thereby freeing clinicians and patient rooms. At an ED this is a permanent concern: "*We always fear a large run-in.*" Several interviewees expressed that the whiteboard information about the patients announced for arrival supported them in being on the top of the situation. Before the introduction of the electronic whiteboard, information about announced patients was only available on paper forms at the control desk and mainly seen by the coordinating nurse. After the introduction of the electronic whiteboard this information was available across the ED and appreciated by the ED staff. The distributed access to whiteboard information from the patient rooms provided for a work practice in which many patients received more attention because the nurses knew that they were not currently needed elsewhere. One interviewed nurse asked to have the electronic whiteboard installed as the screensaver on the computer in the patient rooms to make the whiteboard information readily available whenever the computer was not used for other purposes.

When asked why the physicians were not spending more of their time in the patients rooms after the introduction of the electronic whiteboard one senior physician explained that, in principle, the physicians ought to stay in the patient rooms while writing the patient record but, in practice, "*the junior physicians are often insecure and need advice and therefore leave the patient rooms [to seek advice]*". This state of affairs frustrated the senior physician because he felt that the quality of the treatment and records would improve if the records were written in the patient rooms: "*The contact with the patient during the 40 minutes you spend writing the patient record is important. You hear more, see more, can more readily ask the patient an additional question.*" Several interviewees pointed out that it was also more efficient to write the patient records while in the patient room because "*you are not interrupted as much*". Nevertheless, the physicians generally preferred to sit in the physicians' work area while writing patient records. To be available for consulting the senior physician also spent much of his own time in the physicians' work area and, thus, away from the patient rooms. He felt that this was necessary because there were only two senior physicians on duty at a time and thus few experienced physicians for the junior physicians to consult.

The interviewees disagreed somewhat about the extent to which they had been informed about how to use the electronic whiteboard and whether procedures existed regarding its use. One nurse who had been central to the implementation process said: "*After three-four weeks of use we started to become aware that this was a larger task than we had imagined. We have spent too little energy adjusting our procedures. ... We have not explored the potential of doing things differently.*" Another interviewee felt that after the first round of whiteboard revisions the vendor had been less responsive which had led to some frustration and calmed initiatives to adjust work practices.

4 Discussion

In the following we discuss the work-practice changes that accompanied the introduction of the electronic whiteboard, probable reasons for these changes, and limitations of the study.

4.1 Changes in work practices

After the electronic whiteboard has been in operation for four months, physicians do not spend more of their time in patient rooms but nurses spend an average of 44 additional minutes in patient rooms each shift and are less at the control desk. Physicians and nurses used to spend about the same

percentage of their time in patient rooms but after the introduction of electronic whiteboards the physicians spend 20% and the nurses 28% of their time in patient rooms. Compared to previous studies, the percentage is somewhat low for the physicians and about average for the nurses. For example, Yen et al.[22] find that attending physicians, resident physicians, and nurses at a paediatric ED spend 25%, 35%, and 26% of their time, respectively, in the examination room with the patient and that these percentages nearly equal the total time spent on direct patient care. Hollingsworth et al.[23] find that faculty physicians, resident physicians, and nurses at a general ED spend 32%, 33%, and 31% of their time, respectively, on direct patient care. Thus, with the right support, possibly in terms of a whiteboard with extended functionality, there may be a potential for increasing the physicians' presence in patient rooms.

A major difference between the dry-erase and electronic whiteboards is the possibility for distributed access to the electronic whiteboard from any computer in the ED. This possibility, also emphasized in previous studies[1, 7, 18], is for example used in the patient rooms, especially those dedicated to acute patients. Contrary to expectations, the use of the patient-room computers for applications other than the whiteboard is similar before and after the introduction of the electronic whiteboards. An increase was, for example, expected in the access to treatment instructions because the electronic whiteboard can show links from the problem descriptions recorded on the whiteboard to the associated treatment instruction and, thereby, substantially ease less experienced clinicians' access to the instructions. This facility must, however, be configured by the ED to associate each problem type with an instruction, and this never happened. This example of a possible extension in the whiteboard functionality illustrates the influence of the implementation process on how electronic whiteboards affect ED work. Depending on the implementation process, the same system may have different outcomes[24].

For physicians as well as nurses the time spent with the patients is also time spent away from other clinicians. We observed many brief communications at the control desk, during which less experienced clinicians received information and recommendations from more experienced clinicians, who on their part informally ensured the quality of the treatment of a patient. Also, the electronic whiteboard in the physicians' work area provided a new and frequently used place for the physicians to briefly discuss patients without disrupting work at the control desk. Brief communications about patients are an important aspect of ED work, and they happen routinely and naturally at the control desk and in the physicians' work area, provided that the clinicians frequently gather there for part of their work, thereby making their work visible to their colleagues or themselves available for questions. Wears et al.[9] report that electronic ED whiteboards shift the balance between collaborative and individual work toward more individual work. Such a shift would be an unintended consequence of spending more time in patient rooms and highlights the interrelated concerns the clinicians must continually manage.

For the nurses it appears that the overview they need in their work has to some extent been dissociated from the control desk. It has, for example, become possible for nurses to monitor the arrival of new patients by accessing the electronic whiteboard from the patient rooms and, thereby, maintain an awareness of whether they are needed for other activities or can remain with their current patient. Easing this awareness supports the nurses in their care of the patients, which requires being with the patients. The nurses have moved some of their location-unrelated activities, such as writing patient records, from the control desk to the patient rooms. Positive side effects of this move are that the activities can often be completed better and faster in the patient room because the patient is available for consultation and because there are fewer interruptions, which are otherwise very frequent in ED work[25, 26].

The coordinating nurse uses the electronic whiteboard heavily but has not experienced a reduction in mental workload. Before as well as after the introduction of the electronic whiteboards the upward drivers of the coordinating nurse's mental workload are the mental and temporal demands. Our observations show that the coordinating nurse has a high communication load and is frequently interrupted. Spencer et al.[26] report that coordinating nurses spend 90% of their time in communication events and are interrupted about 25 times per hour for an average duration of 38

seconds. The absence of a reduction in the coordinating nurse's mental workload suggests that the other ED staff's preference for obtaining information by asking the coordinating nurse has not shifted toward obtaining considerably more of it from the electronic whiteboard. However, the interviewees' statements that more of the clinicians now have an overview provide some basis for suggesting that the downward trend in the coordinating nurse's mental workload is promising though not significant. The coordinating nurse still has the demanding and stressful role as the main person responsible for the coordination of ED work. Even so, the coordinating nurse experiences a reduction in physical demand. A likely reason for this reduction is that the coordinating nurse can make whiteboard changes on the computer when seated and on the touch screen when standing, whereas all changes previously had to be made on the dry-erase whiteboard. Though the distance from the coordinating nurse's computer to the whiteboard is just a few meters, the coordinating nurse used to traverse it many times a day.

4.2 Reasons for the changes

As the work-practice changes are not causal effects of the electronic whiteboard it is important to consider the reasons for the changes. We want to point at four probable reasons.

First, the possibility to access the electronic whiteboard from any computer in the ED is a major difference compared to the dry-erase whiteboard. We frequently observed the electronic whiteboard on computers across the ED. Apart from accessing it from the computers in patient rooms, the secretaries have it open to monitor the progress of patients toward discharge and it is accessed on computers at the control desk to facilitate updating of the whiteboard content while seated. In addition, the secretaries, who receive walk-in patients and telephone referrals from general practitioners, started to enter initial information about these patients on the electronic whiteboard. This change in work practice has relieved the coordinating nurse of work and become an established procedure at the ED. The secretaries increased role in initiating new patients on the electronic whiteboard is consistent with Hertzum[27] who finds that ED secretaries tend to incorporate distributed access into their work practices to a larger extent than other ED staff. The distributed access supports the staff in maintaining an overview of the state of the ED while at a distance from the control desk.

Second, the nurses are generally more experienced than the physicians because a temporary ED position is a mandatory part of physicians' clinical training. This difference contributes to explaining why the nurses feel comfortable spending more of their time in patient rooms where they are on their own, whereas the physicians often need to leave the patient room to seek advice from their colleagues. The interviewed senior physician encourages the junior physicians to spend more of their time in the patient rooms and emphasizes that writing the patient record in there provides for better treatment quality due to the increased contact with the patient. However, he also acknowledges the importance to treatment quality of their consulting with more experienced colleagues at the control desk or in the physicians' work area. And, to be available for such consulting the senior physicians too spend much of their time away from the patient rooms.

Third, the implementation of the electronic whiteboard at the ED has been somewhat laissez faire. That is, the electronic whiteboard provides some new opportunities but its introduction has not been accompanied by an orchestrated, department-wide effort to pursue these opportunities. For example, the communication load on the coordinating nurse has not been reduced and links from problem descriptions to treatment instructions have not been configured. Some interviewees are in doubt whether procedures exist regarding the use of the electronic whiteboard, and an interviewee central to the implementation process states that to the extent new procedures do exist they have not been devised with the aim of exploiting the new opportunities provided by the whiteboards. The formally enforced procedures have not driven the work-practice changes that have ensued. The ensued work-practice changes are instead those that could be pursued by individual ED clinicians, such as nurses spending more of their time in patient rooms.

Fourth, the physical layout of the ED provides a good overview of the ED from the control desk. The importance of the physical layout has, for example, been emphasized by Scupelli et al.[28]. By

spending time at the control desk the clinicians not only get access to their colleagues and the whiteboard, they also get a first-hand impression of the level of activity and urgency in the ED. Specifically, the coordinating nurse can see who enters and leaves most of the patient rooms. The good physical layout probably contributes to explaining the absence of an effect of the electronic whiteboard on the coordinating nurse's mental workload, and it suggests larger effects of electronic whiteboards on EDs with a poorer physical layout.

4.3 Limitations

Three limitations should be remembered in interpreting the results of this study. First, there is no causal link between the electronic whiteboard and the changes in ED work practices. While the use of the electronic whiteboard in the patient rooms supports a link between the whiteboard and the nurses' increased presence in the patient rooms, it cannot be assumed that the whiteboard will lead to the same work-practice changes at other EDs. To investigate this issue, we are conducting a similar study at another ED. Second, the functionality of the electronic whiteboard resembles that of dry-erase whiteboards. This simplicity has advantages in terms of ease of understanding, which may have expedited adoption. Electronic whiteboards with more functionality may lose these advantages but, at the same time, enable more profound work-practice improvements. Third, the measurements in this study concerned the clinicians' work practices. This focus is important in its own right and it is likely to have an impact on patient treatments and outcomes. Conclusions about effects on patient treatments and outcomes are, however, outside the scope of this study.

5 Conclusion

Four months after the introduction of an electronic ED whiteboard, it is frequently accessed from the computers in patient rooms, and nurses spend more of their time with patients and less at the control desk with their colleagues. These are important work-practice changes that affect how the ED staff maintains the overview they need in performing competently and how the patients experience their treatment. At the same time, physicians are not spending more of their time with patients, indicating that the electronic whiteboard is experienced as providing different possibilities by physicians and nurses as a result of differences in their experience, tasks, or preferred ways of obtaining information. The coordinating nurse experiences no change in mental workload, apart from a decrease in physical demand. For the physicians and the coordinating nurse the electronic whiteboard, which in the main is a manually updated standalone system, has remained a minor improvement compared to the essence of their work. It appears that for the electronic whiteboard to support further changes in work practices, the whiteboard functionality must be extended, but the ED must also take a firmer grip on the implementation process. While the simplicity of the whiteboard has made it possible to attain the current improvements with little organizational effort, this is unlikely to remain possible with extended whiteboard functionality that connects the whiteboard with other electronic records.

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Table 1. Control variables, $N = 2177$ patients

	Before		After	
	Mean	*SD*	*Mean*	*SD*
Admissions per day	39.4	7.9	38.3	6.3
Patient age (years)	55.6	23.7	56.0	24.5
Triage level (1-5)	3.30	0.93	3.28	0.82

Table 2. Percentage of physician time spent in patient rooms versus at control desk, $N = 316$ shifts

		Before		After	
		Mean	*SD*	*Mean*	*SD*
Patient rooms		19	13	20	12
Control desk	**	52	17	59	20
Other	***	29	12	20	13

** $p < 0.01$, *** $p < 0.001$

Table 3. Percentage of nurse time spent in patient rooms versus at control desk, $N = 347$ shifts

		Before		After	
		Mean	*SD*	*Mean*	*SD*
Patient rooms	***	17	13	28	15
Control desk	**	55	19	44	18
Other		27	12	28	11

** $p < 0.01$, *** $p < 0.001$

Table 4. Computer use in minutes a day per patient room, $N = 211$ room days

		Before		After	
		Mean	*SD*	*Mean*	*SD*
Electronic whiteboard	***	0.0	0.0	24.8	24.5
Electronic patient record		47.3	35.2	55.6	42.1
Test results and images		1.0	5.0	1.3	5.2
Treatment instructions		0.1	0.6	0.2	1.4
Other		66.8	39.3	58.5	40.4
Total	*	115.2	66.5	140.3	86.9

* $p < 0.05$, *** $p < 0.001$

Table 5. Mental workload of coordinating nurse, $N = 147$ TLX ratings

		Before		After	
		Mean	*SD*	*Mean*	*SD*
Mental demand		47	31	42	29
Physical demand	*	31	24	23	21
Temporal demand		44	30	39	30
Effort		40	29	35	29
Performance		24	19	25	23
Frustration		28	22	32	29

* $p < 0.05$

Figure 1. The electronic ED whiteboard (names are concealed for reasons of privacy).

Figure 2. The control desk.