

Electronic Emergency-Department Whiteboards: A Study of Clinicians' Expectations and Experiences

Morten Hertzum

Computer Science, Roskilde University
Universitetsvej 1, Bldg 43.2, DK-4000 Roskilde, Denmark
phone: +45 4674 3077, email: mhz@ruc.dk

Abstract

Purpose. Many emergency departments (EDs) are in a process of transitioning from dry-erase to electronic whiteboards. This study investigates differences in ED clinicians' perception and assessment of their electronic whiteboards across departments and staff groups and at two points in time.

Method. We conducted a survey consisting of a questionnaire administered when electronic whiteboards were introduced and another questionnaire administered when they had been in use for 8-9 months. The survey involved two EDs and, for reasons of comparison, a paediatric department.

Results. The ED respondents consider the whiteboard information important to their overview, and they approve of the introduction of electronic whiteboards. With the electronic whiteboards, the ED respondents experience a better overall overview of their work than with dry-erase whiteboards. They also experience that whiteboard information has to a larger extent become available where and when they need it. Conversely, the ED respondents' expectations toward the electronic whiteboards have not been fulfilled when it comes to keeping information current and obtaining improvements for the patients. The ED staff groups of physicians, nurses, and secretaries experience the electronic whiteboards differently. The physicians, for example, consider it faster and simpler than the nurses to find information on the electronic whiteboards. After extended use, multiple questionnaire items about achieved performance and required effort contribute to explaining the variation in the nurses' overall assessment of the whiteboards; for physicians and secretaries few items contribute to explaining the variation in their overall assessment. The respondents from the paediatric department perceive their whiteboards as less important to their overview and collaboration than the ED respondents.

Conclusion. The ED clinicians experience positive effects of electronic over dry-erase whiteboards. However, their assessment of electronic whiteboards depends on their staff group, evolves over time, and differs from that of paediatric clinicians. These results likely affect clinicians' acceptance of electronic whiteboards and their command of their work.

Keywords: Electronic whiteboard, status board, emergency department, technology adoption, before/after survey

1 Introduction

An important element of the clinical work at departments that treat acute patients consists of forming and maintaining an overview [1-4]. At emergency departments (EDs), the support for clinical overview includes whiteboards with carefully selected, frequently updated, and highly visible information about the patients [5-9]. Currently, many EDs are in a process of replacing their old dry-erase whiteboards with electronic whiteboards that preserve many surface features of dry-erase whiteboards but differ in multiple other ways [e.g., 5, 10]. This transition process accentuates considerations about how to support clinical overview, how to introduce new technology, and whether ED clinicians perceive electronic whiteboards as an improvement over dry-erase whiteboards. One challenge in the transition to electronic whiteboards is that the dry-erase whiteboards are generally effective and appreciated [11, 12].

EDs have newly been established in Denmark, and we collaborate with one of the five Danish healthcare regions, Region Sjælland, about the design, introduction, and evaluation of their electronic whiteboards. This study reports from a survey at two EDs and, for reasons of comparison, a paediatric department, which was included in the survey to assess how specific our results are to EDs. We investigate differences in the clinicians' perception and assessment of their electronic whiteboards across departments and staff groups and at two points in time. First, the clinicians were asked about their expectations toward the electronic whiteboards immediately after their introduction while the clinicians were in the midst of the transition from dry-erase to electronic whiteboards. Second, the clinicians were asked about their experience of the electronic whiteboards eight to nine months later after they had become thoroughly familiar with the electronic whiteboards and after the new work practices associated with the whiteboards had had time to settle. Thus, we investigate effects of electronic whiteboards on the clinicians and, especially, on their sense of having the overview they need in their work. This focus is important because clinicians' work conditions are themselves of great consequence and because the clinicians' sense of having the overview they need impacts their command of their work and thereby the attainment of 'downstream' effects on patient outcomes. In addition, clinicians' perception and assessment of new technologies such as electronic whiteboards are important because they impact whether departments consider technologies for introduction, how clinicians adopt – or work around – technologies, and thereby to what extent technologies become successful [13].

The electronic whiteboards, developed by Imatis, give one row of information for each patient, including information such as time of arrival, room, patient name, age, triage level, problem, allocated physician, allocated nurse, and next action. That is, the electronic whiteboards resemble those in other studies of electronic ED whiteboards [e.g., 1, 5] and largely mimic dry-erase whiteboards in content and surface structure. The whiteboards combine a logistic function with clinical patient data and are used by all ED staff to coordinate work and prioritize resources. Nurses triage patients upon arrival to determine the importance and urgency of the patients' condition. Selected triage information is written on the whiteboard, including the triage level and any tests ordered. This information triggers the next sequence of actions, which includes allocating a physician to the patient. Often, physicians will monitor the whiteboard to align their examination of a patient with the arrival of test results. All clinicians will use the whiteboard information to change the order in which they see patients so as to attend to the most urgent patients, to locate patients who have been moved, to keep track of the progress of their patients toward discharge from the ED, and to maintain an awareness of their colleagues' work load. Most updates of the whiteboards are made by nurses. The secretaries announce walk-in patients that arrive in the waiting room, rather than by ambulance, and monitor the whiteboard for patients for whom records must be finalized, for example because the patient is about to leave the ED. The electronic whiteboards are permanently displayed on centrally located, 52-inch touch screens and can also be accessed on any computer at the departments. More information about the design of the surveyed whiteboards and the process of their organizational implementation can be found in Rasmussen et al. [14]. While the electronic whiteboards were at the time of the survey updated manually, they are gradually being extended with automatically updated fields of information, for example vital signs and the results of blood tests. As the electronic whiteboards over time get increasing numbers of automatically updated fields, they will increasingly become a widely visible front end to the departments' electronic patient records with which the whiteboards will become still more integrated. The surveyed whiteboards were, however, standalone.

2 Related work

Previous studies of ED whiteboards find that interaction with dry-erase whiteboards is direct, fast, flexible, and central to the coordination of ED work [6, 11, 12]. Gathering around a dry-erase whiteboard provides opportunities for communication and coordination and for others to notice and infer activities [15]. While clinicians can also gather around an electronic whiteboard, the electronic whiteboards can usually be accessed from many computers and may thus be used in a more individual and less visible manner [16]. In addition, dry-erase whiteboards are low-tech and therefore robust, and they have over several decades evolved into an effective and efficient coordination tool [11]. The shortcomings of dry-erase whiteboards include that information is lost when erased, that information is rarely updated in real time, that information can only populate multiple dry-erase whiteboards through repeated manual data entry, which incurs risk of incompleteness and inconsistency, and that there is no possibility of automatic integration with information in other systems [5, 10]. Electronic whiteboards may address these shortcomings. It has also been found that nurses experienced the dry-erase whiteboards at their department as an imposition and a cause of conflict [17], and that nurses gamed the whiteboard by, for example, erasing their name on the whiteboard without informing the nursing coordinator of their availability for a new task, effectively making themselves temporarily invisible [18]. Electronic whiteboards are unlikely to remedy such issues.

The transition from dry-erase to electronic whiteboards is not instant. Horak [19] reports a gradual shift from a reluctant attitude toward the electronic whiteboards during the first three months of use to an improved level of compliance in

whiteboard use after six months. Pennathur et al. [20] found that shortly after the transition the clinicians experienced a negative impact of the electronic whiteboards on their ability to make sense of the overall state of the ED, concerns over loss of control over information, problems concerning the physicians' ability to communicate patient status information, and problems regarding whiteboard usability. Electronic whiteboards have also been found to be less accurate and less used than dry-erase whiteboards [21]. Bisantz et al. [5, p. 40] make the general note that the successful design of electronic whiteboards "requires a careful understanding of the functions afforded by the old systems and the manner in which the manual systems supported clinical work." In addition, the safety-critical nature of ED work implies that the usability flaws found in some electronic whiteboards are potentially life-threatening [22]. Several positive effects of electronic ED whiteboards have also been reported, including that they improve the efficiency of work and communication [8], increase patient satisfaction [7], and potentially serve as the primary portal for information needs in the ED [1]. To serve as the primary information portal electronic ED whiteboards must be integrated with the other electronic patient records in the ED. While such integration reduces redundancy and repeated entry of the same data, it also reduces the opportunities for cross-checking the content of the recorded data [23]. Staff assessments of electronic ED whiteboards may vary by staff group. Wong et al. [24] got neutral or slightly negative median responses from physicians to questions about whether an electronic whiteboard had expedited and improved patient treatment, whereas nurses answered the same questions somewhat more positively. Finally, Bardram et al. [2] emphasize the use of dedicated displays for systems such as electronic whiteboards because the persistent visibility of the whiteboard information is important to its support of overviewing, awareness, and ad hoc coordination.

3 Method

To investigate clinicians' perception and assessment of electronic whiteboards we conducted a survey at two EDs and a paediatric department. The survey was approved by the management of the three departments and by the healthcare region's department for quality and development.

3.1 Respondents

The two emergency departments, ED1 and ED2, were established in April 2009 by uniting previously separate departments under one management. ED1 had about 30 beds divided onto a fast-track area, an acute area, and an acute-medical area. ED2 had about 15 beds divided onto a fast-track area and an acute area. The paediatric department was a longstanding department with about 22 beds; it was partly a paediatric ED. The staff at the three departments consisted of physicians, nurses, auxiliary nurses, and secretaries. To characterize the departments further the vendor of the electronic whiteboards provided us with an anonymized log of their content during the two-month period leading up to and including the second round of the survey. We extracted the number of patients, their age, length of stay, and triage level from the log data, see Table I. The triage level was recorded on the whiteboard for 49% of the patients in terms of a number from 1 (life-threatening) to 5 (normal). ED1 and ED2 were roughly similar with respect to average patient age, length of stay, and triage level; the difference in the number of patients corresponded to the difference in the number of beds at the two EDs. The paediatric department differed from the EDs for all but the patients' average triage level.

Questionnaires were administered to all staff, a total of 187 people during the first round of the survey and 130 people during its second round. Due to high staff turnover, especially among the physicians, the members of staff employed during both rounds of the survey were considerably fewer than the members of staff employed during either its first or second round. We received a total of 161 useful responses to the survey, for an overall response rate of 51%. An additional 15 responses were considered non-useful and excluded because less than half of the questionnaire had been completed. Table II breaks down the 161 useful responses on the two rounds of the survey and the three participating departments.

3.2 Survey questionnaires

The survey instrument was a pair of related questionnaires: Prospectively, a questionnaire asked respondents about their use of the dry-erase whiteboards and their expectations toward the electronic whiteboards. Retrospectively, another questionnaire asked the respondents about their experiences with the electronic whiteboards. The two questionnaires partially overlapped, asking respondents the same questions with only changes of tense (expectations vs experiences) or technology (dry-erase vs electronic whiteboards). This allowed us to compare, for each respondent, the answers given before and after the introduction of the electronic whiteboards.

The two questionnaires shared 21 closed questions, which concerned the clinicians' sense of having the overview they needed in their work (9 questions), the clinicians' perception of the dry-erase/electronic whiteboards (5 questions), and their expectations toward/experiences with the electronic whiteboards (7 questions). These questions formed the main part of the questionnaires and were devised in collaboration with representatives from the healthcare region. In addition, the first questionnaire contained seven closed questions about the respondents' general attitude to technology and their satisfaction with their work environment, and the second questionnaire contained three additional closed questions about the clinicians' perception of the electronic whiteboards. Responses to the closed questions were indicated on seven-point rating scales with the end points *Disagree* (1) and *Agree* (7), except three questions with responses indicated on ten-point rating scales from *Low* (1) to *High* (10). All questions had an additional response option of *Don't know*. Apart from the closed questions, the first questionnaire contained three free-text questions and the second questionnaire two. All five free-text questions were broad (e.g., "Any other comments about the whiteboards and their introduction?") and were included to capture any additional comments from the respondents. Both questionnaires were refined through informal pilot testing prior to their administration.

3.3 Procedure

The administration of the questionnaires followed the schedule for the introduction of the electronic whiteboards at the three departments. The first questionnaire was administered when the departments had completed training in the use of the electronic whiteboards and had just started using them. This happened in December 2009 at ED1, in January 2010 at ED2, and in March 2010 at the paediatric department. The second questionnaire was administered in September 2010 after ED1 had used the electronic whiteboards for nine months and ED2 for eight months. The paediatric department did not receive the second questionnaire because the main focus of the study was on the EDs and because the first questionnaire was sufficient to show that non-ED clinicians assessed the whiteboards differently than ED clinicians.

We contacted the staff via their professional email address. Each staff member received an email with a link to the online questionnaire. The email guaranteed that no individual respondent would be identifiable in the reportings from the survey, informed the staff that their department management approved of the survey, and made explicit that participation in the survey was voluntary. Staff members who did not respond within ten days received a reminder. A second reminder was sent to staff who did not respond within another ten days. The questionnaires were closed a month after they were initially administered.

3.4 Data analysis

The closed questions yielded ordinal data and were, therefore, analyzed with non-parametric tests. We used Kruskal-Wallis tests for the analyses of differences between departments and between staff groups. All pairwise comparisons following Kruskal-Wallis tests were performed with Man-Whitney tests and were Bonferroni-adjusted to compensate for multiple comparisons. We used Wilcoxon tests for the analyses of differences between the same respondent's answers to the questions shared by the two questionnaires. Finally, we used Spearman correlations to analyze the relationships between questionnaire items and the respondents' overall assessment of whether it was a good idea to introduce the electronic whiteboards. The aim of this correlational analysis was to identify the items that explained considerable variation in the respondents' overall assessment. In all analyses *Don't know* responses were treated as missing values.

The five free-text questions were analyzed together because all five questions were quite broad and the responses overlapped in content. The author read all the free-text comments several times to develop an understanding of their content and then grouped the comments into groups representing the main content elements of the comments. To condense the analysis further, the groups were clustered into higher-level groups, each containing several related groups of comment.

4 Results

The respondents' perceptions and assessments of the electronic whiteboards are analyzed below for all three departments (Sections 4.1 and 4.2) and exclusively for the two EDs (Sections 4.3 to 4.6).

4.1 Control variables

The first questionnaire included seven background questions about the respondents' general attitude to technology and their satisfaction with their work environment, see Table III. The respondents indicated that they generally embraced new technology. At the same time they gave largely neutral median answers to the questions about whether new

technology generally leads to improvements in patient care and staff conditions. The respondents were fairly satisfied with their professional and social work environments, but neither satisfied nor dissatisfied with their physical work environment. A difference between departments was only found for satisfaction with the professional work environment, $\chi^2(2, N=83) = 7.94, p < 0.05$, with pairwise comparisons showing higher satisfaction for Paediatric than ED1 respondents.

4.2 Departmental differences

The first questionnaire contained three questions that asked respondents about their overall assessment of their overview, the dry-erase whiteboards, and the electronic whiteboards, see Figure 1. First, the median responses for the question about the clinicians' overall sense of having the overview they needed in their work were 5, 5.5, and 6 for ED1, ED2, and Paediatric, respectively, and thus in the positive half of the scale. There was a significant effect of department, $\chi^2(2, N=89) = 6.94, p < 0.05$, with pairwise comparisons showing that Paediatric respondents reported having more of an overview than ED1 respondents. Second, the respondents perceived the information on the dry-erase whiteboards important to their overview, as indicated by median ratings of 7, 7, and 5.5 for ED1, ED2, and Paediatric, respectively. We found a significant effect of department, $\chi^2(2, N=84) = 13.71, p < 0.01$, with pairwise comparisons showing that Paediatric respondents considered the information on the dry-erase whiteboards less important to their overview than ED1 and ED2 respondents. Third, the respondents considered the introduction of the electronic whiteboards a good idea, as indicated by median ratings of 7, 7, and 6 for ED1, ED2, and Paediatric, respectively. There was a significant effect of department, $\chi^2(2, N=77) = 7.84, p < 0.05$, with pairwise comparisons showing that Paediatric respondents were less positive about the introduction of the electronic whiteboards than ED2 respondents.

An additional four of the 21 questions presented in Table IV and analyzed in the next section showed significant differences between the Paediatric department and one or both of ED1 and ED2 (Q8: $\chi^2(2, N=87) = 9.44, p < 0.01$; Q11: $\chi^2(2, N=77) = 7.91, p < 0.05$; Q16: $\chi^2(2, N=80) = 11.73, p < 0.01$; Q19: $\chi^2(2, N=82) = 9.85, p < 0.01$). Conversely, only one question showed a significant difference between ED1 and ED2 (Q15: $\chi^2(2, N=84) = 6.80, p < 0.05$). These results indicate that the Paediatric department differed from the EDs, which on their part were quite similar. We, therefore, restrict the remainder of the analysis to ED1 and ED2.

4.3 Before-after effects of the electronic whiteboards

The questions included in both questionnaires provided for an analysis of before/after effects of the electronic whiteboards. Table IV shows the median responses to these questions for respondents from ED1 and ED2 in the first ($N = 61$) and second ($N = 71$) questionnaire and reports whether the clinicians who responded to both questionnaires ($N = 36$) gave different answers after they had used the electronic whiteboards for eight or nine months. To clarify the data based on which we analyzed whether the clinicians gave different answers before and after they had gained experience with the electronic whiteboards, the table also gives the median responses for the 36 clinicians who responded to both questionnaires. These clinicians comprised 4 physicians, 26 nurses, 4 secretaries, and 2 auxiliary nurses. By inspecting the table it is evident that the responses from the 36 clinicians who responded to both questionnaires were largely similar to those from the total of 61 and 71 ED clinicians who responded to the first and second questionnaire, respectively.

Two questions received a median response of 7 (the maximum) in both questionnaires. These questions read "The information on the dry-erase/electronic whiteboards is important to my overview" and "Overall, it is/has been a good idea to introduce the electronic whiteboards". This indicates the fulfilment of high expectations toward the electronic whiteboards. For six of the 21 comparisons, the 36 clinicians who responded to both questionnaires were significantly more positive in the second questionnaire (z s = -2.64, -2.85, -3.49, -3.24, -2.49, -1.97, all p s < 0.05, for questions Q3, Q8, Q9, Q10, Q13, Q21, respectively, see Table IV). Four of the improvements concerned the clinicians' sense of having the overview they needed in their work; most notably the clinicians experienced an improvement with respect to the question "Overall, I have the overview I need in my work". Also, the information on the electronic whiteboards was perceived to be available where and when needed to a larger extent than the information on the dry-erase whiteboards. For two of the 21 comparisons, the electronic whiteboards did not live up expectations (z s = -2.46, -2.07, both p s < 0.05, for questions Q20 and Q23, respectively, see Table IV): After extended use of the electronic whiteboards the clinicians were less positive concerning whether the electronic whiteboards would lead to improvements for the patients and always be up to date. It should be remembered that because the clinicians who responded to both questionnaires were mainly nurses the before/after effects mainly concern this staff group and cannot be interpreted as indicative of physicians, secretaries, and auxiliary nurses.

4.4 Differences in staff-group experiences

Table V shows the responses to the second questionnaire for the ED clinicians, divided onto the staff groups of physicians, nurses, and secretaries. The auxiliary nurses were so few in number (4 respondents) that we excluded them from this analysis. There were significant effects of staff group for six questions (Q4: $\chi^2(2, N=66) = 9.91, p < 0.01$; Q7: $\chi^2(2, N=67) = 7.39, p < 0.05$; Q8: $\chi^2(2, N=66) = 10.88, p < 0.01$; Q15: $\chi^2(2, N=62) = 10.69, p < 0.01$; Q22: $\chi^2(2, N=49) = 9.22, p < 0.01$; Q24: $\chi^2(2, N=63) = 11.11, p < 0.01$). Pairwise comparisons showed that for all these questions the physicians were more positive than the secretaries; for two questions (Q8, Q15, see Table V) the nurses were also more positive than the secretaries; and for two questions (Q22, Q24) the nurses were less positive than the physicians. Notably, the physicians considered it faster and simpler to find information on the electronic whiteboards but equally fast and simple to update it, compared to the nurses. And, the physicians disagreed that the electronic whiteboards had reduced the clinicians' shared understanding of their work to a larger extent than the nurses and secretaries, who neither agreed nor disagreed to this question.

4.5 Factors influencing overall assessment

To analyze which survey items influenced the clinicians' overall assessment of the electronic whiteboards we correlated the clinicians' responses with their overall assessment of whether it was a good idea to introduce the electronic whiteboards. Table VI shows the correlations.

For the physicians, a different picture emerged for the two questionnaires, that is for expectations toward electronic whiteboards versus experiences with them. The physicians' overall expectations toward the electronic whiteboards were significantly correlated with whether they expected the electronic whiteboards to yield improvements in patient treatment, to foster a reduction in the clinicians' shared understanding of their work, and to become pivotal to important collaborative activities among the clinicians. The variation in these three items individually explained (r^2) 79%, 68%, and 47%, respectively, of the variation in the physicians' overall expectations toward the electronic whiteboards. After having used the electronic whiteboards for eight to nine months, the physicians' assessment of whether it had been a good idea to introduce the electronic whiteboards was not significantly correlated with any of the 14 items.

For the nurses, three items correlated significantly with their overall expectations toward the electronic whiteboards. The variation in whether they expected the electronic whiteboards to yield improvements in patient treatment, to become pivotal to important collaborative activities among the clinicians, and to always be current explained 53%, 40%, and 15%, respectively, of the variation in their overall expectations. After they had gained experience with the electronic whiteboards, the nurses' overall assessment correlated significantly with ten of the 14 items, the variation in which individually explained between 15% and 62% of the variation in overall assessment. The four items that explained most variation consisted of the item about the importance of the whiteboard information to the nurses' overview ($r^2 = 42\%$), that is to the quality of their work, and three items about the effort required to use the electronic whiteboards: the whiteboard information is available where and when needed (62%), fast and simple to find (50%), and easy to understand (36%).

For the secretaries, a significant 51% of the variation in overall expectations were explained by the variation in whether the secretaries liked to start using new technology. The same item explained a significant 86% of the variation in the secretaries' overall assessment after they had gained experience with the electronic whiteboards. The only other item that correlated significantly with the secretaries' overall assessment of the electronic whiteboards after they had used them was whether the whiteboard information was available where and when needed ($r^2 = 52\%$). A high number of *Don't know* answers precluded analysis of three items about the secretaries' experiences with the electronic whiteboards.

4.6 Comments from respondents

The respondents provided a total of 85 comments in response to the five free-text questions. The content of these comments formed four main groups: (1) departmental differences, (2) technical and user-interface issues, (3) implementation and use issues, and (4) fields of information currently missing on the electronic whiteboards.

The first group of comments concerned differences in the perception of the electronic whiteboards depending on department type. Six comments mentioned that the electronic whiteboards were mostly designed for the acute areas of the EDs and were less useful in the fast-track areas because the patients were in the fast-track area for too short a period to warrant multiple manual updates of the electronic whiteboards. Another five comments appeared to be specific to the Paediatric department in that they mentioned needs and circumstances concerning patient admissions of longer duration than at the EDs.

The second group of comments concerned technical and user-interface issues. Nine comments mentioned that several of the whiteboard fields were too small to show all their content or that the entire interface was too small to show information about all patients. The need for scrolling or other kinds of interaction with the whiteboard in order to see all information was perceived as a limitation (relative to dry-erase whiteboards). In addition, seven comments in the second questionnaire mentioned that the system was, at times, unstable and three that it was slow.

The third group of comments concerned the implementation and use of the electronic whiteboards. Seven comments mentioned that the organizational implementation of the electronic whiteboards had required effort and commitment from all staff, three comments expressed a wish for more training in the use of the electronic whiteboards, and two comments emphasized the importance of adapting the technology to local needs. With respect to whiteboard use, four comments expressed concerns that the electronic whiteboards were not kept current, three that they were too time consuming to use, and four that some clinicians' focus shifted from the treatment of the patients toward the use of the electronic whiteboards.

Finally, the fourth group of comments consisted of fields of information considered to be currently missing on the electronic whiteboards, including vital signs, important blood tests, highlighting of isolation patients, an easier way of setting and updating the patient priority, a possibility for the physicians to indicate that they had seen a patient, and a field for medication and treatment orders or, more broadly, for messages from physicians to nurses. Several of these fields of information can readily be added by the departments through the configuration facility of the electronic whiteboard.

5 Discussion

In the following we discuss the effects of the electronic whiteboards on the clinicians' perceptions and assessments, the possible reasons for these effects, and the limitations of the study.

5.1 *Effects of electronic whiteboards*

With the transition from dry-erase to electronic whiteboards, the clinicians at the two EDs have experienced an improvement in their overview of their work. Because the clinicians who responded to both questionnaires were mostly nurses this result is valid for the nurses but cannot, based on the present study, be extended to other staff groups such as physicians or secretaries. The clinicians, specifically the nurses, have experienced that with the electronic whiteboards they have a better overview of the patients who are on their way but have not yet arrived, the patients in the waiting room, and the occupancy level in their area of the ED. While they also experience that whiteboard information is to a larger extent available where and when they need it, their expectations have not been fulfilled when it comes to keeping the electronic whiteboards current and deriving improvements for the patients from the electronic whiteboards. Also, the free-text comments suggest several user-interface issues and missing fields of information. A comparison of our results to the more negative results that Pennathur et al. [20] obtained shortly after the transition to electronic whiteboards indicates that considerable time may be required for a new technology to settle and for improvements to be captured and perceived by clinicians. Horak's [19] study of an electronic ED whiteboard suggests that six months may be required. For information systems in general, Jurison [25] estimates that effects at the level of individual users can be observed within 6-8 months whereas organization-level effects may take a year to materialize.

Our comparisons across departments show that although the Paediatric department is partly a paediatric ED, the clinicians at this department perceive their whiteboards as less important to their overview and collaboration than the ED clinicians. Possible reasons for this include that the paediatric patients are fewer and stay longer. We speculate that the role and importance of whiteboards differs even more at non-emergency, non-acute departments. In spite of differences in the organization of work at ED1 and ED2, the clinicians' survey responses contain very few differences between the two EDs. Consequently, we may hope that with modest differences in its setup the same electronic whiteboard can be used at multiple EDs. Electronic whiteboards may, however, be better suited for the acute areas of EDs than for the fast-track areas. Additional caution and redesign will be required to transfer electronic whiteboards to other types of department.

The different ED staff groups experience the electronic whiteboards differently. This is most visible in the large differences concerning which questionnaire items contribute to explaining the variation in the staff groups' overall assessment of the electronic whiteboards. After extended use of the electronic whiteboards, ten of 14 items contribute to explaining the variation in the nurses' overall assessment, two items to explaining the variation in the secretaries' overall assessment, and none to explaining the variation in the physicians' overall assessment. Given the staff groups' different responsibilities these differences may be unsurprising but they are more pronounced than in previous studies

of physicians' and nurses' satisfaction with electronic whiteboards [24] and electronic ED records more generally [26]. The staff-group differences show that ED whiteboards must simultaneously support disparate sets of need. For example, the secretaries are less involved in patient treatment and their use of the whiteboards centres on the periods where the patients enter and are about to leave the ED. This emphasizes the importance of involving all relevant staff groups in the design work.

In the technology-acceptance literature [27, 28] the strongest predictor of acceptance is performance expectancy, including factors such as perceived usefulness, whereas effort expectancy, including perceived ease of use, has particularly been found to influence the early use of a system. The variation in the physicians' and nurses' expectations toward the electronic whiteboards was mainly explained by items concerning performance expectancy, for example expected improvements in patient treatment. The absence of an effect of effort-expectancy items may suggest that the clinicians perceived the electronic whiteboards as a simple system, the adoption of which did not present a learning barrier. After extended use, the variation in the physicians' overall assessment of the electronic whiteboards is explained by neither items concerning performance, nor by other items. This is surprising and suggests the presence of explanatory factors not covered by our survey. A possible factor is social influence, which has previously been found to affect technology acceptance [27] and might consist of a perception that peers and important others approve of electronic whiteboards. The variation in the nurses' overall assessment of the electronic whiteboards after extended use is partly explained by items concerning achieved performance and required effort. The impact of items concerning required effort, for example that it is fast and simple to find and update whiteboard information, is somewhat unusual after extended use [cf. 27] and might suggest that the electronic whiteboards are perceived as very easy to use. The free-text comments suggest that whereas the electronic whiteboards may be easy to use, the process of their implementation has been effortful for the ED staff. Finally, the variation in the secretaries' overall assessment of the electronic whiteboards is to a larger extent explained by their general attitude to technology than by performance and effort considerations.

5.2 Possible reasons for the positive results

One reason for the positive results probably is that we allowed the clinicians to get eight to nine months of experience with the electronic whiteboards before we conducted the second round of the survey. Apart from this reason, which concerns our research methodology, we see four main reasons for the results:

First, the transition to electronic whiteboards constituted an unthreatening change due to their resemblance in layout to dry-erase whiteboards and their touch interface, which affords direct manipulation. This was deliberately achieved by introducing electronic whiteboards that initially provided quite simple facilities [14]. The initial system has gradually evolved through extensions that have added more facilities and tailored the whiteboards to the individual department.

Second, the electronic whiteboards have been accompanied by new ways of working. For example, the work of the triage nurse, who needs continual access to the whiteboard, has been physically separated from the three daily timeouts during which the clinicians gather at the whiteboard to walk through the patients currently at ED2 [14]. These two activities were previously co-located because they both involved access to the dry-erase whiteboard; they are now in separate rooms each equipped with an electronic whiteboard, resulting in better conditions for both activities. It would be a misconception to think of the transition to electronic whiteboards as merely a change of technology. This is also evident in the free-text comments, in which clinicians for example emphasize the staff effort required to succeed with the introduction of the electronic whiteboards and the importance of adapting the whiteboards to local needs.

Third, the process of adopting the electronic whiteboards has been kept going by releases of several new whiteboard versions. The new releases extended the electronic whiteboards with facilities requested by the clinicians but also helped prolong the temporal window during which the clinicians worked with fitting their work practices and the electronic whiteboards to each other. Other studies have found that work practices often congeal after a brief temporal window, leaving new technologies only partially adopted [29]. The need for making changes to work practice over a longer period of time may be interpreted as compensation for limitations of the technology [30] or as improvisational exploitation of emergent effects of the technology [31].

Fourth, the electronic whiteboards have been persistently visible on large, dedicated displays at central ED locations. This is contrary to some studies in which electronic whiteboards run on personal computers alongside other applications [e.g., 16]. We concur with the studies that emphasize the importance of persistent whiteboard visibility [2] at central locations [9]. Distributed use of electronic whiteboards on bedside computers is also important but was at the two EDs allowed to evolve as a gradually recognized, additional benefit of the electronic whiteboards.

While the positive results are encouraging, they are moderated by some negative results, most prominently that the electronic whiteboards have not led to the expected improvements in the treatment of the patients. This result may be

related to the free-text comments talking about a shift in the clinicians' focus from patient treatment toward whiteboard use. The clinicians' positive overall assessment of the electronic whiteboards shows that there are other drivers of their assessment besides performance improvements. This is a common finding [32]. We propose that the clinicians' sense of having the overview they need to perform their work competently is one such driver, which may reduce mental workload and thereby be important to maintaining a high level of performance.

5.3 Limitations

Four limitations should be remembered in interpreting the results of this study. First, the clinicians perceive the electronic whiteboards in use. Thus, their perceptions and assessments of the whiteboards include the new technology but also the new ways of working and the gradual implementation process. It must be expected that the same whiteboards may be perceived and assessed differently by clinicians who adopt different ways of working with the whiteboards or experience an implementation process less responsive to local needs and circumstances. Second, the department-level analyses are dominated by the nurses because they are the largest group of respondents. This correctly reflects that the nurses are the largest staff group at the three departments but specifically for the analysis of before/after effects it also prevents conclusions about staff groups other than the nurses. Third, the number of respondents is modest. Whereas the response rate is similar to that of other medical surveys [33], the three surveyed departments are from one Danish healthcare region and the electronic whiteboards from one vendor. Generalization beyond these settings must be made cautiously. Fourth, the survey is restricted to the clinicians' perceptions and assessments of the electronic whiteboards. This focus is important in its own right and likely to have an impact on patient treatments and outcomes but it does not allow direct conclusions about effects on treatments and outcomes.

6 Conclusion

The clinicians at both surveyed EDs perceive dry-erase whiteboards as important to their overview and, thereby, to their competent performance of their work. This calls for care in the design of electronic whiteboards and in their incorporation into ED work. Positive effects of electronic compared to dry-erase whiteboards are found for the nurses, who are the only staff group with sufficiently many respondents to both questionnaires to allow conclusions about before/after effects of the electronic whiteboards. The nurses experience an improved sense of having the overview they need in their work. In addition they experience that the information on the electronic whiteboards is to a larger extent available where and when needed but also that the electronic whiteboards have not led to the expected improvements in patient treatment. Importantly, these effects should be attributed to the combination of the whiteboards, the associated work practices, and the implementation process during which whiteboards and work practices have evolved. The ED clinicians' experience of the whiteboards after months of use has evolved differently for the different staff groups. Performance expectancy affected the physicians' and nurses' early assessment of the electronic whiteboards, but after extended use the nurses' assessment is affected by both achieved performance and required effort, whereas the survey explains little of the variation in the physicians' overall assessment of the whiteboards after extended use. In contrast, the secretaries' general attitude to new technology appears important to their early assessment of the whiteboards and even more important to their assessment of the whiteboards after extended use. Notably, the differences between physicians, nurses, and secretaries in how they perceive and assess the electronic whiteboards appear to increase with extended use of the whiteboards. In addition, the ED clinicians consider the electronic whiteboards more important than the paediatric clinicians. Thus, EDs may comprise a work setting with a particular good match between the characteristics of whiteboards and the clinicians' need for continually creating and recreating an overview of their work.

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Summary table

What was known on the topic before this study

- Dry-erase whiteboards are a central and appreciated coordination tool in EDs
- Many EDs are in a process of transitioning from dry-erase to electronic whiteboards
- The results of previous studies of user perceptions and assessments of electronic ED whiteboards are mixed

What this study has added to our knowledge

- ED clinicians, specifically the nurses, experience positive effects of electronic over dry-erase whiteboards
- Clinicians' assessment of electronic whiteboards depends on their staff group and evolves with experience
- A process of gradually extending the electronic whiteboards and adjusting associated work practices appears to contribute to the positive results achieved with the electronic whiteboards

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Table I. Profile of the three departments ^a

	ED1	ED2	Paediatric
	<i>M (±SD)</i>	<i>M (±SD)</i>	<i>M (±SD)</i>
Number of patients a day	95.5 (±13.2)	49.0 (±8.6)	8.3 (±6.2)
Patient age (years)	46.1 (±25.6)	55.4 (±21.8)	6.7 (±7.7)
Length of stay (hours)	4.3 (±23.9)	4.0 (±25.9)	61.8 (±130.5)
Triage level (1-5)	3.2 (±0.8)	3.6 (±0.7)	3.5 (±0.6)

^a Calculated based on log data from the electronic whiteboards in the period August-September 2010

Table II. Response rates

Dept.	First questionnaire			Second questionnaire			Both questionnaires		
	Administered	Responses	%	Administered	Responses	%	Administered	Responses	%
ED1	62	33	53	59	36	61	50	21	42
ED2	69	28	41	71	35	49	41	15	37
Paediatric	56	29	52						
Total	187	90	48	130	71	55	91	36	40

Table III. Median responses to background questions in the first questionnaire

Id	Question	ED1 (N = 33)	ED2 (N = 28)	Paediatric (N = 29)	Sign.
27	I like to start using new technology ^a	6	7	7	
28	The use of IT in my daily work often increases my mental workload ^a	4	4	3	
29	When new IT is introduced at the wards, it usually leads to improvements for the patients ^a	4	5	4	
30	When new IT is introduced at the wards, it usually leads to improvements for the staff ^a	4	5	5	
31	Satisfaction with the professional work environment ^b	7	7	8	*
32	Satisfaction with the social work environment ^b	7.5	8	8	
33	Satisfaction with the physical work environment ^b	5.5	5	5	

^a Response options: 1 (disagree) - 7 (agree), ^b Response options: 1 (low) - 10 (high), * $p < 0.05$ (Kruskal-Wallis)

Table IV. Median responses from ED1 and ED2 to the questions included in both questionnaires

Id	Question ^a	Before	After	Before	After	Sign.
		(N = 61)	(N = 71)	(N = 36)		
3	Overall, I have the overview I need in my work	5	6	5	6	**
4	I have an overview of the patients' condition	5	5	5	5	
5	I have an overview of the relative priority of the patients	5	5	5	5	
6	I have an overview of ongoing and planned patient treatments	4	5	5	5	
7	I have an overview of who is presently responsible for which patients	6	6	6	6	
8	I have an overview of the occupancy level in my area of the department	6	6	6	7	**
9	I have an overview of the patients who are on their way but have not yet arrived at the department	6	6	5	7	***
10	I have an overview of the patients in the waiting room	5	6	4	6	**
11	I have an overview of the occupancy level in the other areas of the department	3	2	2.5	3	
12	The information on the dry-erase/electronic whiteboards is important to my overview	7	7	7	7	
13	The information on the dry-erase/electronic whiteboards is available when and where I need it	5	6	5	6	*
14	The information on the dry-erase/electronic whiteboards is easy to understand	6	6	5.5	6	
15	It is fast and simple to update the information on the dry-erase/electronic whiteboards	6	5	5	5	
16/18	The dry-erase/electronic whiteboards are pivotal to important collaborative activities among the clinicians	6	6	6	6	
17	Overall, it is/has been a good idea to introduce the electronic whiteboards	7	7	7	7	
18	The electronic whiteboards will become/are pivotal to important collaborative activities among the clinicians	6	6	6	6	
19	It will likely take/has taken a long time to incorporate the electronic whiteboards in the daily work practices	4	5	5	4	
20	The electronic whiteboards will, over time, lead to/has led to improvements in the treatment of the patients	7	5	7	6	*
21	The electronic whiteboards will be/are used by clinicians individually to an extent that reduces each clinician's overview	4	3	4	3.5	*
22	The electronic whiteboards will reduce/have reduced the clinicians' shared understanding of their work situation	3	3	2	2.5	
23	The electronic whiteboards will always be/are always up to date	5	4	5	3.5	*

^a Response options: 1 (disagree) - 7 (agree), * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Wilcoxon)

Table V. Median responses from ED1 and ED2 to the second questionnaire, divided onto staff groups

Id	Question ^a	Physicians (N = 14)	Nurses (N = 44)	Secretaries (N = 9)	Sign.
3	Overall, I have the overview I need in my work	6	6	6	
4	I have an overview of the patients' condition	5.5	5	3	**
5	I have an overview of the relative priority of the patients	5.5	5	4	
6	I have an overview of ongoing and planned patient treatments	5	5	3.5	
7	I have an overview of who is presently responsible for which patients	7	6	5	*
8	I have an overview of the occupancy level in my area of the department	7	7	5	**
9	I have an overview of the patients who are on their way but have not yet arrived at the department	7	6.5	6	
10	I have an overview of the patients in the waiting room	5	6	6	
11	I have an overview of the occupancy level in the other areas of the department	3	1	1	
17	Overall, it has been a good idea to introduce the electronic whiteboards	7	7	6.5	
12	The information on the electronic whiteboards is important to my overview	7	7	5.5	
13	The information on the electronic whiteboards is available when and where I need it	6	6	5	
14	The information on the electronic whiteboards is easy to understand	6	6	5	
15	It is fast and simple to update the information on the electronic whiteboards	6	5	3.5	**
18	The electronic whiteboards are pivotal to important collaborative activities among the clinicians	6	6	6	
19	It has taken a long time to incorporate the electronic whiteboards in the daily work practices	5	5	4	
20	The electronic whiteboards has led to improvements in the treatment of the patients	6	5	5.5	
21	The electronic whiteboards are used by clinicians individually to an extent that reduces each clinician's overview	3	4	2	
22	The electronic whiteboards have reduced the clinicians' shared understanding of their work situation	1.5	3	4	**
23	The electronic whiteboards are always up to date	5	3	3	
24	It is fast and simple to find information on the electronic whiteboards	6.5	5	4	**
25	After the introduction of the electronic whiteboards I spend more time by the patients	3.5	3	1	
26	Some fields with information important to my overview are missing on the electronic whiteboards	6	4	3	

^a Response options: 1 (disagree) - 7 (agree), * $p < 0.05$, ** $p < 0.01$ (Kruskal-Wallis)

Table VI. Correlation of responses from ED1 and ED2 with overall assessment of the electronic whiteboards

Id ^a	Physicians		Nurses		Secretaries	
	Expectations (N = 11)	Experiences (N = 14)	Expectations (N = 35)	Experiences (N = 44)	Expectations (N = 12)	Experiences (N = 9)
17	1.00	1.00	1.00	1.00	1.00	1.00
18	0.69 *	-0.12	0.64 ***	0.54 ***	0.31	-0.08
19	-0.21	0.10	-0.14	-0.38 *	-0.34	-0.39
20	0.89 **	-0.12	0.73 ***	0.57 ***	0.66	-
21	-0.69	0.14	-0.02	-0.09	-0.42	-
22	-0.83 *	0.09	-0.16	-0.49 **	-0.58	0.00
23	0.58	-0.21	0.38 *	0.27	0.30	0.51
27	0.49	0.51	0.22	0.56 ***	0.71 *	0.93 **
12		0.36		0.65 ***		0.20
13		0.25		0.79 ***		0.72 *
14		-0.27		0.60 ***		0.62
15		0.31		0.45 **		0.27
24		-0.06		0.70 ***		0.49
25		-0.59		0.02		-
26		-0.47		-0.32		0.00

^a See Tables III to V for the questions, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Spearman)

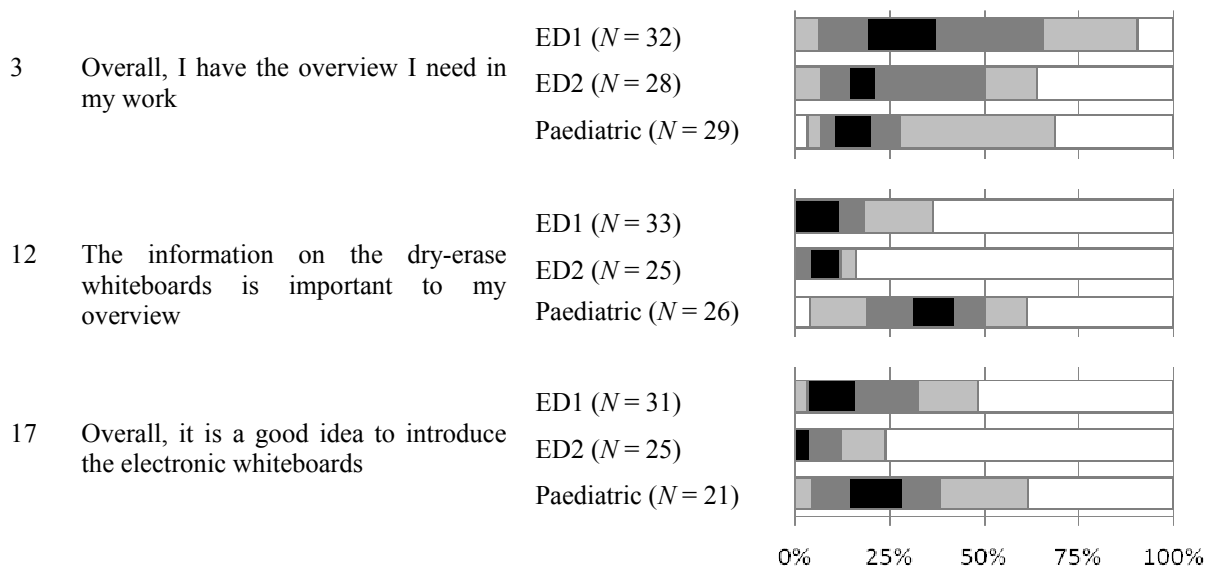


Figure 1. Distribution of responses to three main questions from the first questionnaire. Legend: leftmost white – 1 (disagree), through black – 4 (neutral), to rightmost white – 7 (agree)