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A Systematic Review

Rasmussen, Rasmus

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Electronic Whiteboards in Emergency Medicine: A Systematic Review

Rasmus Rasmussen

Department for Communication, Business and Information Technologies, Roskilde University
Universitetsvej 1, 4000 Roskilde, Denmark

rasmura@ruc.dk

ABSTRACT

As more and more Emergency Departments replace the manual dry-erase whiteboards used for coordination of patient care and communication among clinicians with IT-based electronic whiteboards a need to clarify the effects of implementing these systems arises. This paper seeks to answer this question by systematically reviewing studies on electronic whiteboards. The results of the review indicate that electronic whiteboards influence the work at Emergency Departments in various different ways e.g. changes to work practice and changes to whiteboard information accuracy. Also, the review finds that there are mediating factors that have an impact upon these effects e.g. display format and integration with other clinical IT systems. However, the results are somewhat inconclusive and of a mixed nature and therefore this paper calls for more focused and specific research.

Categories and Subject Descriptors

J.3 [Life and medical sciences] – Medical information systems

General Terms

Design, Human Factors, Management

Keywords

Systematic review, healthcare informatics, electronic whiteboards, emergency medicine

1. INTRODUCTION

At most Emergency Departments (ED) the use of a patient tracking and coordination system is critical as well as essential for maintaining a smooth operation of the department [3], [33]. Often, the cornerstone of this type of system is a large dry-erase whiteboard with a matrix-like information structure displaying information regarding the current ED patients. The whiteboard is often placed centrally in the ED and is frequently accessed and manually updated by the ED staff [33], [34]. As such, the whiteboard functions as the central communication and coordination tool for ED clinicians allowing them to retain an overview of the status of individual patients and the department in general as well as allowing clinicians to pass information on to their colleagues [34]. Previous research has shown that these types of systems play a vital role in facilitating communication between ED staff and coordinating care for the ED patients. As a result of this, they have become an integrated part of the working practices

of EDs and hospital departments in general [19], [34], [37]. These systems have achieved such a central role due to their ability to function as effective and efficient coordination and communication artifacts despite the unpredictable and chaotic working environment that characterizes many EDs [37].

Recently, EDs in Europe and the U.S.A have started to replace these manual patient tracking and coordination systems with IT-based systems for a number of different reasons [3], [7]. With an increase in popularity of these IT-based patient tracking and coordination systems, known as electronic whiteboards, a need for summarizing the type of effects that can be expected to occur when implementing these systems has arisen. This study will seek to fulfill this need by systematically reviewing the published literature on studies of electronic whiteboards used in emergency medicine.

2. RESEARCH QUESTION

In this study the following two research questions are addressed:

RQ1. What consequences does introducing and using electronic whiteboards have on ED work?

RQ2. What mediating factors influence these consequences?

RQ1 is the main research question for this study. However, the reviewed literature indicates that there are several mediating factors that may influence what effects an IT-based electronic whiteboard system may have. These factors include the format in which the electronic whiteboards present information, the integration to other clinical IT systems, the visual layout and interface design of the electronic whiteboards and finally the process of developing and implementing these systems. RQ2 addresses these factors.

3. METHOD

The study reported in this paper has been conducted as a systematic literature review based on the guidelines proposed in Kitchenham et al. [17]. The aim of the review is to gather knowledge regarding the effects of implementing electronic whiteboards in emergency medicine. As such, the current study can be categorized as a secondary study.

3.1 Search process

The literature search process was a four-step process designed to cover as much literature as possible. Initially, three automated searches were conducted using Google Scholar, ISI Web of Science and PubMed with the keywords “Emergency department*”, “Clinical overview”, “Medical informatics” and “Healthcare informatics” combined with the following search terms: “Electronic whiteboard*”, “computerized whiteboard*”, “status board*” and “tracking board*”. The asterisk after each search term indicates that any inflection of the word is accepted in the search results. The author perused the titles in the search results and based on this, articles that were found to be relevant were saved for further reading. After having filtered through the initial search results the abstracts of the saved articles were read to

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further filter and refine the results. Based on this a selection of articles was saved for a full reading.

Following the automated searches a journal specific search was conducted in the following six journals:

- International Journal of Medical Informatics
- Journal of the American Medical Informatics Association
- Journal of Emergency Nursing
- Journal of Emergency Medicine
- International Journal of Human-Computer Interaction
- ACM Transactions of Human-Computer Interaction

The selection of the above journals was conducted as a two-step process. First, a list of approximately 21,000 international journals was searched for journals relevant to the topics of this study. From this list a selection of 20 internationally recognized journals was made and out of these the selected six were chosen on the basis of a reading and evaluation of their scope and aims. This was done to ensure a fit between the research questions and the content of the journals. The last two journals on the list were included in order to find articles published in journals that do not have a specific focus on medical informatics or emergency medicine. The journal specific searches were carried out manually in order to ensure that the shortcomings of an automated search did not affect this search, i.e. using words when searching for concepts. In order to limit the amount of material to filter, the manual searches were limited to cover only a period of six years from 2005 to 2010. Again, the titles of the journal articles were used as the first filter and following this the abstracts of any saved articles were read. If an abstract indicated that an article might be relevant for the review the full article was selected for further reading.

Next, the references of the already selected articles were perused for relevant articles that had not been found during the previous steps. Finally, a search on ISI Web of Knowledge was conducted to find articles that referred to the already selected articles. The combined search process led to a selection of 20 articles plus one that was sent to the author by a colleague after having completed the search process.

3.2 Inclusion and exclusion criteria

During the search process the following inclusion and exclusion criteria were applied. Based on a reading of article abstracts, full articles in English on one or more of the following topics were included in the literature review:

- Evaluation of the effects on work practices caused by electronic whiteboards.
- The process of developing and implementing electronic whiteboards.
- Description of the interface design of electronic whiteboards and integration with other systems
- Theoretical aspects of designing, developing, implementing and using electronic whiteboards.
- Combinations of the above topics.

Articles that did not fulfill the stated inclusion criteria were excluded from the literature review. This included papers such as:

- Articles without relevance to any of the above stated topics
- Conference abstracts
- Letters to the editor or editorials
- Duplicates or near identical papers

Table 1: Search results

Search type	Number of articles
Automatic	16
Manual	2
References of found articles	1
ISI search for articles referring already found articles	1

Table 1 shows the results of each step in the search process after having applied the inclusion criteria.

3.3 Quality assessment

The articles selected for the study were evaluated according to the type of paper using a ranking system reflecting the following:

- Journal articles/book chapters
- Conference articles
- Practitioners reports

Also, the articles were classified according to the type of study reported on in the paper. This was done using a classification system similar to the one used by Wiler et al. [35]. However, this classification was not used in an assessment of the quality of the selected articles.

3.4 Data collection and analysis

Data was collected from the selected articles via a thorough reading of the articles and writing a summary of the contents. Besides the summary the following data were also extracted from the articles:

- The source and full reference
- Author(s)
- Study category
- Methods
- Main topic
- Setting
- Relevance to the two research questions
- Quality assessment

After having extracted the data from the selected articles, a selection of these data was tabulated in order to present an overview of the selected literature.

4. RESULTS

Table 2 shows the selected articles and displays information regarding the setting for the different studies, the type of studies, the methods employed, the topics of the studies and finally an assessment of quality. In the following the results shown in table 2 will be related to the two research questions in order to allow a discussion of the results. Since a number of the articles relate to more than one of the research questions, these articles will be discussed more than once in the following sections.

4.1 General description of results

As table 2 shows, the majority of the articles reviewed are either single- or multi-site case reports. This appears to be the dominant type of literature within the chosen research area, possibly because it can be difficult to carry out controlled experiments using specific metrics in the setting of ED's. As such, these are the circumstances, under which the review has been preformed.

It is often argued that case reports sacrifice reliability and generalizability in order to achieve a higher degree of realism of context in their results [20]. In this sense it could be argued that the strength of evidence of the selected articles is limited.

Table 2: Reviewed studies.

Reference/year	Setting	Type	Method	Topic(s)	Quality assessment
Abujudeh et al. (2010) [2]	Emergency radiology department, approx. 101,000 examinations pr. year	Single site Case report	Descriptive/not reported	Dry-erase vs. electronic whiteboards, system description, effects on work practice	Journal article
Aronsky et al. (2008) [3]	Adult and pediatric emergency departments	Multi site Case report	Descriptive/not reported	Dry-erase vs. electronic whiteboards, system description, effects on ED work	Journal article
Bardram et al. (2006) [4]	Operating ward at hospital	Single site Case report	Descriptive/not reported	Development considerations, system description, technical implementation, system usage	Conference article
Belser et al. (2005) [5]	Emergency department	Single site Case report	Descriptive/not reported	Implementation and development considerations	Book chapter
Bisantz et al. (2010) [7]	Emergency department, approx. 95,000 visits pr. year	Single site Case report	Photography	Dry-erase vs. electronic whiteboards, changes to information content	Journal article
Boger (2003) [8]	Emergency department	Single site Case report	Descriptive/not reported	Implementation considerations, effects on length of stay for patients, patient satisfaction	Practitioners report
Fairbanks et al. (2008) [10]	Emergency department, approx. 95,000 visits pr. year	Single site Controlled trials	Observations, simulations, field notes	Usability testing of a electronic whiteboard system	Conference article
France et al. (2005) [11]	Adult emergency department, approx. 43,000 visits pr. year	Single site Case report	Observations, system workload, TLX ratings, pedometer	Effects on clinicians behaviors and workload	Journal article
Gorsha and Stogoski (2006) [12]	Emergency department, approx. 30,000 visits pr. year	Single site Case report	Descriptive/not reported	Installation, implementation, evaluation	Practitioners report
Hertzum and Simonsen (2010) [14]	Two emergency departments & one pediatric department	Multi site Survey	Online survey	Clinicians' expectations towards a electronic whiteboard system	Conference article
Horak (2000) [15]	Emergency department	Single site Case report	Descriptive/not reported	Development and implementation considerations	Practitioners report
Jensen (2004) [16]	Hospital inpatient operating rooms and day surgery center	Single site Case report	External consultancy report	Benefits of implementing a patient status and tracking system	Practitioners report
Nicholls and Young (2007) [21]	2 hospitals	Multi site Case report	Descriptive/not reported	Geographical layout used as interface for a bed/patient tracking system, development considerations	Journal article
Patterson et al. (2010) [22]	Two emergency departments, approx. 22,500 visits pr. year	Multi site Case report	Observations	Compare extent of usage, information accuracy and functions for dry-erase and electronic whiteboards	Journal article
Pennathur et al. (2007) [23]	Two emergency departments	Multi site Case report	Observations, photography	Effects on work practices	Conference article

Continues

Reference	Setting	Type	Method	Topic(s)	Quality assessment
Pennathur et al. (2008) [24]	Emergency department, approx. 95,000 visits pr. year	Single site Case report	Photography	Dry-erase vs. electronic whiteboards, changes to information content	Conference article
Potter (2005) [25]	Emergency department	Single site Case report	Descriptive/not reported	Design, development and implementation considerations, implementation strategy, effects on length of stay and triage times	Practitioners article
Rasmussen et al. (2010) [26]	Two emergency departments	Multi site Case report	Observations, interviews	System description, implementation considerations, effects on work practice	Conference article
Wears et al. (2003) [32]	Four emergency departments	Multi site Case report	Observations, photography	Effects on work practices cause by the differences between dry-erase and electronic whiteboards with regards to: Interface design, information content, language and usage.	Conference article
Wong et al. (2009) [36]	General Internal Medicine department	Single site Case report	Descriptive/not reported	Development and implementation considerations, system description, effects on work practices	Journal article
Zimmerman and Clinton (1995) [38]	Emergency departments, approx. 95,000 visits pr. year	Single site Case report	Descriptive/not reported	Prescriptions for designing computerized tracking, triage and registration systems	Practitioners report

However, I would argue that realism of context is important for understanding some of the unique work practices of the different settings, in which the studies have been performed. Therefore, I argue that for the purpose of this review the lack of generalizability and reliability does not subtract from the strength of evidence and that the selected articles are suitable for the review.

4.2 Consequences of electronic whiteboards

The reviewed literature contains examples of different types of consequences for ED work caused by electronic whiteboards. Table 3 summarizes these consequences and the articles that discuss the specific types of consequences. It should be noted that even though these consequences are discussed separately they are in fact interrelated in many ways e.g. changes to information content on the electronic whiteboard is related to the task of coordinating patient care.

One of the most prevalent consequences reported is that electronic whiteboards affect existing working practices at EDs. Here, the reviewed literature presents mixed results with five articles reporting positive consequences of electronic whiteboards on working practices, two reporting negative consequences and one that does not differentiate between positive and negative consequences. Also, the literature indicates that these consequences often affect workflow, alter the characteristics of the work carried out and decreases interruptions of patient care work. Abujudeh et al. [2] and Aronsky et al. [3] both describe cases where alterations aimed at improving and simplifying the ED workflow were successfully incorporated in the

implementation strategies for the electronic whiteboards. On the other hand, Pennarthur et al. [23] observed that the electronic whiteboard system had a negative impact on the working practices. This was caused by the system's inflexibility and thereby lack of support for parts of the workflow where system flexibility was considered important e.g. triage and patient tracking. Rasmussen et al. [26] report on an implementation process, in which a gradual approach to implementing and developing the electronic whiteboard was followed. This allowed the clinicians and project group to alter both the system and working practices iteratively and concurrently, thereby avoiding any dramatic or negative effects on the existing working practices.

Wears et al. [32] and Wong et al. [36] provide examples of how an electronic whiteboard system changes the characteristics of the work done at EDs. Wears et al. [32] observed that due to the format in which the electronic whiteboard presents the contained information the work practice lost its collaborative nature and turned to be more individualistic. Contrary to this, Wong et al. [36] describe how an electronic whiteboard system helped a general internal medicine department transform their discussions regarding discharge planning from being unstructured to be a structured process that drives discussion and increases transparency.

Finally, Abujudeh et al. [2], France et al. [11] and Bardram et al. [4] find that the rate of interruptions and unnecessary communications is reduced after the introduction of an electronic whiteboard system, thus improving the quality of care and the ED work in general.

Table 3: Different types of consequences.

Type of consequence	Positive	Negative	Neutral
Changes to work practice	[2]; [3]; [4]; [11]; [36]	[23]; [32]	[26]
Effects on communication and coordination	[2]; [3]; [36]	[7]; [23]	
Changes to whiteboard information content, language and accuracy		[7]; [22]; [24]; [32]	
Changes to whiteboard role and usage		[7]; [22]; [24]; [32]	[26]
Clinicians' perceptions, attitudes and satisfaction	[11]; [14]; [36]		
Effects on patient care e.g. general patient satisfaction, patient safety, length of stay etc.	[8]; [16]; [21]; [25]	[10]	
Effects on financial and administrative aspects	[3]; [16]		

The communication and coordination between ED clinicians is also influenced by the introduction of electronic whiteboards. This aspect is closely related to the effects on working practice since communication and coordination obviously constitute significant parts of the work performed in an ED. However, since the electronic whiteboards are often referred to as tools for coordination and communication this aspect is discussed separately. Again, the reviewed literature presents mixed findings indicating that electronic whiteboards can have both positive and negative consequences for this aspect of ED work. Abujudeh et al. [2], Aronsky et al. [3] and Wong et al. [36] present results indicating that electronic whiteboards have a positive influence on the communication among ED clinicians. However, Pennarthur et al. [23] find through their observations that the electronic whiteboard had a negative impact on the intradepartmental communication due to the lack of a common discussion artifact. The literature also presents mixed findings regarding how electronic whiteboards influence the coordination of work and patient care at EDs. Abujudeh et al. [2] and Wong et al. [36] both state that the introduction of an electronic whiteboard system has enhanced the coordination between ED clinicians. This is reported to be caused by several features of the electronic whiteboards e.g. distributed access to whiteboard information, quick and easy access to relevant information, the ability to retrieve previously saved information etc. However, the results presented in Pennarthur et al. [23] and Wears et al. [32] point in the opposite direction. In these studies the authors observe that the electronic whiteboards had negative effects on coordination between clinicians. The negative effects on communication caused some of these effects while others were caused by system deficiencies e.g. system properties that allowed only three lines of text to be shown in comment fields and the system's lack of support for other input than text, e.g. symbols and domain specific codes.

The reviewed literature provides examples of how the transition from manual to electronic whiteboards has changed the information content of the whiteboards, the accuracy of the information and the language used on the whiteboards. Generally, the literature reports that the electronic whiteboards are less effective for providing information related to the coordination of

patient care [7], [22], [24], [32], that they contain unique information relevant for administration purposes [7], [32], that the information presented by these systems is less accurate than the manual systems [22] and that the language used in the electronic whiteboards is less flexible than in the manual systems [32].

Bisantz et al. [7], Pennarthur et al. [24], Patterson et al. [22] and Wears et al. [32] find that the manual and electronic whiteboards to some degree contain the same core information e.g. arrival time, patient identification, chief complaint etc. However, they also find that there are certain differences between the two types of systems. For example, Bisantz et al. [7] and Pennarthur et al. [24] find that the manual whiteboards contain more information related to the coordination of patient care while Wears et al. [32] and Patterson et al. [22] observe that the manual whiteboards are more effective for relaying extra information by allowing the usage of special shorthand symbols. On the other hand, the findings presented by Bisantz et al. [7] and Wears et al. [32] show that the electronic whiteboards contain information unique to this type of system. This information includes calculated length of stay, automatic flagging of information, census information and number of patients waiting.

Wears et al. [32] also study the differences in language used in the two types of whiteboard systems. Here, they observe that each ED in their study has developed an agreed upon language for displaying information. However, they also find that when this language is codified in the electronic system it becomes static and inflexible. Compared to the manual whiteboards this is a disadvantage of the electronic systems because real-time additions and customizations are not easily made. A part of the study reported in Patterson et al. [22] concerns the accuracy of the information shown by manual and electronic whiteboards. Here, the findings show that the electronic whiteboards contain more errors and types of errors than the manual whiteboards.

The reviewed literature also studies what changes to role and usage occur when transitioning from manual whiteboard systems to the electronic whiteboards systems. Again, the literature presents mixed results. Three articles report that the role of the electronic whiteboards is mostly an administrative one [7], [22], [32], one article reports that the electronic whiteboard system is used for the same purposes as the manual system [26] and three articles report that the electronic whiteboards are used less frequently than the manual systems [7], [22], [24].

Patterson et al. [22] and Wears et al. [32] compare the functions of manual and electronic whiteboards and find that the manual whiteboards are used more often for tasks related to coordination of patient care than the electronic whiteboards. Concurrently, Patterson et al. [22] observe that the electronic boards are mostly used for administrative tasks e.g. collecting data for reporting purposes. Bisantz et al. [7] support this finding by stating that after the ED whiteboard in their case was computerized, its role changed from being a tool for communication and coordination between ED clinicians to a tool for tracking support functions and communication between ancillary ED staff. Somewhat contrary to these findings, Rasmussen et al. [26] find that the electronic whiteboards in their case are used in the same manner as the manual whiteboard thereby retaining its role as a tool for coordination and communication among ED clinicians.

The literature offers examples of how the usage of the ED whiteboard changes when transitioning from a manual to an electronic system. Here, the literature indicates that manual whiteboards are used in a more dynamic manner than the electronic whiteboards [7], [24] and Patterson et al. [22] observe

that the physicians in their case were more reluctant to use the electronic whiteboard system than the manual dry-erase whiteboard.

The reviewed literature also gives some insight as to how the clinicians perceive the electronic whiteboards. In this case, the results indicate that the clinicians are generally positive toward the electronic whiteboards. For example, Wong et al. [36] report that even though their survey shows that physicians were less satisfied there was an overall satisfaction with the electronic whiteboard system in the ED. Also, the mental workload scores (rated on the TLX scale) reported by France et al. [11] indicate that the electronic whiteboards can improve the distribution of workload amongst resident and faculty physicians. Finally, the survey results reported by Hertzum and Simonsen [14] show that the ED clinicians in this case have positive expectations towards the introduction of an electronic whiteboard and that they expect the electronic whiteboards to be beneficial for their working practices.

Another consequence for ED work when introducing electronic whiteboards is the effect this has on patient care e.g. general patient satisfaction, patient safety and length of stay. These effects are mostly reported in practitioner’s reports such as Boger [8], Jensen [16], Nicholls and Young [21] and Potter [25] who all find that the introduction of an electronic whiteboard system reduces patient length of stay. Furthermore, Boger [8], Jensen [16] and Potter [25] find that the electronic whiteboards helped reduce the number of patients who left the department without “being seen”. Finally, Boger [8] and Jensen [16] find that patient satisfaction increased after introducing an electronic whiteboard system at the respective EDs.

It is also likely that patient safety may be affected by the introduction of electronic whiteboards. One issue that could influence patient safety is the usability of these systems as investigated by Fairbanks et al. [10]. Here, the authors find that the interface of the electronic whiteboard system in their case has many flaws in terms of the usability principles applied in their trials. As a result of this the authors speculate that these flaws could have potential negative effects on patient safety and therefore encourage the purchasers of the electronic whiteboard to consider these issues when purchasing the system in question.

Finally, the reviewed literature also presents consequences that relate to the administrative and financial aspects of ED work. Here, the literature indicates that electronic whiteboards have a positive influence on both of these aspects. Aronsky et al. [3] find that the electronic whiteboard system supports many of the administrative processes related to the operation of an ED e.g. daily and monthly reporting, providing educational feedback and impact assessment of improvement initiatives.

Table 4: Mediating factors

Mediating factor	Articles
Presentation format	[2]; [3]; [4]; [7]; [8]; [11]; [15]; [22]; [23]; [25]; [26]; [32]; [36]
Integration	[2]; [3]; [5]; [22]; [32]; [36]
Interface design	[2]; [3]; [4]; [5]; [7]; [10]; [15]; [21]; [22]; [23]; [24]; [25]; [26]; [32]; [36]; [38]
Development and implementation	[4]; [5]; [8]; [12]; [15]; [21]; [25]; [26]; [36]; [38]

Aronsky et al. [3] also report that the electronic whiteboard system had financial benefits for the ED mainly due to an improvement of the discharge process leading to a 2 % increase in posted charges, which translated to additional revenue in excess of \$1 million. These results are supported by the findings presented in Jensen [16], stating that the ED in their case experienced multiple financial benefits caused by improvements to a number of aspects to the ED work e.g. reducing the number of patients who leave the ED without “being seen”.

4.3 Mediating factors

When reviewing the literature it becomes apparent that there are several mediating factors that could influence how the introduction of an electronic whiteboard system affects the work at Emergency Departments. In this section a number of these factors will be highlighted and exemplified with parts of the reviewed literature. Table 4 summarizes the mediating factors.

One of the clearest mediating factors is the format in which the electronic whiteboards present the contained information. Three of the 13 articles that mention the display format state that the electronic whiteboards are not displayed in a large format and that they are accessed through individual workstations. All of these articles report negative effects on different aspects of ED work. Work practices, communication and coordination seem especially affected by the lack of a large display format [32], [23]. Furthermore, it is likely that the change in function towards an administrative tool, as reported by Patterson et al. [22], is influenced by the lack of a large format display. It should be noted though that not all problems with electronic whiteboards are caused by lack of large format displays. In the study performed by Fairbanks et al. [10] the usability problems discovered here are unrelated to the fact that the electronic whiteboard information is displayed in a large format. Similarly, the changes and loss of critical information as reported by Bisantz et al. [7] are unrelated to the information being displayed in a large format. However, it does seem apparent that there must exist some relation between the successful use of an electronic whiteboard and displaying the contained information in a large format. This becomes apparent when reading the remaining eight articles that all report successful usage of electronic whiteboards and presenting information in a large format [2], [3], [4], [11], [15], [25], [26], [36].

Another mediating factor in the literature is the integration between the electronic whiteboard system and other clinical IT systems. As pointed out by Abujudeh et al. [2], an electronic whiteboard system with manual data entry and updating is no more accurate than the people who enter information into the system. Also, there is an extra time-consuming work burden associated with the entry and updating of information that could hinder effective usage of an electronic whiteboard system. These drawbacks could be reduced by extracting information from other clinical IT systems, e.g. electronic medical records and computerized provider order entry systems [2], [22]. Aronsky et al. [3] provide a thorough description of how an electronic whiteboard can be integrated with a wide range of clinical IT systems and how this provides its users with “an indispensable tool to access patient-specific information, coordinate patient management, track individual patient care, and monitor overall ED operations in real time” [3], p. 192. Belser et al. [5], Wears and Perry [32] and Wong et al. [36] also find that the integration between the electronic whiteboards and clinical IT systems such as patient registration systems, laboratory/x-ray systems and clinical information systems is beneficial for the users of the electronic whiteboards. Thus, it seems that widespread integration

with other clinical IT systems is an important factor to consider when introducing electronic whiteboards.

A third mediating factor that could potentially have an impact on how electronic whiteboards influence ED work is the user interface design of these systems. When reviewing the selected literature it becomes apparent that there have been no significant changes to the basic visual layout when transitioning from the dry-erase to the electronic whiteboards. Aronsky et al. [3] describe the layout of the electronic whiteboard in their case as “*much like a real time interactive spread sheet*” [3], p. 185]. The description of the visual layout as a tabular information structure is repeated in 14 of the 16 articles that either describe or present examples of the user interface [2], [3], [5], [7], [10], [15], [22], [23], [24], [25], [26], [32], [36], [38]. Only two articles describe interface designs that deviate from the tabular information structure. Bardram et al. [4] describe an electronic whiteboard system designed to support awareness, coordination and communication in an operating ward. Here, the interface design consists of a more dispersed layout showing different interface elements such as an overview of the staff on duty, a scheduling tool and video feeds from different rooms in the ward. Nicholls et al. [21] describe an even more radical approach to designing the visual layout of an electronic whiteboard used for tracking patients. Here, the user interface design is inspired by geographic information systems and thus, the visual layout is a geographical reproduction of the ward showing rooms and bed locations.

However, due to the widespread use of the traditional visual layout of the user interface it is difficult to draw any conclusions from the literature as to whether or not the interface design of electronic whiteboards has any effect on how these systems influence ED work. This point will be revisited in the discussion of the results.

Finally, the process of developing and implementing electronic whiteboards seems to be another mediating factor that influences the consequences for ED work when introducing this type of system. This seems apparent since the type of development and implementation process followed has a strong influence on how new IT systems are received in organizations.

Six of the reviewed articles include descriptions of development and implementation processes and also include descriptions of the consequences of using the electronic whiteboards [4], [8], [21], [25], [26], [36]. Another four articles describe only the development and implementation processes but do not couple these to the consequences of introducing the electronic whiteboards [5], [12], [15], [38]. Common to most of the studies in the abovementioned literature is a strong focus on a user-centered approach to both the development and implementation of the electronic whiteboards e.g. user involvement in all parts of the processes, extensive user training as well as support for the users.

User involvement is highlighted as critical for the successful development and implementation of electronic whiteboards. This is well exemplified by the studies reported in Potter [25] and Rasmussen et al. [26]. In general, the reviewed literature presents examples of user involvement in which a few participants are involved as representatives of the larger group of end-users. Belsler et al. [5] and Wong et al. [36] are examples of how administrative staff members have been involved as representatives for the future users while Horak [15], Potter [25] and Rasmussen et al. [26] are examples of how clinical staff members have been involved in developing and implementing electronic whiteboards.

The reviewed literature also highlights user training as an important aspect of implementing electronic whiteboards. This is exemplified in Boger [8] and Potter [25] where training was tailored to suit each staff group in the ED. In the case described in Horak [15] this was taken one step further and included individual training for all ED staff members.

User support in the initial phases of electronic whiteboard usage is also pointed out as an important part of the implementation processes. Horak [15] and Potter [25] present cases where this support was provided by developing support manuals for the ED staff. Wong et al. [36] describe another approach where technical personnel provided on-site support for two weeks after implementing the electronic whiteboard.

Interestingly, these articles do not reveal which type of user involvement, user training or type of support work is preferable as they all report successful implementation and usage of the electronic whiteboards.

5. DISCUSSION

As section 4.2 and 4.3 have shown, the results found in the review are of a mixed and somewhat inconclusive nature. Consequently, this makes it difficult to draw conclusions based on the results. However, the results are relevant for pointing out areas of interest where more research is necessary for clarifying the consequences of implementing electronic whiteboards. These areas will be pointed out in the following sections.

5.1 General discussion of results

Existing work practices including coordination and communication is one aspect of ED work that seems to be especially affected by the introduction of electronic whiteboards. This is not surprising since the manual whiteboards, which the electronic whiteboards are intended to replace, constitute a vital artifact for these practices. The results of this study show that the electronic whiteboards have both positive and negative consequences for working practices of EDs.

The results suggest that electronic whiteboards have negative consequences for whiteboard information content, information accuracy, the language used and whiteboard functionality after implementing electronic whiteboards. It is particularly interesting to note that the electronic whiteboards have a tendency to reduce the accuracy of the information presented and that the role of the whiteboard changes from a tool used for coordination and communication among the clinicians to a tool mostly used for administrative purposes.

Positive results were found in studies with a focus on patient related aspects such as patient satisfaction and length of stay as well as financial and administrative aspects. The shift in role for the electronic whiteboards, as mention above, corresponds well with these advantages for the administrative aspects of ED work.

The results showed that the clinicians generally had high expectations to the electronic whiteboards and that they perceive them to support and enhance their work practices. The studies that investigate these aspects are all in one way or another based on the clinicians' subjective evaluations and as such they are vulnerable to variations due to the clinicians' personal feelings towards the system. An interesting pattern emerges when the results of these studies are compared to the results of the other reviewed studies. The pattern shows that the studies based on the clinicians' subjective perceptions and attitudes are all predominantly positive while the other studies show results of a more mixed nature. One possible reason for this pattern could be a

mismatch between what is measured by the researchers in the more objective studies and the factors that shape the clinicians' attitudes and perceptions of the system. In a sense, this means that if the researchers' measurements do not concern the aspects of the electronic whiteboards that matter to the actual end-users, the results might not reflect their attitudes towards the electronic whiteboards. On the other hand, it is also possible that the studies based on the clinicians' attitudes and perceptions, show these predominantly positive results simply because the researchers and subjects interacted during the investigation. This is known as demand characteristics or interpersonal expectancy effects and may influence the results of such studies [29], [30]. It seems reasonable to assume that such effects could have influenced the results of the studies that are based on the clinicians' subjective attitudes and perceptions towards the electronic whiteboards. This must therefore be taken into consideration when interpreting the results of studies that utilize methods through which the researcher could possibly influence the participants, e.g. surveys, interviews, etc.

5.2 Discussion of mediating factors

The mediating factors presented in Section 4.3 can be divided into two groups of factors: System specific factors and general factors.

5.2.1 System specific factors

The first three factors (display format, integration and interface design) can be categorized as system-specific factors since they concern different parts of the particular systems in the different studies. Since the results of the review suggest that these factors have an influence on how the end-users perceive and adopt the electronic whiteboards, they will be discussed in the following using the Unified Theory of Acceptance and Use of Technology (UTAUT) model as presented in Venkatesh et al. [31].

As mentioned in section 4.3 one of the mediating factors found in the reviewed studies is the format in which the electronic whiteboards present information. As the results suggest, there seems to exist a relation between using large format displays and the successful implementation of the electronic whiteboards. A reasonable explanation for this relationship is that the clinicians are accustomed to using a display format that can be easily viewed and scanned for information without necessarily having to interact with the system itself e.g. the large manual dry-erase whiteboards [37]. Following the transition to the electronic whiteboards the clinicians might expect to be able to maintain this working practice, which however only seems possible if a large and easily viewed display is used. If this is not the case, the clinicians will have to log onto a computer terminal every time they want to retrieve information from the electronic whiteboard. If this leads the clinicians to perceive the system as less efficient and more laborious to use an increase to the users effort expectancy and a decrease to their performance expectancy might result. According to Venkatesh et al. [31], the users' performance expectancy and effort expectancy have a high impact on their perception of the system. A negative impact on these constructs will therefore decrease the likelihood of the system being accepted by the users and thereby reduce the probability of a successful implementation process. The relationship between display format and successful implementation is however not investigated in detail by the reviewed literature and presents an area of interest for conducting more research.

The results of the review also suggest that there is a positive relationship between a successful implementation and widespread integration between the electronic whiteboards and other clinical IT systems. One reasonable explanation for this relationship is

that this integration provides the clinicians with new opportunities compared to the old dry-erase whiteboards e.g. retrieving patient information from electronic health records or automatic notification of lab results. As such, the clinicians could perceive the electronic whiteboards as being able to help them attain gains in their work. According to Venkatesh et al. [31], this will have a positive influence on the users performance expectancy and thereby increase the likelihood of the system being accepted. On the other hand, it also seems likely that the lack of integration between electronic whiteboards and other clinical IT systems could have a negative impact upon the users' effort expectancy. This seems reasonable to suggest, since the lack of integration would result in the clinicians having to manually enter information into the electronic whiteboards thus increasing the effort and complexity of using the system. According to Venkatesh et al. [31], this will reduce the likelihood of the users accepting the system and thereby the probability of a successful implementation. However, once again the reviewed literature does not contain any studies that specifically investigate these relations and as such there is a need and opportunity to conduct more research in this area of interest.

The third system specific mediating factor concerns the interface design of the electronic whiteboards. As the results in section 4.3 showed there have not been any significant changes to the visual layout of the whiteboards after the transition from the manual to the electronic versions. As Rasmussen et al. [26] find in their study, this could be an explicit choice in the development process to ensure compatibility and recognition when shifting from the dry-erase to the electronic whiteboards in order to ease the transition. This will in turn have a positive impact on the users' effort expectancy since they are not required to adapt to a new visual layout. However, it seems reasonable to argue that this layout offers few new possibilities for the clinicians and as such the interface itself does not add to the users' performance expectancy. Therefore, the choice to keep the interface design from the manual whiteboards can be seen as a short-term prioritization of effort expectancy over performance expectancy. According to Venkatesh et al. [31], performance expectancy is the strongest predictor of the users' intention to adopt and use an IT system. Effort expectancy is also a strong predictor in the early stages of using a new system but becomes less significant after periods of sustained usage. Following this line of argumentation, it would seem that the positive long-term effects of introducing a user interface with new possibilities and better support for the clinicians' work would supersede the short-term effects of having a recognizable user interface. However, since the reviewed literature does not reveal what effects the user interface has on the users' usage of electronic whiteboards it is difficult to draw any conclusions regarding the possibilities for improving the visual layout of electronic whiteboards.

5.2.2 Development and implementation factors

The fourth mediating factor is of a more general nature than the three discussed previously and concerns the manner, in which the electronic whiteboards are developed and implemented – including user training and support. As the results in section 4.3 show there is a strong focus in the reviewed literature on having a user-centered approach. This factor can be seen in the light of the theories regarding user participation in IT development and implementation projects. User participation in IT projects, as defined by [9], [13], is often heralded as an important part of achieving a fit between the system, the users' needs and the context of use [18]. This fit is especially important in complex working environments such as EDs, where previous research has

shown that developing and implementing usable IT systems can be a challenging and complex process [1], [6]. Therefore, it appears essential that users participate in the development and implementation of the electronic whiteboards.

However, there are certain difficulties associated with the involvement of users in such projects. As the results in section 4.2 suggest, the new electronic whiteboards have the ability to support a wider range of working practices than the manual dry-erase whiteboards did e.g. communication and coordination for the clinical personnel as well as storing and retrieving information for administrative purposes. This is also evident from the results showing that the electronic whiteboards assumed a more administrative role than the manual whiteboards. These changes will in effect expand the group of potential end-users since this group no longer consists of only the clinical ED personnel but also management and ancillary staff members. This expansion of the end-user group has consequences for the processes of developing and implementing the electronic whiteboards since more interests and work practices need to be considered during these processes. As previous research has shown it can be difficult to manage and actively involve larger groups of participants in IT development and implementation projects [1]. Therefore, it is often decided to involve only a few users as representatives for the entire group of end-users [27]. This pattern is also evident from the reviewed articles that describe the manner of user involvement. However, with the expansion of the end-user group it not only becomes more difficult to select the right participants but it also increases the difficulty of undertaking the task as an effective user representative. This increase occurs because higher demands are put on the participants' professional and personal competences e.g. a broader range of domain knowledge as well as an empathy and understanding of needs and wishes from a large group of users [27]. Therefore, it appears important to consider carefully which users are chosen as participants when developing and implementing electronic whiteboards for use in EDs.

6. CONCLUSION

Different aspects of electronic whiteboards have been investigated in 21 different studies and this systematic review has shown that the electronic whiteboards affect the work performed at EDs at multiple levels e.g. working practices, coordination and communication, information content and information accuracy. The review has also shown that there are several mediating factors that have an impact upon the effects of implementing electronic whiteboards in Emergency Departments. These mediating factors contribute to how the end users perceive the electronic whiteboards and therefore they are instrumental in securing organizational implementation and adaptation.

However, the results found in the review have proven to be of a mixed and somewhat inconclusive nature. This is to a high degree caused by the anecdotal nature of many of the studies reviewed. Despite this, the results of this review can be used as a springboard to more focused and specific studies. Therefore, the final conclusion of this review is a call for more focused and specific research into the effects of implementing electronic whiteboards and the factors that have an impact upon these effects. Especially, research into the areas of display format, interface design, integration to other systems and user involvement seems relevant in order to increase our knowledge regarding the development and implementation of electronic whiteboards. An example of this could be to research how electronic whiteboards could be designed to work with mobile technologies e.g. smartphones and

tablets in regards to the interface and display format of these technologies.

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