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Artefactual Multiplicity: A Study of Emergency-Department Whiteboards

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Abstract. Whiteboards are highly important to the work in emergency departments (EDs). As a collaborative technology ED whiteboards are usually placed in the dynamic centre of the ED, and all ED staff will approach the whiteboard regularly to organize their individual yet interdependent work. Currently, digital whiteboards are replacing the ordinary dry-erase whiteboards in EDs, which bring the design and use of whiteboards in ED to our attention. Previous studies have applied the theoretical lenses of common information spaces, coordination, and awareness to the investigation of whiteboard use and design. Based on an ethnographic study of the work practices involving two differently designed ED whiteboards, we found these concepts insufficient to explain one essential characteristic of these heterogeneous artefacts. In this paper, we suggest an additional theoretical concept describing this characteristic of heterogeneous artefacts; namely artefactual multiplicity. *Artefactual multiplicity* identifies not only the multiple functions of heterogeneous artefacts but also the intricate *relations* between these multiple functionalities.

Introduction

Work practices in emergency departments (EDs) are characterized by rapid changes, information-intensive practices, and collaborative activities between interdependent, heterogeneous healthcare professionals. The central artefact used

to handle ED work typically takes the form of a whiteboard used to coordinate and align the distributed and yet collaborative activities. ED whiteboards are essential instruments for clinical and operational management (Aronsky et al. 2008) and are fundamental to the handling of patient trajectories. A patient trajectory is the unfolding course of a patient's disease including the totality of work done over that course, and the impact of that work on those involved in it (Strauss et al. 1985). This work is profoundly affected by temporal considerations and includes the continual readjustment and coordination of staff effort in response to, for example, developments in a patient's condition, the unpredictability of arriving patients, the replacement of staff across shifts, and other contingencies in the organization of work.

In investigating the complexity of coordination in hospital work a distinction between situated coordination and predefined coordination has been proposed as one way to grasp the variations in how healthcare professionals handle particular situations (Lundberg and Hellioglu 1999). This distinction is relevant to whiteboards, which get their overall structure from recurrent, preplanned coordination needs but must at the same time accommodate the situatedness of each moment in the course of patient trajectories. Apart from whiteboards, coordination in hospitals is achieved through the use of a range of interrelated artefacts such as work schedules, care records, and post-it notes (Bardram and Bossen 2005b). Temporal considerations abound in the use of individual artefacts as well as in the assemblage of information from multiple artefacts into a common information space. In addition, time and coordination are closely interlinked at multiple levels of abstraction, which have been labelled synchronisation, scheduling, and allocation (Bardram 2000). This demonstrates the variety of coordination needs and practices, which we must examine to understand the use and role of whiteboards in hospital work.

Examining the data from an ethnographic study of the work practices in an emergency department at a Canadian paediatric hospital, this paper focuses on the use and role of whiteboards in the collaborative activities of ED staff. The paper investigates the small details and distinctions in whiteboard use because these details and distinctions are essential to how whiteboards support ED work and, therefore, also critical to the design of the digital whiteboards that are in the process of replacing dry-erase whiteboards. We view the whiteboards as a heterogeneous artefact and propose to use the concept of multiplicity (Mol 2002; Law 2004) as an analytic lens for investigating such heterogeneous artefacts. Applying multiplicity as an analytic lens on our ethnographic observations, we develop the concept of artefactual multiplicity. *Artefactual multiplicity* is a concept for identifying not only the multiple functions of heterogeneous artefacts but also the *relations* between these multiple functionalities. Understanding the relations between the functionalities embedded in artefacts such as whiteboards is essential for the digitalization of these artefacts. When designing a digital

whiteboard we need to identify its multiple functionalities as well as to identify the links between these functionalities. Our concept of *artefactual multiplicity* can be used as an analytic lens for identifying the multiple and interrelated functionalities in artefacts that support collaboration. In this paper we argue that identifying the artefactual multiplicity of heterogeneous artefacts is vital when re-designing such artefacts, e.g. when changing analogue artefacts into digital ones.

The paper is structured as follows. In section two we present previous work on whiteboards as related to common information spaces, awareness, and coordination. Moreover, we introduce the concept of artefactual multiplicity. Section three provides an overview of the empirical case and the ethnographic field study. Sections four and five are the main parts of this paper presenting how we have analysed the role and use of the whiteboards in the paediatric ED using the concept of artefactual multiplicity. In section six we discuss how artefactual multiplicity may serve as an approach for analysing the use of current whiteboards and as an approach for designing digital whiteboards. Finally, section seven is the conclusion.

2. Related Work

2.1 Common information Spaces, Awareness, and Coordination

Whiteboards support collaborating actors' coordinative practices and their awareness of the state of their joint work, especially in settings where the actors are locally mobile within a shared workspace. Hospitals are a prime example of such a setting, and whiteboards are widely used and studied in hospital settings (Xiao et al. 2001; France et al. 2005; Bardram et al. 2006; Aronsky et al. 2008; Wong et al. 2009). While physical and digital whiteboards are distinct kinds of artefact, both kinds are essentially large, shared displays that hold key information – often in condensed formats – and are continuously updated.

Xiao et al. (2001) studied how a large, physical whiteboard in a trauma centre supported coordination by facilitating negotiation of scheduling, joint planning, and inter-personal communication. The authors observed that the sheer size of the whiteboard was a major factor in how it affected clinicians' interactions. The large size of the whiteboard meant that it accommodated groups of clinician standing in close proximity either discussing or modifying the board. This observation is consistent with Whittaker and Schwarz (1999) who concluded that the large size and public location of physical whiteboards engendered group processes that the digital whiteboards available at the time of their study failed to support. They found that a physical whiteboard located in a public area induced greater responsibility, commitment, and updating. The public location of the whiteboard enabled collaborative problem solving among the project participants

who used the whiteboard for project scheduling. As a result the schedule was both accurate and current. In contrast to these coordination and awareness qualities, an electronic scheduling tool used by another project group in Whittaker and Schwarz's study was mostly used individually by the project manager and was often neither accurate nor current. As a further quality of physical whiteboards, Tang et al. (2009) note that they are suitable for multiple activities and for smoothly transitioning between related activities. Aronsky et al. (2008) emphasize the possibilities of digital whiteboards, for example that they can provide rapid access to more detailed information by retrieving it from the patient records.

Bardram et al. (2006) showed that large, interactive displays may promote social, spatial, and temporal awareness among the clinicians at a surgery ward. The primary property of the displays, which were situated around the hospital, was to make readily available information that otherwise had to be searched. This seemed, for example, to support awareness of the unfolding of work inside an operating room and, thereby, to allow people in other rooms to react quickly to delays. Similarly, the improved awareness of the whereabouts of the clinical staff was used extensively, for example to locate specialists when their opinion was needed. France et al. (2005) found that the use of an electronic whiteboard improved the efficiency of work and communication among physicians in an emergency department. A likely reason for this improvement was that information physicians previously had to obtain by interrupting each other was now available on the whiteboard, reducing the physicians' mental workload. In another study of the use of digital whiteboards in emergency departments, Wong et al. (2009) reported that clinicians experienced improved communication and time savings because the whiteboard brought together information that was previously distributed across many people and records. Specifically, the whiteboard transformed the morning rounds, by communicating more information and engendering more consolidation of issues raised. A similar move toward a process of collective reading was observed during team conferences and, especially, nursing handovers in a study of the trial use of a large, shared display at a stroke unit (Hertzum and Simonsen 2008).

In contrast to the above studies, which emphasize positive effects of whiteboards, Riley et al. (2007) found that nurses at an operating-room department gamed the whiteboard. After completion of an operation they would, for example, erase their name from the whiteboard without informing the nursing coordinator, effectively making themselves invisible and delaying the possibility of being assigned another task. Also, completed cleaning tasks were often marked with a tick rather than the required initials and, thereby, protected the person against scrutiny and complaints. Interestingly, the whiteboard was sometimes used to circumvent face-to-face interaction because this provided the nurses with an opportunity for displaying messages calling attention to incorrect or

inadequate documentation of medication orders. To balance the urgency of these messages against the inappropriateness of the nurses' surveillance of the physicians, the messages were usually anonymous and directed to an unidentified member of the medical staff. In a similar vein, Chaboyer et al. (2009) found that surgical nurses experienced the whiteboards at their department as an imposition and a cause of conflict.

Prominent concepts for describing the use and role of whiteboards have in previous work been common information spaces, awareness, and coordination. In relation to *common information spaces*, Schmidt and Bannon (1992, p. 27) state that cooperative work is not facilitated simply by the provision of a shared artefact but "requires the active construction by the participants of a common information space where the meanings of the shared objects are debated and resolved, at least locally and temporarily." This understanding of the meaning derived from artefacts as constructed and negotiated is common to all the concepts describing the use and role of whiteboards. Scupelli et al. (2010) show how the layout of the physical surroundings in which whiteboards are located influence whether they succeed in supporting participants in constructing a common information space. For example, the out-of-the-way location of one whiteboard from important staff groups discouraged face-to-face communication around the whiteboard and reduced its role in the staff's construction and maintenance of their common information space. Bannon and Bødker (1997) introduce a distinction between common information spaces that are interpretively flexible and malleable and those that are "immutable" and stable when they move across the boundaries between communities. Whiteboards are at the malleable end of the spectrum as evidenced by the differences in the whiteboard studies cited above and by the differences between ED tracks investigated in sections four and five. Reasons for such differences are discussed by Bossen (2002) in terms of seven parameters of common information spaces: the degree of distribution of work, the multiplicity of webs of significance, the level of required articulation work, the range of means of communication, the web of artefacts, the immaterial mechanisms of interaction, and the need for precision and promptness of interpretation. Notably, none of these parameters resemble our notion of artefactual multiplicity. The range of means of communication is probably the one that comes closest, but it concerns the number of available means of communication and the intensity of the communication they afford.

Whiteboards support *awareness* (Schmidt 2002) by amassing and broadcasting selected information about the collaborating actors' joint work. The need for collaborating actors to take heed of the context of their joint work has often been approached at a micro level concerning the ways in which co-located people render aspects of their activities visible in order to have others unobtrusively notice and align with actions and events, which might otherwise pass unnoticed

(e.g., Heath and Luff 1992; Heath et al. 2002). At this micro level, awareness is generally accomplished by pauses, gazes, and other moment-by-moment means, and it rarely involves dedicated artefacts. Hospital staff, who are not continuously co-present, must, however, make use of dedicated artefacts in communicating the interwoven states of the trajectories of the admitted patients. Bardram and Bossen (2005a) argue that local mobility arises from clinicians' need to get access to people, places, knowledge, and/or resources. Artefacts aiming to support awareness can either provide direct access to, for example, knowledge and information about the availability of places, thereby reducing the need for mobility, or support clinicians in maintaining an overview of the whereabouts of, for example, people and resources, thereby increasing the effectiveness of mobility work. Whiteboards have been used successfully for both these purposes (e.g., Bardram and Bossen 2005a; France et al. 2005).

Awareness is often described as an inner or mental picture of what is happening. For example, Endsley (2006) finds that people in many domains spend a large part of their time building such a coherent mental picture and trying to ensure that it stays current and correct. The integration involved in maintaining a coherent mental picture of what is happening suggests that artefacts supporting awareness should not only broadcast information but also aim to integrate multiple pieces of information. Burns (2000) compared a process-control interface consisting of one integrated display with another interface distributing the same information onto four displays. Whereas the time to detect anomalies was shorter with the four-display interface, the integrated display resulted in shorter time to diagnose anomalies and higher diagnosis accuracy. Thus, the intricately related activities of becoming aware of an anomaly and reaching an understanding of it pointed toward interface designs that differed in information density. Artefactual multiplicity will likely involve denser displays and may, thus, impact the balance between these two activities, both of which are frequent and important in domains such as healthcare.

The *coordinative* function of whiteboards rests on actors' awareness of the whiteboard content and their joint commitment to the coordinative practices associated with this content (Schmidt and Simone 1996). While coordinative practices can exist as conventions without supporting artefacts (cf. Mark 2002), they generally become strengthened when they are objectified and made permanently and publicly accessible in an artefact. The coordinative practices associated with an artefact may take many forms, ranging from rigid stipulations that must be followed meticulously to general heuristics that offer a map rather than enforce a script (Schmidt and Simone 1996). Moreover, collaborating actors may bypass their coordinative practices to handle exceptions or work around known limitations of their systems (Gasser 1986). Actors' awareness of the moment-to-moment evolution of the state of their joint work is critical to their knowledge of when to follow and when to bypass stipulated procedures, implying

a tight integration of awareness and coordination. It is, therefore, an important property of whiteboards that they provide support for both awareness and coordination.

Bardram (2000) emphasizes the temporal aspect of coordination and distinguishes three levels of temporal coordination: allocation, scheduling, and synchronization. Several studies have found that whiteboards serve as meeting places where people gather to synchronize activities and negotiate rescheduling decisions (Whittaker and Schwarz 1999; Xiao et al. 2001). In relation to this, Egger and Wagner (1993) emphasize the negotiated nature of temporal order, which has to be achieved within scheduling ambiguity, conflicting interests and requirements, and scarcity of allocated resources. Different coordinative artefacts may focus on different levels of temporal coordination. A frequent issue with electronic artefacts for temporal coordination is that they overemphasize the planned schedule and leave insufficient freedom for people to perform the multiple, ad hoc adjustments necessary to manage the complexity, diversity, and unruliness of their work (Gasser 1986; Whittaker and Schwarz 1999).

2.2 Artefactual Multiplicity

The most well-known use of multiplicity as a concept is in the multiplicity of bodies as enacted in the practices of atherosclerosis (Mol 2002) or HIV-positive patients (Barbot and Dodier 2002). Multiplicity has, however, also been examined in terms of how the expectations of present, emergent, and future users become represented as a multiplicity of users (Wilkie and Michael 2009). These studies convincingly demonstrate that users and medical practices are multiple heterogeneous (Berg and Mol 1998) and that understanding them, therefore, requires careful examination of the *relations* that make the object of concern.

The notion of multiplicity assumes that there is no one reality; instead multiple realities co-exist and the way to understand objects is to investigate how the objects are performed in these multiple practices and realities. Objects are manipulated in practices and it is through detailed investigation of these practices that we can understand the multiple realities of the objects. “If practices are foregrounded there is no longer a single passive object in the middle, waiting to be seen from the point of view of seemingly endless series of perspectives. Instead, objects come into being – and disappear – with the practices in which they are manipulated” (Mol 2002, p. 5). Multiplicity avoids assuming consistency and homogeneity. In the studies of bodies, a multiplicity of partial instantiations of bodies were discovered, and the interconnections between these bodies were always tentative, often problematic, and never self-evident (Mol 2002; Berg and Akrich 2004). The point here is that we are not dealing with possibly flawed perspectives on the single object. Instead viewing the single object as a multiplicity entails perceiving the single object as comprised of various

overlapping objects produced in multiple practices. “Different realities are being created and mutually adjusted so they can be related – with greater or lesser difficulties” (Law 2004, p. 55). We propose to investigate neither bodies nor users as multiplicities, but instead to investigate collaborative heterogeneous artefacts as multiplicities. This investigation is constituted by an interest in how the artefact comes into being through multiple interdependent, yet individual, practices.

The *multiplicity* of heterogeneous artefacts has, to our knowledge, not been investigated in previous work in CSCW. When multiple, interlinked artefacts have been discussed, it has been to analyse how they extend each other in constituting configurations that support more aspects of work (e.g., Bardram 2000). In our study the focus is, instead, on the *single* artefact – the whiteboard – and the ways in which this single artefact is constituted by multiple practices, events, and people. It is when multiple people engage in various practices involving the single artefact that it becomes a multiplicity. What might seem as a singularity (one single artefact) is in practice a multiplicity. With this perspective we investigate how the single artefact (in our case, the ED whiteboard) becomes a multiplicity in action and how the *artefactual multiplicity*, as a concept, might inform the design of digital whiteboards supporting collaborative work.

3. The Pediatric Emergency Department

The pediatric ED sees approximately 38,000 children yearly and operates with two parallel patient areas: acute area for high urgency patients (17 beds) and fast-track area resembling a walk-in clinic (6 beds). The ED is part of a provincial tertiary pediatric hospital, which means that all severe pediatric cases from the whole province are transported by ambulance, by jet, or helicopter to the ED. Children are pediatric patients until their 17th birthday. For each shift 24/7 one to three ED pediatric physicians are on duty working in 8 hours shifts. Sometimes MDs from other departments or from one of the ambulatory clinics bring in patients to use the ED facilities. Finally, consultants with particular medical expertise (e.g., orthopedic, oncology, neurology) are regularly called to the ED. There are approximately 75 registered nurses in the ED, mostly working in 12 hours shifts. Each nursing shift comprises 7-9 nurses.

To investigate the use of whiteboards and the transformation from ordinary dry-erase whiteboards to digital whiteboards, we conducted an ethnographic case study of the work practices (Forsythe 1999) in the pediatric ED over two years. This research was initiated by observations at the ED in November 2006, focusing on the work practices involved with the triage activities (Bjørn and Rødje 2008) and continued with investigations of the use of the acute and fast-track whiteboards over the Summer of 2007. From Spring 2007 until March 2008, the first author was involved with design workshops where a standardized

electronic triage template was designed (Bjørn et al. 2009) while the patient tracking system, which was the foundation for the digital whiteboards, was re-configured and customized.

The first part of the Cerner FirstNet system was implemented in March 2008 and the second part in June 2008. Both of these implementations were observed, which included investigating how the ED staff took the new digital whiteboards into use. Finally, in November 2008 follow-up interviews were conducted with key people involved in the design and adaptation of the Cerner FirstNet system. In addition, the work practices associated with the system were observed four months after the initial implementation. In this paper we focus on the use of the ordinary dry-erase whiteboards and leave out the design and implementation of the digital whiteboards. Table 1 summarises the data sources of the empirical study.

Table 1: Data sources

4 Work practices within the ED

ED work practices comprise multiple individual and yet highly interdependent activities handling the trajectories of people, activities, and artefacts. When a patient enters the ED a triage nurse assesses the level of urgency and divides the patients into two groups: acute patients and fast-track patients. The acute patients are the ones who require immediate care and who usually stay in the ED for a longer time receiving care and treatment before either being admitted to a ward or sent home. The fast-track patients are the less urgent patients. They are rarely admitted and are usually sent home after treatment. Fast track thus refers to ‘fast cured patients’ as opposed to the acute patients who need more treatment. Because the patient populations are different in terms of urgency when entering the acute area or the fast-track area, they also require different types of treatment and care; thus, the work is organized differently in the two areas. The main coordinative artefacts supporting the organization of the work are two locally based whiteboards: one in the centre of the fast-track area and one in the centre of the acute area. It is important to understand the differences in work practices in the two areas when investigating the different designs and usages of the whiteboards and in the next two sub-sections the work practices of first the acute area and then fast-track area are described.

4.1 Organizing work in the acute area

The acute area is a location with 14 examination rooms each with one bed; a trauma room with two beds; and two rooms for psychiatric patients. The nursing

station is in the centre of the acute area, right next to the smaller physician area. At the nursing station most of the work is organized by the charge nurse, who manages incoming patients, examinations, nurse assignments, bed managing, treatment of patients, tests, and so forth. At any time the charge nurse is the main figure of the whole ED, including the triage and fast-track areas.

High-level-of-urgency patients referred to the acute area come sorted into three categories by the triage nurse. Patients at the highest level of urgency (CTAS[1]1) are assigned directly to the trauma room, which faces the ambulance entrance to the ED on the one side and the nurse station on the other side. The trauma room is in this way designed with only two full walls while the other two are curtains. This design makes it easy for both the patients, typically arriving with paramedics from either an ambulance or a helicopter, and the ED staff to enter and start treatment. When a trauma-room patient has been stabilized the staff most often moves the patient up-stairs in case of admission or to a room in the acute area. Patients who are not trauma-room patients but still at a high level of urgency will be assessed and sorted by the triage nurse into two subgroups, labelled CTAS2 and CTAS3. For all CTAS2 patients the triage nurse will phone the charge nurse directly, who then will assign the patient to a room. CTAS3 patients will be referred to the acute waiting area, and when there is space available be assigned to a room by the charge nurse.

When a patient is assigned to the acute area all the paperwork (including the physician chart, triage and nursing sheets) will be placed in a tray at the charge nurse desk. The charge nurse frequently empties the tray and divides the papers into a nurse pile and a physician pile. Each pile is attached to a separate clipboard. When calling up and assigning a patient to a room the charge nurse will take the nursing clipboard and hang it on the wall in the room (Figure 1), while placing the physician clipboard in the chart-rack labelled “not seen by physician”. The patient stays assigned to the particular room for the whole stay in the ED, even at times where the patient might be sent to the x-ray department or the sedation room. So even though the patient might not be physically in the room, the cubicle is blocked and kept free for the patient to return.

Figure 1: Nursing clipboard hanging on the wall in an examination room in the acute area

The order in which the physician chart-rack is organized creates a queue of patients in the order they arrived. There are multiple physicians on duty in the ED at all times. There will always be at least one physician who is a specialist in both pediatrics and emergency medicine. In addition, there are typically a number of fellows, medical students, and other types of physicians being guided by the

[1] CTAS: Canadian Triage and Acuity Scale

specialist. When the physician picks up a patient clipboard she or he assumes responsibility for the patient for the whole time the patient is in the ED.

Nurses are assigned differently. During all shifts there will be 7-9 nurses. One will be the charge nurse. The charge nurse assigns roles to all other nurses. At all times there is a triage nurse, and since triaging at times is very exhausting the role as triage nurse shifts approximately every four hours. There is also always a break nurse, three bed-side nurses, and sometimes also a float nurse, which is an extra pair of hands during busy periods. In the time periods where fast track is open, one nurse will be assigned the role as fast-track nurse. The nurses in the pediatric ED collaborate a lot and help each other when caring for patients. In this way nurses are not assigned to particular patients, but continuously keep track of all patients in the ED.

4.2 Organizing work in the fast-track area

The fast-track area has six examination rooms and a suture room. In the centre of the fast-track area there is a small space with two desk tables; this is where the fast-track nurse and the fast-track physician are located. When the less urgent patients are assigned to fast track all the papers (including nurse and physician charts) will be placed in a tray in the centre of the fast-track area. Here the fast-track nurse will pick up the papers and place them all on one clipboard. The clipboard is then placed in the hanging folders chart-rack at the central area. When a patient is called into a room the fast-track nurse will follow and do a quick examination before placing the clipboard in the chart-rack labelled “Not seen by physician” (Figure 2). Subsequently, the fast-track physician will pick up the clipboard and go to see the patient.

Figure 2: Chart-rack “Not seen by physician” on a table in a fast-track examination room

There is only one fast-track nurse at any one time, so assigning duties at fast track is not an issue. Mostly there will also only be one physician present at fast track, which makes it easy to determine who is responsible. At times there will also be medical students or fellows present; it is, however, always the main ED physician who is responsible.

When the physician has examined a fast-track patient and decided that further tests or events are required, the patient is either sent directly to tests (radiology for x-rays or the suture room for sewing) or to the fast-track waiting room. When fast-track patients leave a fast-track examination room they are re-assigned to the fast-track waiting room on the whiteboard, making examination rooms available for new fast-track patients. This process is different from the acute process, where the patient keeps the room.

Figure 3: Tray for paper of patients assigned to fast-track area

5. The Artefactual Multiplicity of Whiteboards

Investigating how the whiteboards were used in the ED it became clear that they served as the main artefact in the organization of the work and were a centre of attention for the staff on duty. In addition, it became clear that the acute and fast-track areas of the ED used the whiteboards differently. Finally, through our analysis we identified not only the multiple functionalities supported by the two whiteboards but, importantly, the *relations* between these functionalities. In short, we identified the artefactual multiplicity of the whiteboards. In this section we will describe the multiple practices co-existing in the ED whiteboards.

5.1 Overall structure of the Acute and Fast-track whiteboards

The acute whiteboard (Figure 4) is located on the centre wall at the nursing station. It is divided into a row for each cubicle, and the cubicle numbers are permanently written vertically at the far left of the whiteboard. When reading a row from left to right there are nine columns, eight of which have pre-printed headings: cubicle number (Room), patient name (Name), the time the patient arrived and in some cases the time of a decision to admit the patient (Time Triage-ERO/ERW), attending physician (MD), whether specialists are seeing or have seen the patient (Consultant[2]), whether x-rays have been ordered/done (Radiology), information about ordered/done lab work (Laboratory), and whether the physician has ordered the nurse to collect specimens such as urine analysis (Specimens). The ninth column, which does not have a pre-printed heading, has multiple purposes such as information about medication doses and time. The room numbers at the far left are pre-printed on the whiteboard and as such the acute whiteboard is structured according to the acute examination rooms. Only patients assigned to a room figure on the whiteboard. Thus, all patients assigned to the acute area, but still in the waiting room, are not represented on the whiteboard. Above the columns on the acute whiteboard there is a pre-printed role area for the main nurse assignments: Charge nurse, Break nurse, Triage nurse, and Fast-track nurse. At the beginning of each shift, the charge nurse fills in this area with the names of the nurse assigned to these roles.

Figure 4: Reconstruction of acute whiteboard

[2] In the Canadian Pediatric ED they use the term ‘consultant’ to indicate whether a patient needs to be seen by a medical specialist. If the attending physician requests that a consultant from, say, the orthopedic department must see the patient, the charge nurse will call the orthopedic department. At this time the charge nurse does not know which orthopedic consultant will arrive and, therefore, writes the requested service ‘ortho’, instead of the name of the consultant, on the whiteboard. When they know the name, they will write, e.g., ‘Smith’. This way, the label ‘consultant’ may seem confusing, because the content of the column is more of a service even though the label ‘consultant’ refers to a role.

The fast-track whiteboard (Figure 5) is located in the centre of the fast-track area. There are 10 columns on the fast-track whiteboard, however only nine of them have headings. The headings resemble those of the acute whiteboard and are: Cubicle number (Room), patient name (Patient), triage time (Time), attending physician (Physician), requested specialized medical expertise (Consultant), the status of x-rays or other medical imaging (Radiology), status of tests requested or sent to the laboratory (Laboratory), status of requested tests done by the fast-track nurse such as urine samples (Specimens), and status of requested old patient charts (Old chart). The Old chart column is usually used for free-text comments and not only to indicate whether the patient has an old chart and, if so, whether it has been requested. The tenth column does not have a heading and is used for writing who is the fast-track nurse on duty and, in case there are several fast-track nurses, the name of the attending nurse. Sometimes they use the free-text column to indicate who is taking over during breaks. There is a clear difference in the first column of the acute and fast-track whiteboards. While the room numbers are pre-printed on the acute whiteboard, they are manually filled in, and revised, on the fast-track whiteboard.

Figure 5: Fast-track whiteboard

The fast-track whiteboard lists all patients assigned to fast track, not only patients in the examination rooms. This means that all patients assigned to fast track but still in the waiting room also figure on the fast-track whiteboard. It is the absence of pre-printed room numbers that makes this possible. When a patient is assigned to fast track the patient name will be written on the whiteboard in the row below the last patient row. The nurse will also write the triage time on the whiteboard because this indicates which patient must be seen first. At first there will be no information in the room–number field. Then, when a room becomes available at fast track, the nurse will write the room number next to the patient name on the whiteboard and call in the patient. The room number will stay next to the patient as long as the patient is in the room, but if the patient is sent to x-rays or back to the fast-track waiting room, the room-number field will be changed to WR (waiting room). WR indicates that the patient has seen the physician but is back in the waiting room awaiting results of some kind. When the results arrive, the patient is again moved to a cubicle and the WR is changed to the room number. This tracking of patients' movements among various cubicles, the waiting room, and external departments creates a more dynamic whiteboard than the acute whiteboard. The below figure illustrates the dynamics of the fast-track whiteboard over a short period of time.

Figure 6: The dynamics of the fast-track whiteboard

In Figure 6 the fast-track whiteboard is represented at three different times. In the first snapshot there are seven patients on the whiteboard, four are in cubicles and three are in the waiting room. However, while Liz and Diana have not yet seen the physician, Ian has seen the physician but has returned to the waiting room, waiting for results. This is indicated by the WR as well as in the triage time, which shows that Ian arrived before any of the other patients. The second snapshot shows that John has left the ED, Sue and Thomas are still in their rooms, Terry has been moved from cubicle 5 to the waiting room, and both Liz and Diana have been placed in rooms. Also three new patients have arrived in the waiting room. One should also notice that now there is no more space below the last patient. In the third snapshot Ian's results have arrived and he is now in room 3. Thomas and Diana have been sent to the waiting room providing room for James and Morgan. Also three new patients have arrived: Taylor, Derek, and Winston. As there was no space below the last patient, the whiteboard is used from the top again. The top three rows without patients have been used for the new patients, placing Winston in the middle of patients already present in the ED. However it is still possible to keep track of the order due to the triage time. Here it is evident that Winston is the last arrival to the ED.

Comparing the overall structure of the acute and fast-track whiteboards it becomes clear that the design of the two whiteboards is adapted to the particular type of flow in the two areas of the ED. The fast-track whiteboard is designed to be dynamic (no room numbers) in order to support the rapid flow of patients and can be classified as a 'rolling whiteboard' where the patient flow is represented in continuous iterative cycles. Conversely, the acute whiteboard has a stable design (indicated by the pre-printed room numbers) representing the stability in the patients' location, whereas their condition may be unstable. While most of the activities that result in annotations on the acute whiteboard are linked to a particular patient located in a particular cubicle, the majority of activities that result in annotations on the fast-track whiteboard concerns the tracking of the patients' locations.

5.2 Micro coordination, arrows, check marks – past, present, and future

Zooming in on the different annotations used at the whiteboards it becomes clear that the whiteboards not only represent a current image of the situations in the ED, but also provide indications of both past and future activities. One example is the little red check mark next to the patient's name on the acute whiteboard (Figure 7).

Figure 7: Red check mark by patient's name (reconstruction)

When a patient is placed in a cubicle at the acute area the patient's name is listed on the whiteboard, the nurse chart is placed on the wall in the cubicle, and the physician chart is in the chart-rack 'not seen by physician'. Immediately after a patient is moved to a cubicle the nurse responsible assesses the patient's condition and documents the assessment in the nursing notes. The physician is not supposed to see the patient until after the nursing assessment has been made. To indicate that the patient is ready to be seen by a physician, the nurse writes a red check mark next to the patient name. The red check mark indicates that the nurse assessment has been made. When a physician is ready to see a new patient, the physician will glance at the whiteboard to see which new patients have red check marks and no attending physician assigned. This is indicated in the 'MD' column. In this way the red check mark serves two purposes. The absence of a check mark indicates that the nurse must do something, while the presence of a red check mark indicates that something has been done in the past (nurse assessment) and a new activity must be executed in the future (physician assessment).

Patients assigned to fast track get a full assessment by the triage nurse, before the fast-track nurse takes over. Thus, each patient on the fast-track whiteboard is ready for the physician. Consequently, red check marks are not used on the fast-track whiteboard.

Figure 8: Arrows system on the whiteboard (reconstruction)

An important indication of time and coordination common to both types of whiteboard is the arrow system (Figure 8). The arrow system indicates whether an activity should be done (indicated by an arrow down), is in progress (indicated by an arrow across), or has been done (indicated by an arrow up). However, the detailed use of the arrow system varies with the activity connected to the particular arrow.

When treating particular patients, the ED needs assistance from various specialists such as orthopedics, dentists, and neurologists. On the whiteboard these specialists are referred to as consultants. It is important to note that the consultant does not necessarily take over the patient from the attending physician but in many cases sees and treats the patient and then turns the patient back to the attending physician. When requesting a consultant the process is to call up the relevant department and leave a message (first step indicated on the whiteboard by arrow down), then a consultant in the department calls back to ask about the patient (second step arrow across), and finally when the consultant has been to the ED to see the patient the completion of the 'consulting visit' is indicated (arrow up). The arrow related to the consultant is thus recording the articulation work involved in getting a consultant to see a patient. When the complexity of a patient's condition requires a consultant, it is most often the case that several consultants are required. Thus, 'consultant management' is the practice where the

ED staff keeps track of the status of all the requested consultants for the particular patient.

The arrow system related to specimens is different. A typical specimen activity would be for the physician to request a urine analysis. This would mean that the nurse would provide the accompanying adult of the child with a beaker to sample the urine (arrow down), and then when the accompanying adult has managed to sample urine in the beaker and it is handed over to the nurse (arrow across), the nurse will dip the urine, read the results, and write them on the chart (arrow up). In most cases of specimens the nurse does the analysis, and the two last steps are in practice one process. However, in cases where a specimen is sent to the lab to grow bacteria or other more complex tests there are two separate steps.

In relation to the laboratory, the arrow system is often about blood work. Getting the laboratory to do blood work in the ED is similar to the consulting process. The first step is to call up the laboratory (arrow down), then the laboratory calls back (arrow across), and later the staff from the laboratory arrives in the ED to do the sampling, which ends the process (arrow up). Here it is important to notice that while specimen activities typically are handled by the ED nurse and finishing the process (arrow up specimen) means that the result is available for the physician; finished laboratory work (arrow up lab) only means that the sample has been collected and sent to the laboratory thus a finished lab arrow does not indicate available results.

5.3 Nursing assignments, break management, and cleaning

In addition to tracking patients and handling the temporal sequencing of activities the whiteboard is also used to handle nursing assignment, break management, and cleaning. One of the charge nurse's key activities is to assign the nurses to the various roles during their shift. There are two main nurse shifts for each 24 hours, at 7:00 and at 19:00. At the morning shift the nightshift charge nurse stays for a short while to hand over all patients who have arrived during the night to the day shift. After the update the day charge nurse begins to assign the nurses on duty to particular tasks: triage nurse, fast-track nurse, break nurse, float nurse, and bed-side nurse. Moreover, each bed-side nurse will be assigned to particular cubicles. Each time a patient is placed in one of these cubicles, the nurse assigned to that cubicle is responsible. These assignments are written on the acute whiteboard by listing the nurses' names next to the cubicle numbers. Being assigned to particular cubicles also entails particular tasks. For example, the bed-side nurse assigned to cubicles 17A and 17B is responsible for all psychiatric patients, since these cubicles are psychiatric facilities.

When assigning tasks the charge nurse will use her knowledge of the competences and skills of particular nurses. For example, to be qualified as a triage nurse, the nurse must have particular triage training, which includes at least

one year as a bed-side nurse in the ED, formal triage training taught by the ED clinical nurse educator, and a particular number of supervised hours in the triage area (Bjørn and Rødje 2008). To be a break nurse requires that the person can handle all types of role, since the break nurse should be able to release the triage nurse, the fast-track nurse, the charge nurse, and all types of bed-side nurses.

On the acute whiteboard nurses' names are written in the pre-printed role area for assignments such as charge nurse, break nurse, triage nurse, and fast-track nurse. However, the names of the bed-side nurses are written next to the cubicles, e.g. Sue is assigned to rooms 1-4 (Figure 9).

Figure 9: Nurse Sue is assigned to particular rooms (reconstruction)

Break management is an essential activity for ED nurses since working 12 hours and still providing patients the best care requires periodic rest. Break management is handled using the acute whiteboard. In the space after the free-text field, where the nurse assigned to the particular cubicles is indicated (see Figure 9), the charge nurse writes the time and length of each nurse's shift. Most nurses work 12-hour shifts, typically 7-19 and 19-7. However, some nurses work different hours. When all nurses have been assigned tasks, the charge nurse will provide each nurse name with a number from 1 to the total number of nurses on duty. These numbers indicate the order in which the nurses will go on breaks, creating the break queue while taking the shift type into account. For a 12-hour shift a nurse will usually have three breaks. Having the break queue, the break nurse will be in charge of handling the breaks. So the break nurse will start by releasing nurse 1, and when nurse 1 returns the break nurse will write a red check mark next to nurse 1's number indicating that the first break has taken place. In this way, it is easy to see who is next for a break and how many breaks each nurse have had.

Ensuring the hygiene in EDs is vital to prevent the spread of bacteria and viruses. This makes the *cleaning* of rooms and equipment critical for the everyday work in EDs, although this work is typically 'invisible'. Each time a patient leaves the ED, the room and equipment must be cleaned. Cleaning a room can be done in three different modes depending on the patient leaving. In cases where patients are re-organized between multiple locations at fast track the cleaning between patients is usually reduced to the fast-track nurse changing the paper on the stretcher in the room. This is the lowest degree of cleaning required between patients. The second mode is done by housekeeping in acute examination rooms each time a patient leaves. This cleaning mode is the most common and it is handled collaboratively by the bed-side nurse and housekeeping. When a patient is discharged from the ED, but still present in the room, the bed-side nurse will make a swirl line over the patient's name (see Figure 10, upper left).

Figure 10: Discharge (upper left); Housekeeping (upper right); Cleaning done (lower left); Terminal cleaning (lower right). Reconstruction

When the patient actually leaves the ED, the bed-side nurse will erase all patient information on the whiteboard and write “HSKG” for housekeeping (Figure 10, upper right). This flags to housekeeping, who is present in the ED at all times, that this particular cubicle must be cleaned in mode 2. When housekeeping is finished cleaning the cubicle they will erase the “HSKG” (Figure 10, lower left) from the whiteboard, indicating to the charge nurse that the room is now available for new patients. In some cases of particular illnesses the infected patients must be isolated to prevent infection of other patients. These patients will typically be placed in an isolation room. There is one isolation room at fast track and one at the acute track. When isolation patients are leaving the ED, the room and equipment must be cleaned using particular cleaning products and devices. This type of cleaning is referred to as “terminal clean”. To indicate that a patient has left the ED leaving a room that requires terminal cleaning the bed-side nurse will erase the patient information and write “terminal” in the row (Figure 10, lower right). Housekeeping will then know where to do terminal cleaning, and when finished they will clear the row and the charge nurse will know that the room is ready for new patients. Since housekeeping cleans the acute rooms more frequently than the fast-track rooms the use of the whiteboard for coordinating cleaning refers mostly to the acute area. If the fast-track nurse needs housekeeping she will phone the charge nurse or, typically, walk to the acute area and ask for housekeeping.

5.4 Whiteboard use during handover

The whiteboard is also pertinent during handovers. There are five scheduled handovers each 24 hours (nursing handovers are at 7:00 and 19:00, physicians handovers at 8:00, 16:00, and 24:00) and a large number of informal handovers during the day. Handovers are complex coordination activities. During nursing handovers the following staff will be present: the charge nurse leaving her shift, the charge nurse taking over the shift, all the new bed-side nurses, and the new triage nurse (provided the triage desk is not too busy). In some situations the physicians will listen in on the nursing handover at 7:00 to become updated about the patients before their own handover at 8:00. The following observation note describes some of the complexities during nursing handovers.

> “The charge nurse changes the list of nurses names on the acute whiteboard – who is coming or going and what their assignments are. The previous charge nurse goes through all the patients on the acute whiteboard and takes the time to explain the particular situation of each patient. She uses the acute whiteboard to organize her report.

She points to Room 2 on the whiteboard. It reads that the patient arrived at 22:04; and that ERW time is 02:30. The leaving charge nurse takes the physician clipboard in the hanging folders under the whiteboard and begins to tell about this patient. The patient had NPO done because (..) and the patient will go to the OR (Operation Room), the patient is an ERW patient (Emergency Department patient Waiting to be admitted upstairs) and the time of the decision to admit the patient was 02:30 – 4.5 hours ago.

The charge nurse mentions a boy who arrived at the ED last night but went home and might come back again later.

She points to Room 6 on the whiteboard. The patient arrived at 21:34, and at 22:50 the patient became an ERO patient (Emergency department patient admitted to the ED department). The nurse goes through all the events for this patient and explains the plans for when the patient wakes up. While doing this she frequently points to the whiteboard and uses the arrow system related to the medication information in the free-text column to make her report. It is an asthma child and he needs to go to x-rays.

In Room 8, the patient arrived at 02:20. This patient is a 12-year-old girl who has been assaulted in a park. The charge nurse mentions that it was the second assault of the evening. The charge nurse tells the story. They have done a urine test to see if she was pregnant. She was not pregnant, so they were able to do x-rays of her bruises. She is asleep now, lives in a group home, and will need to have a social worker come and pick her up.

In Room 12, the patient arrived at 00:40 and the decision to admit upstairs was made at 01:20. The patient is an ERW patient. The patient fell down at a playground – he is transferred from another hospital to see neurology at the pediatric hospital. There is an X in the column for physician, because the child is to be seen directly by a consultant (NEURO) in the ED while waiting for a bed in the neurology department." (excerpt from observation notes, 07:00, August 2007)

The above observation note shows how all whiteboard information about each patient is reported during the handover. Thus, the charge nurse reports time of arrival and which tests and interventions (blood work, specimens, x-rays) have been ordered, are in progress, or finished. She also reports which consultants have been or are involved (e.g., neurology surgery) and who needs to be contacted (social worker). During the handover the charge nurse refers many times to the comment column on the whiteboard, where she provides an overview of each patient's medication. For example, information such as "v*A*3 Vgh Prn 09:00#12" on the whiteboard refers to a particular type of medication, where the next dose (dose number 12) should be given in two hours time at 09:00. All this information is also on the nurse and physician charts; however, having it on the whiteboard provides an overview of the patients' current status without locating each chart.

6. Conceptualizing Artefactual Multiplicity

ED whiteboards are central artefacts guiding and stipulating the collaborative work in emergency departments. In this way whiteboards can be seen as common

information spaces (Schmidt and Bannon 1992), as supporting awareness (Lundberg and Hellioglu 1999) and as an articulation of the ED's where, what, when, and who. In addition, ED whiteboards support the coordination required to handle the patient trajectories (Bardram and Bossen 2005b). In our case all of the above concepts make sense when investigating the use of the ED whiteboards. However, we also observed other uses of the ED whiteboard, which the above concepts leave unexplained. These uses are, nevertheless, essential to the design of digital ED whiteboards.

ED work comprises multiple practices serving to link the trajectories of people, activities, actions, objects, and artefacts. Each of these practices represents a partial perspective on ED work. The ED whiteboards are used to organize these multiple, partial practices of work in the ED while at the same time collecting them in a single artefact. In this way the ED whiteboard should be viewed as a single artefact that constitutes a multiplicity. Multiplicity does not imply fragmentation (Mol 2002); instead, multiplicity understood as interlinked practices refers to the relations between various essential practices (e.g., patient tracking, break management, and cleaning), which co-exist in the emergency department and are all organized through a single artefact. ED whiteboards are central artefacts and the ways in which they are enacted by healthcare practitioners link the partial perspectives together. Each partial perspective brackets out other perspectives. Physicians are, for example, not interested in cleaning, just as cleaners are not interested in nurse break management. The totality of ED work would, however, risk breaking down without the relations created by the artefactual multiplicity of the whiteboards linking the partial practices. It is the stable procedures for the use of the whiteboards that make it possible for the cleaners to bracket out all practices not related to cleaning. Each group of healthcare practitioners has its own professional practice in which they are highly capable, and they perceive and interpret all the work in the ED according to this professional practice. Thus, 'ED work' is an ambiguous and complex 'entity' comprising multiple entangled practices of people, professions, activities, artefacts, places, illnesses, conditions, urgencies, emergencies and so forth. No one person has a complete overview of all practices at all times, nor is it anyone's job to have such an overview. Healthcare professionals rely on the whiteboard as an artefactual multiplicity that interlinks the various ED practices. Each healthcare professional can view the whiteboard from his or her perspective and see only what is relevant to that perspective. However, the whiteboard also provides the possibility to step back and change the perspective from cleaner to nurse, from nurse to physician, while viewing the whole. By zooming in on one task or zooming out to view the whole, each professional group can interpret their individual work in relation to other groups. This opportunity for flexibility in perspectives is essential, since at busy times it is often important to monitor the whole to make sense of the particular.

Mol (2002, p. 54) argues that "to be is to be related" and thereby stresses the importance of the *relations* between the multiple practices involved in whiteboard use. Designing with artefactual multiplicity as a guiding principle entails respecting the interlinked practices embedded in ED work, including the tacit, unarticulated, and less valued practices such as cleaning, break management, and nursing assignment. Cleaning practices are highly interlinked with patient care, diagnostic work, and treatment. These practices depend on each other, and it is only through an understanding of their interdependencies we can fully understand the collaborative practices of ED work. Consistent with our concept of artefactual multiplicity the definition of patient trajectories (Strauss et al. 1985) emphasizes careful examination of the relations between all the trajectories involved in the social organization of medical work.

Investigating multiplicity we must "attend to the craftwork implied in practice" (Law 2004, p. 59), since it is in the relations between the various ED practices that ED work is produced. It is in the relations between the multiple practices involved in handling patients' trajectories that we locate the multiplicity required to manage ED work. The multiple practices in this case include managing patient locations, medication, assignment of resources, break management, cleaning, managing consultants, radiology, and laboratory work. While each of these practices could be perceived as individual singularities, which simply happen to co-exist in the ED, this would imply that the connection made between these practices in the use of the whiteboards is coincidental and can, thus, be cut without affecting ED work. However, we would argue that the set of relations between these individual practices should be understood as one artefactual multiplicity crucial to the functioning of the ED, and cutting the connections between the practices currently embedded in the use of the whiteboards would seriously impact the work. For example, cleaning is closely related to patient location and treatment, since without clean cubicles there are no places for the patients, and each time a patient leaves a cubicle housekeeping plays the important role of ensuring patient safety. Nursing assignment is highly linked with patient treatment, since nursing assignment is linked to particular nursing training to ensure patient safety, which again is related to break management. Similarly, medication and intervention practices are interlinked with the patient location, since particular locations are designed for particular interventions: the suture room for wound treatment, the cast room for broken limbs, the isolation room for infectious diseases, and the trauma room for trauma patients. The artefactual multiplicity may appear invisible, providing an impression of multiple singularities rather than one multiplicity (Bjørn and Rødje 2008), because when work proceeds as expected the required articulation work becomes invisible (Suchman 1995). Concepts typically used when investigating whiteboards tend to entail a focus on singular practices, such as coordinative practices for surgery departments (Bardram 2000), how awareness features support work (Lundberg

and Hellioglu 1999), or how healthcare professionals gather around the whiteboard to be updated (Hertzum and Simonsen 2008). Identifying such singular coordinative practices is important but, we argue, insufficient. One must also capture the relations between the processes.

Prescriptive design processes are distinctly different from descriptive ethnographic processes (Grudin and Grinter 1995). To be able to design coherent artefacts it is tempting to clean up the complexity of the messy realities experienced during ethnographic studies. Thus, experiences of the ambivalence and elusiveness of real work may get reduced. In this process we tend to exclude descriptions that are faithful to the work practices investigated (Hine 2007, p. 663). Attending to artefactual multiplicity may support designers in recognizing all practices as well as their relations. This entails in-depth investigations of the particulars of local work practices, which exhibit a high degree of variation in healthcare (Balka et al. 2008).

Dry-erase whiteboards are in the process of being replaced by digital whiteboards (Aronsky et al. 2008) and it is, therefore, crucial to identify the distinctions important to the design of digital whiteboards. In our empirical case, the design of the digital whiteboards did not take the artefactual multiplicity of the dry-erase whiteboards into account, and this negatively impacted the later use of the digital whiteboards. ED whiteboards do not simply "keep track of patient information and provide an up-to-date view of the overall ED operation" (Aronsky et al. 2008, p. 184). Rather, they integrate and interlink the multiple yet interdependent practices required to make the ED function. It is in the mediation of the relations between these practices that the whiteboard gains its artefactual multiplicity, and new designs of digital ED whiteboards should recognize this feature of ED whiteboards.

7 Conclusion

To understand the complexity of the collaborative work involved in handling patient trajectories in emergency departments we have examined the use and role of two whiteboards in a pediatric emergency department. We found that the design of the two dry-erase whiteboards had distinct features created to support contingencies particular to the local contexts of the acute and fast-track areas (e.g., pre-printed or fill-in room numbers). While these differences might appear insignificant, we found that they were crucial to the enactment of the whiteboards and the organization of work in the two ED areas. There were also similarities between the two whiteboards, for example in the ways of keeping track of time, as in past, present, or future events. Temporal sequencing was important to the ED work, and simple marks with high interpretive complexity were used on both whiteboards (e.g., the red check marks and the arrow system). Finally and most importantly, we identified how processes and practices usually not articulated as

directly relevant to medical care in EDs were interlinked and related to the total organization of medical work, including processes for cleaning, nurse assignment, and break management. The whiteboards not only served multiple functions, they also created the *relations* between the multiple functionalities.

In this paper, we propose the concept of *artefactual multiplicity* as a way of capturing a central feature of heterogeneous collaborative artefacts such as ED whiteboards. Artefactual multiplicity identifies not only the multiple functions of heterogeneous artefacts but also the *relations* between these multiple functionalities. Understanding the relations between the functionalities embedded in artefacts is essential for the re-design of such artefacts. When designing digital whiteboards we need to know their multiple functionalities as well as to identify the interrelations between these functionalities. Our concept of *artefactual multiplicity* can be used as an analytic lens for identifying the multiplicity of collaborative artefacts. Artefactual multiplicity emphasizes that design decisions about such artefacts should include the *relations* between the individual functionalities. These relations are easily rendered invisible during design; thus, artefactual multiplicity points toward a design strategy that aims at articulating these relations to ensure their inclusion in new designs. We argue that identifying the artefactual multiplicity of heterogeneous artefacts is very important, for example, when analogue artefacts are replaced with digital ones.

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Data sources
Workshops
Participation in 22 design workshops between July 2007 and January 2008, each lasting from 4-8 hours and involving 3-12 participants
The First author spent approximately 132 hours participating in design workshops. After each design workshop the first author wrote reflective notes as well as observation notes of the activity
The workshops focused on ED work practices were facilitated by the first author
Observations
12 observations sessions of ED work practices took place between November 2006 and August 2007 focusing on work practices
11 observations sessions in March, June, and November 2008 focusing on the implementation and use of the electronic triage and patient tracking system
10 front-end observations were focused on the triage nurse and registration clerk (front-end). At each observation incident 1-5 triage nurses (at busy times there can be up to 3 active triage nurses triaging at the same time; also other nurses might take over during breaks etc) and 1-2 registration clerks were observed.
9 back-end observations were focused on the charge nurse, unit clerk, fast-track nurse, and 7 bedside/break nurses working each shift including their use of whiteboards, clipboards, chart racks, and other artefacts. Observations took place at the acute area and at the fast-track area.
4 observations included both front-end and back-end observations
Many staff members were observed more than once. Digital images of a wide range of artefacts and copies of various paper forms have been collected during observations. In total the front-end was observed for 47.85 hours and the back-end for 50.5 hours.
Interviews
Informal interviews were conducted during observations with 39 different ED staff members in total, mainly comprising 35 different nurses (triage, charge, break, float, and bedside nurses), two clerks (one registration and one unit clerk), and two physicians.
8 formal interviews were conducted, one group interview, one with the clinic information officer, three with the clinical nurse educator, and three with the emergency program manager. Five of the formal interviews were recorded and transcribed.
Informal conversations took place with the clinical nurse educator and the emergency program manager, as well as with various nurses, clerks, and physicians between July 2007 and January 2008, where the first author was present at the hospital on average 2.5 full days each month.
Additional activities
Field trip to two of the regional hospitals together with the core group observing triage work using the Cerner Firstnet application in two adult EDs
Phone interview survey with 8 out of the 10 pediatric EDs in Canada
Participation in numerous meetings (formal/informal) at the hospital

Table 2: Data sources

Figure 11: Nursing clipboard hanging on the wall in an examination room in the acute area

Figure 12: Chart-rack “Not seen by physician” on a table in a fast-track examination room

Figure 13: Tray for paper of patients assigned to fast-track are

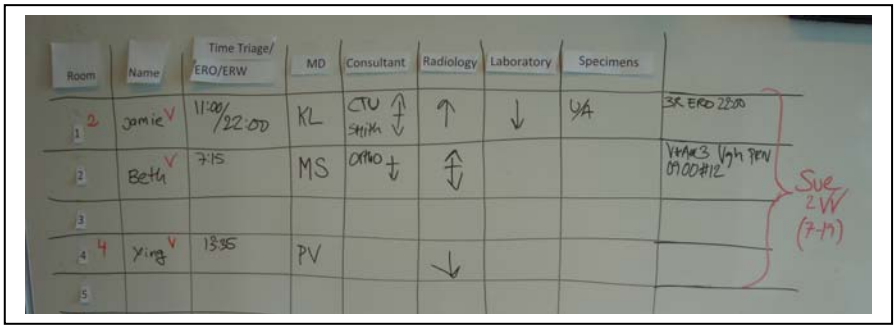

Figure 14: Reconstruction of acute whiteboard

Figure 15: Fast-track whiteboard

Room	Patient	Time
3	Sue	10:05
2	John	10:11
WR	Ian	09:30
4	Thomas	10:30
5	Terry	11:20
	Liz	11:35
	Diana	11:37

Room	Patient	Time
3	Sue	10:05
WR	Ian	09:30
4	Thomas	10:30
WR	Terry	11:20
2	Liz	11:35
5	Diana	11:37
	James	12:01
	Morgan	12:05
	Emma	12:12

Room	Patient	Time
	Taylor	12:30
	Derek	12:30
3	Ian	09:30
WR	Thomas	10:30
	Winston	12:35
2	Liz	11:35
WR	Diana	11:37
4	James	12:01
5	Morgan	12:05
	Emma	12:12

Figure 16: The dynamics of the fast-track whiteboard

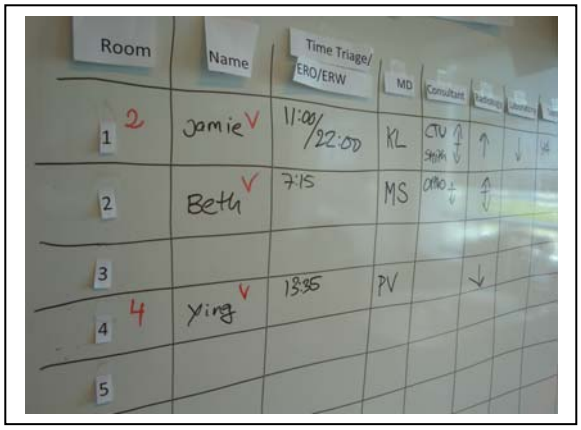

Figure 17: Red check mark by patient's name (reconstruction)

Figure 18: Arrows system on the whiteboard (reconstruction)

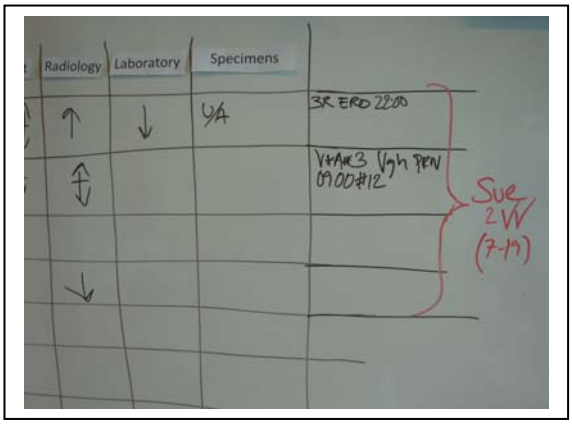

Figure 19: Nurse Sue is assigned to particular rooms (reconstruction)

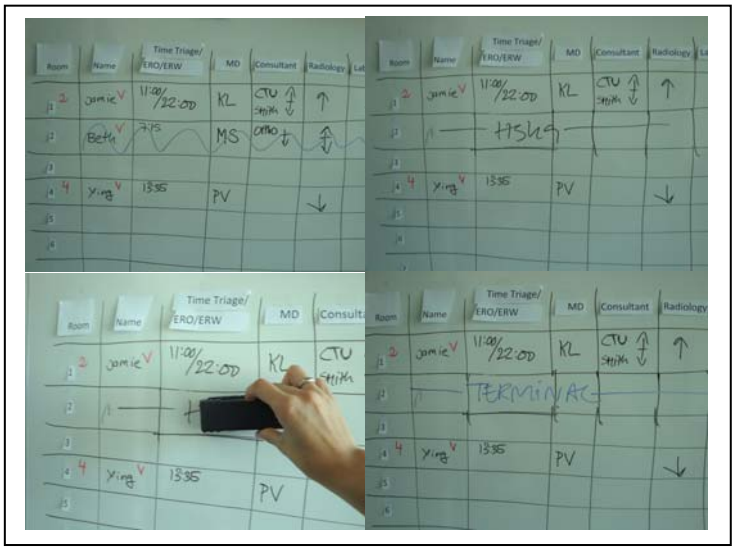

Figure 20: Discharge (upper left); Housekeeping (upper right); Cleaning done (lower left); Terminal cleaning (lower right). Reconstruction