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Visualizing the Application of Filters: A Comparison of Blocking, Blurring, and Colour-coding Whiteboard Information

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Abstract. Through a mixed-design experiment we compare how emergency-department clinicians perform when solving realistic work tasks with an electronic whiteboard where the application of information filters is visualized either by blocking, colour-coding or blurring information. We find that clinicians perform significantly faster and with less effort and temporal demand when using the blocking interface. However, we also find that the colour-coding interface provides clinicians with a better overview of the information displayed by the electronic whiteboard. The blurring interface did not perform as well as previous research has shown and we discuss the differences between these results and ours. Finally, we find that the clinicians worked much less in parallel than we had expected and discuss the reasons for this.

Keywords: information visualization, filters, colour-coding, semantic depth of field, electronic whiteboards

1 Introduction

The visual information-seeking mantra "*Overview first, zoom and filter, then details on demand*" proposed by Shneiderman (1996) has become a widely used guideline for designing information visualizations (Hornbæk and Hertzum, 2011). While much research has focused on designing interfaces that cater to a smooth progression through the steps in the mantra – from an initial overview to selected details (Ahlberg and Shneiderman, 1994; Card et al., 1999; Plaisant et al., 1996, Williamson and Shneiderman, 1992), we focus solely on the second step of the mantra, specifically on how to visualize the application of filters.

Normally, the application of a filter is visualized by showing only the information that passes through the filter. This approach appears natural in many contexts but may be unsuited to situations in which the filtered-away information provides a background important to the interpretation of the focal information and to situations in which multiple people simultaneously view and use a shared interface for different but related purposes. Simultaneous viewing and use of a shared interface is, for example, common in emergency departments (EDs)

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where whiteboards provide information pertinent to the clinicians' coordination of their activities (Aronsky et al., 2008; Bisantz et al., 2010, Bjørn and Hertzum, 2011). While ED clinicians' activities are fast-paced, parallel, and interrelated, their electronic whiteboards provide for only a single primary user at a time. Additional clinicians may, however, view the whiteboard and use its information for purposes other than that of the primary user. This way, the whiteboard is central to ED clinicians' work because it supports them in a collaborative work practice of concurrently retrieving and updating information about the patients and the general state of the ED. This includes information regarding, amongst others, the patients' condition, how far they are in the treatment process, the occupancy level of the ED, and departmental resource allocation.

This study concerns information filtering on electronic ED whiteboards. Whereas much information-visualization research focuses on large information spaces (Card et al., 1999; Isenberg et al., 2011), the whiteboard is a moderately sized information space and the *overview first* step of the visual information-seeking mantra is therefore relatively easy to accomplish. However, the rapidly changing nature of the information makes the *zoom and filter* step important because the clinicians need to interact with the information at the same pace as changes occur and need to focus on specific parts of the information whilst still being aware of the contextual information surrounding their current focus. Though the clinicians' interactions with the whiteboards are mainly brief they are also numerous and should preferably not prevent other clinicians from reading the whiteboard information they need for their activities. To avoid that the application of a filter makes the filtered-away information unavailable to other clinicians and as contextual information for the current user we investigate the visualization of filters by other means than removing information. Specifically, we investigate how the application of filters can be visualized using colour-coding, which emphasizes the focal information and leaves filtered-away information unchanged, and semantic depth of field (SDOF) (Kosara et al., 2001), which deemphasizes filtered-away information by blurring it.

In short, the purpose of this study is twofold:

- To compare ED clinicians' performance on whiteboard tasks when filters are visualized by blocking (the normal approach), colour-coding, and SDOF.
- To investigate whether blocking, colour-coding, and SDOF are differentially affected by whether the clinicians work individually while solving whiteboard tasks or a pair of clinicians share the whiteboard.

The empirical basis for this study is an experiment in which actual ED clinicians solve realistic tasks on a whiteboard similar to the one they use in their real work, except for the variation in how the application of filters is visualized. Figure 1 shows the whiteboard in actual use at an ED and in one of our experimental sessions.

Figure 1. The electronic whiteboard in use at an ED (left) and in one of our experimental sessions involving shared whiteboard use (right)

2 Related work

In their review of visualization techniques, Cockburn et al. (2008) distinguish between techniques that use a spatial separation between focal and contextual information, a temporal separation, a seamless separation, and cue-based techniques. The way filters are conventionally visualized they are a temporal-separation technique, while colour-coding and SDOF are cue-based techniques.

2.1 Filtering as a temporal-separation technique

In elaborating the *zoom and filter* step of the visual information-seeking mantra Shneiderman (1996) explains filtering like this: "By allowing users to control the contents of the display, users can quickly focus on their interests by eliminating unwanted items." That is, the application of a filter introduces a temporal separation between the contextual information, which is blocked by the filter and thereby ceases to be visible, and the focal information, which passes through the filter and remains visible. The removal of the contextual information creates additional space for displaying the focal information and, thereby, possibilities for displaying it at a finer level of detail or with less need for scrolling. Animation is frequently used to help users assimilate the transition from before to after the application of the filter and has been found not to increase the time to complete tasks (Bederson and Boltman, 1999). An influential interface control for the application of filters is dynamic queries (Ahlberg and Shneiderman, 1994), which couple users' adjustments of sliders and buttons to rapid and dynamic display updates. The tight coupling between slider adjustments and display updates is another way of helping the user assimilate the transition associated with the application of filters. Prominent examples of dynamic queries include Homefinder (Williamson and Shneiderman, 1992), Filmfinder (Ahlberg and Shneiderman, 1994), and Lifelines (Plaisant et al., 1996).

Several previous studies have investigated the possible costs of the temporal separation between contextual and focal information, with mixed results. Nekrasovski et al. (2006) find that users solve tasks faster with a pan-and-zoom interface, which temporally separates focal from contextual information, than with a focus+context interface, in which contextual information remains visible when focal information is shown. The pan-and-zoom interface also required less mental effort. Similarly, Kobsa (2001) finds shorter task completion times and higher task solution rates for two temporal-separation interfaces than for a focus+context interface. Contrary to these studies, Baudisch et al. (2002) find that users solve tasks more quickly with a focus+context interface than a pan-and-zoom interface. Finally, Hornbæk et al. (2002) compare two pan-and-zoom interfaces: one with an overview of the entire information space, the other without an overview. Users perform similarly with the two interfaces but overwhelmingly prefer the interface with the overview. It appears likely that the experimental tasks may partly explain these mixed results by creating situations in which an understanding of the focal information is differentially dependent on contextual information.

2.2 Colour-coding and SDOF as cue-based techniques

The application of a filter can also be visualized by altering how objects are rendered, that is by adding specific visual cues to them. Such cue-based techniques are most efficient when the cues applied are perceived pre-attentively. Humans perceive and process certain basic features of what is seen pre-attentively and in parallel, including such features as orientation, colour, motion, and stereoscopic depth (Treisman et al., 2010; Wolfe, 2005). Pre-attentive cues can be used to guide a user's attention to parts of a display, thereby highlighting these parts of the display and influencing how the user perceives the display (Treisman et al., 2010; Wolfe, 2005). Importantly, the highlighted parts of the display are shown in context in that the rest of the display remains visible. This may help users stay oriented but also restricts cue-based techniques by neither freeing screen space for displaying the cues, nor reducing any need for scrolling. Previous research shows that pre-attentive cues can successfully enhance visualization techniques (Deller et al., 2007; Healey et al., 1996;) and that they are especially useful for rapid detection of targets and regions (Healey et al., 1996).

Colour is well-established as a pre-attentive cue that makes things pop out (Bertin, 1983; Spence, 2007). This pop-out effect facilitates visual search (Wolfe, 1994; Deller et al., 2007) and is the basis for using colour-coding of the focal information as a way of visualizing the application of filters. A related use of colour-coding is for highlighting the appearance of search terms in texts. Deller et al. (2007) point out that in information rich displays colour intensity is important to the use of colour as a pre-attentive cue because intensity can be used to indicate the degree of relevance to the user's search. However, Deller et al. (2007) also mention that the use of colour as a pre-attentive cue may distort the visual appearance of displayed objects or create confusion between the applied colour and coloured display objects.

Drawing on the concept of Depth of Field from cinematography and photography Kosara et al. (2001) have created a visualization technique in which the sharpness of an object indicates its relevance rather than its distance. By blurring irrelevant information this SDOF technique pre-attentively draws the user's attention to the parts of the information space that are still in focus. The degree of blurring is determined by a Degree of Interest (DOI) function, which quantifies how relevant the information is to the user. However, Kosara et al. (2002b) find that users have difficulties distinguishing between multiple levels of blurriness. This suggests the use of a binary DOI function where information is either relevant and in focus or irrelevant and therefore blurred.

Giller et al. (2001) and Schrammel et al. (2003) incorporated SDOF in a text editor and evaluated how searching for information in a text document with SDOF compared to searching with colour-coding of search terms and to searching without any highlighting of search terms. Searching with SDOF and colour-coding was equally efficient. In a second evaluation Giller et al. (2001) compared SDOF with orientation as methods for users to explore and interpret scatterplot data. SDOF resulted in faster performance and more accurate task solutions than using the orientation method. Finally, it appears that SDOF can be combined with other pre-attentive cues without increased cognitive demands on the user (Giller et al., 2001).

2.3 Shared workspaces and information visualization

In a study of the dynamic nature of cooperative work at a hospital surgery ward Bardram (1998) finds that work at hospital wards can be divided into three levels: co-ordination, co-operation, and co-construction. At the co-ordination level the staff members on a ward work with their individual assignments in the pursuit of fulfilling the purpose of the ward, for example nurses perform nursing tasks and physicians perform physician tasks in the interest of caring for patients. At the co-operation level staff members work together on a specific assignment to fulfil the ward's purpose, for example nurses and physicians work together on a shared task. At the co-construction level staff members reconstruct their working practices in a collaborative manner, for example by discussing the rationales behind certain practices and adapting them to new situations. In their study of whiteboard use in EDs Bjørn and Hertzum (2011) find that the work practices at such departments are characterized by interdependent work tasks carried out individually by members of heterogeneous staff groups, resembling the co-ordination level found by Bardram (1998).

The co-ordination level of hospital work corresponds to the collaborative style labelled *independent* by Bederson et al. (1999) in their study of single display groupware. It is noteworthy that working independently was the style employed most frequently by the pairs of users in the study by Bedersen et al. (1999) and that this was the case in the condition with one input device as well as in the condition with two input devices. In spite of the frequency with which single display groupware is used by multiple users who work independently, most research has focused on users who work together on a shared task (Isenberg et al., 2011; Mark et al., 2002, 2003). Isenberg et al. (2011) emphasize a shared task to the extent of excluding multiple people working independently from their definition of collaborative visualization.

Only a few studies mention scenarios where users work in parallel with multi-user visualizations. Tobiasz et al. (2009) describe a visualization that allows multiple users to work both independently and jointly while completing data analysis tasks. The users can create individual workspaces and view information in different views according to their individual preferences. The users can also share views and collaborate directly on tasks or they can simply view the other users' workspaces for inspiration. The support for independent work includes that the system allows the users to tailor their individual workspaces independently of other users. Mark et al. (2003) find that users working alone solve tasks faster than users working in pairs. Possible reasons for this finding are, however, not analysed; the analysis instead focuses on differences among the conditions involving pairs of users. Finally, Spotlight (Khan et al., 2005) is a technique for directing collaborating users' attention to a common focal region on a large shared display. Spotlight is distinctly about supporting users who work together, as opposed to independently, but is relevant here because the technique conceptually resembles SDOF by displaying a region of the display normally while the rest of the display is somewhat darkened. Users locate a focal region much faster with Spotlight than when the focal region is indicated by the position of the cursor (Khan et al., 2005).

3 System description

The emergency-department electronic whiteboard (EW) investigated in this study is visually laid out in a matrix-like structure with rows and columns. Each row represents a patient, with columns containing information about, among other things, the patient's name, age, diagnosis, triage level, attending physician, attending nurse, and time of arrival (see Figure 2). The EW is accessed on a wall-mounted 52" touchscreen. In the experiment all interactions with the whiteboard were through the touch interface.

The whiteboard has two rows of filters. The top row (Figure 3) contains a button for each physician and nurse currently on duty. When a button is tapped the patients shown on the whiteboard are filtered so that only those attended by the specified physician or nurse are displayed. These buttons are used by clinicians to get an overview of their current patients and by the coordinating physician and nurse in assessing and balancing the workload of the clinicians on duty. The lower row (Figure 4) contains four additional filter buttons. Tapping one of these buttons filters the patients on the whiteboard to all patients, those reported but not yet arrived, those arrived and thus in the emergency department, and those in the waiting room. The coordinating physician and nurse mainly use these buttons when prioritizing patients, assessing the load of the department, and preparing for the arrival of new patients.

Figure 2. The emergency-department whiteboard (the names of clinicians and patients in this and the following figures are fictitious).

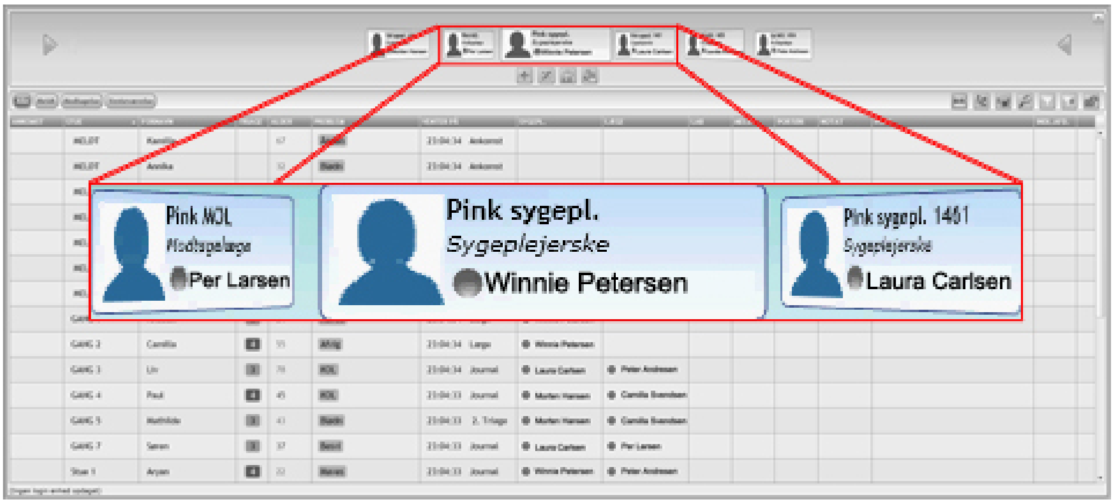

Figure 3. An enlarged image of the filter buttons in the top row.

The only difference between the three versions of the whiteboard we use in our experiment is the way the application of a filter is visualized. A filter is visualized in one of three ways:

The *Blocking* interface (Figure 5 top) filters information using the conventional approach of completely removing filtered-away information and leaving focal information unchanged. Because less information is displayed this interface reduces the number of situations in which the list of patients needs a scrollbar.

The *Colour-coding* interface (Figure 5 middle) filters information by darkening the background of focal information, thereby highlighting the focal information. Filtered-away information is not removed but simply left unchanged. Thus, multiple users can read information on the whiteboard even when a filter is applied.

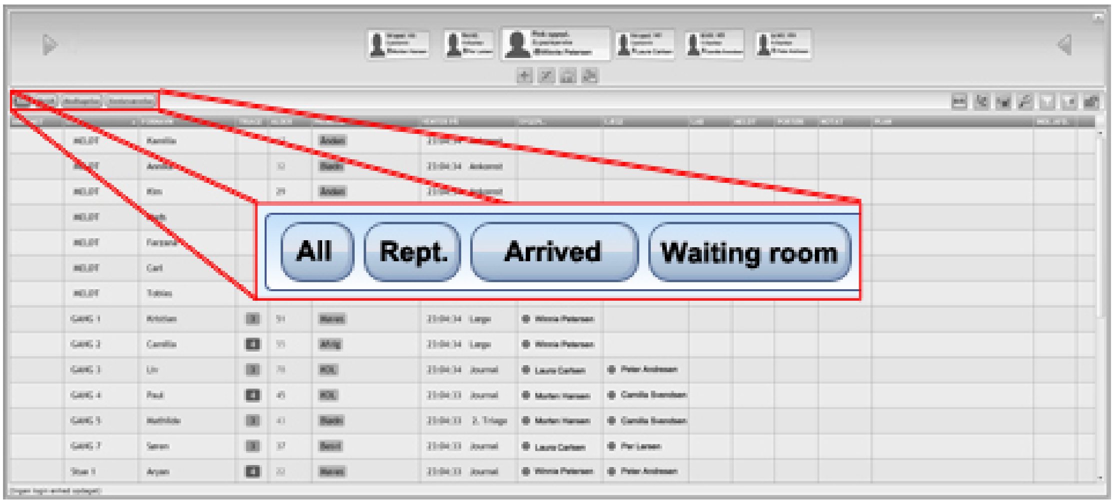

Figure 4. An enlarged image of the second row of filter buttons.

Figure 5. Cutouts from screenshots of the blocking interface (top), colour-coding interface (middle), and SDOF interface (bottom). Each cutout shows the same information filtered according to the nurse named Winnie Petersen.

The *SDOF* interface (Figure 5 bottom) filters information by blurring filtered-away information and leaving focal information unchanged. Like the colour-coding interface this highlights the focal information, while the filtered-away information remains available. The blurring is sufficiently modest that the filtered-away information is still distinguishable for other users viewing the whiteboard. While blurring the filtered-away information might seem counterintuitive in situations where it is still relevant for users viewing the whiteboard but not directly interacting with it (e.g., clinicians retrieving information simply by viewing), previous research has shown that clinicians habitually acquire useful information from the structure of presented information rather than from its content (Nygren et al., 1998). Therefore, we find it likely that the blurred information of the SDOF interface will provide useful information for clinicians viewing the electronic whiteboard "over the shoulder" of a colleague who interacts with it. In addition, information such as the colours that indicate a patient's triage level are easily distinguishable also when blurred.

4 Method

We conducted an experiment to compare the three interfaces on tasks mimicking the normal work practices involving the EW at the ED. Approval for the experiment was obtained from the healthcare region and the management of the ED. The ED was partly compensated for taking part in the experiment by an amount equivalent to 16 staff hours to be able to call in replacement staff. This equalled approximately half of the time the participants dedicated to the experiment.

4.1 Participants

A total of 18 clinicians (13 female, 5 male) participated in the experiment. The participants comprised nine physicians and nine nurses with an average ED seniority of 4.1 years (*SD* = 5.5). Participants were an average of 38.8 years of age (*SD* = 7.2) and rated their frequency of use of the EW at an average of 7.5 (*SD* = 5.5) on a scale of 0 (often) to 100 (never). Thus, all participants were regular users of the EW, which had been in use at the ED for approximately 19 months prior to the experiment being conducted. The selection criterion for both profession groups was that they had to have experience as coordinating physician or coordinating nurse. The coordinating clinicians use the EW throughout their shifts and therefore constitute a user group that is highly affected by the ED whiteboard. In the final selection of participants we had to include two physicians without experience as coordinators. However, these two physicians were frequent users of the EW and therefore considered to be acceptable as participants in the experiment. Participation in the experiment was voluntary. The participants took part in the experiment during their working hours and were not compensated individually.

4.2 Sessions

The experiment involved two types of sessions. In the *individual sessions* a single participant used the whiteboard and could focus exclusively on her or his own task performance. In the *shared sessions* a pair of participants shared use of the whiteboard and had to negotiate how to take turns in accessing it. Each pair consisted of a physician and a nurse. In the individual as well as the shared sessions each participant strictly solved his or her own set of tasks. That is, in the shared sessions the pair of participants were not collaborating but working in parallel on tasks that involved access to a common resource, the whiteboard.

4.3 Tasks and datasets

The experiment involved six tasks, which were repeated for each interface. Based on knowledge collected via interviews with and observation of coordinating physicians and nurses the six tasks were designed to mimic tasks that the participants regularly encountered in their everyday work. Therefore, separate sets of tasks were made for the physicians and the nurses.

For both physicians and nurses there were two types of tasks. The first type concerned the extent to which the three interfaces supported the participants in creating and maintaining an overview of the clinical situation at the ED in terms of arriving patients, waiting patients, and patients undergoing care. There were three tasks of this type. For example, one of the tasks for the nurses read:

> *"Due to one of your nurses wishing to leave early you need to assess the department's collective workload and the future situation. Compare the number of patients admitted to the department against the number of reported patients and decide whether or not you will allow the nurse to leave."*

The physicians' tasks differed from the nurses' tasks in concrete content but were similar in the way they were phrased and the type of situation that they described. For the example above the corresponding physician task read:

> *"Since one of your physicians has called in sick, you wish to assess the present situation and compare this to the immediate future situation in order to determine if it is critical to call in a substitute. Compare the number of patients admitted to the department against the number of reported patients and determine whether or not a substitute needs to be called in."*

The second type of task concerned the extent to which the interfaces supported the participants' overview of their colleagues' workload. These tasks consisted of distributing workload evenly across all clinicians. The clinicians' workload could be gauged on the basis of their patients' triage level, diagnoses, age, estimated time of discharge, and other whiteboard information. There were three tasks of this type. For example, one of the tasks for the physicians read:

> *"A new patient has arrived at the department. The patient has been triaged and is now waiting to have a physician assigned. Find the physician you estimate to have the necessary competencies and lowest workload and assign the patient to him or her."*

Six fictive datasets were constructed for the experiment – one for each of the three interfaces in each of the two sessions. The different datasets used for each interface meant that the content of the tasks differed across interfaces though the tasks were the same for all interfaces. This resembles real use, during which clinicians regularly use the ED whiteboard for identical purposes but in situations defined by different patients and ED staffing.

Like the tasks, the datasets were constructed on the basis of interviews with clinicians and observation of ED work. The datasets represented situations of high intensity and workload. We chose such situations to evaluate the interfaces under conditions where the participants need good interfaces to maintain an overview, and we acknowledge that the datasets were not representative of average ED conditions. Also, being fictive the datasets did not include all details regarding the patients. Participants were asked to disregard such omissions. Prior to the experiment, the managing head nurse from the ED reviewed the tasks to ensure their realism and practical relevance.

4.4 Experimental design

The experiment employed a mixed design with interface (Blocking, Colour-coding, SDOF) and session (individual, shared) as within-group factors and profession group (physician, nurse) as a between-group factor. Each participant took part in an individual session and a shared session. Eight participants had the individual session first and the shared session on a later day; the other ten participants had the shared session first and the individual session later. The interval between the two sessions was on average 7.5 weeks. In each session a participant solved the six tasks with each of the three interfaces. To counter order effects, the order of the three interfaces was varied across participants by means of a Latin square.

The six tasks for an interface were solved on the same dataset. The datasets were randomly assigned to interfaces by first assigning three of the six datasets to the interfaces in a pair of participants' shared session and then the remaining three datasets to the interfaces in the two participants' individual sessions. The order of the six tasks for an interface was fixed to establish a flow in the tasks and to ensure that the participants would not be completing similar tasks in close succession.

4.5 Procedure

The sessions were carried out in a quiet room at the ED where the participants worked. In this room the three EW interfaces were available on a 52-inch touch-sensitive display similar to the displays the participants use in their everyday work – see Figure 1**Error! Reference source not found.**. When participants arrived for a session they were greeted and allowed to relax before the session proceeded.

Upon initiating the session the participants were handed and asked to read an introductory text explaining the purpose of the experiment and their role in it. Participants gave their informed consent by signing at the bottom of the introductory text. Then, participants were invited to try out the interfaces to become familiar with them. After familiarizing with all three interfaces, the participants were handed and asked to read the definition of the subscales of the NASA task load index (TLX) (Hart and Staveland, 1988) used for measuring mental workload in the experiment.

When ready the participants were handed the first task and asked to solve it as completely and precisely as possible. In the shared sessions, the physician and the nurse received different tasks and solved them in parallel, negotiating access to the interface as they went along. After having solved a task the participants were asked to rate their mental workload, their overview of the information contained in the interface, the ease of use of the interface, and the completeness and precision of their task solution. Then, the next task was handed to the participants. In the shared sessions this did not happen until both participants had completed the previous task, ensuring that both participants started on the new task simultaneously. Upon completing the sixth task for an interface the participants were allowed a short break while the experimenter changed the interface and dataset.

After having completed the six tasks with all three interfaces the participants were asked to rank order the interfaces according to which they preferred to work with and provide their reasons for this ranking. The sessions lasted an average of 42 (individual) and 58 (shared) minutes.

4.6 Measurements

Participants' performance and perception of working with the interfaces were measured for each task. The measurements comprised:

The completeness and precision of task solutions were rated by participants on a continuous scale from agree (0) to disagree (100) in response to statements that the task solution was complete, respectively precise. We chose the participants' perception of solution completeness and precision as indicators of the quality of task solutions because the tasks did not have formally correct solutions against which to measure the participants' task solutions.

Task completion times were logged by the experimenter on a digital stopwatch. A task extended from when the participant had read and understood the task until the participant announced that the task had been completed.

Mental workload was measured using TLX (Hart and Staveland, 1988), which consists of the subscales mental demand, physical demand, temporal demand, effort, performance, and frustration. Participants rated each subscale on a continuous scale from low (0) to high (100), except performance for which the endpoints were good (0) and bad (100).

Overview was rated on a continuous scale from agree (0) to disagree (100) in response to statements that the participant had an overview of the admitted patients, the reported patients, and the staff on duty. We chose these three aspects of overview on the background of observations of and interviews with coordinating clinicians.

Ease of use was rated on a continuous scale from agree (0) to disagree (100) in response to a statement that the task was easy to solve.

Finally, we video and audio recorded the sessions to capture the participants' utterances and how they negotiated access to the interfaces in the shared sessions. A screen recorder captured the participants' interaction with the interfaces. The video and audio recordings were analysed for any matters of interest for our quantitative results.

5 Results

The data were analysed for physicians and nurses, using analysis of variance (ANOVA) with interface (Blocking, Colour-coding, SDOF), session (individual, shared), and profession group (physician, nurse) as independent variables. Before the analyses we removed 24 (4%) outlier tasks, which were more than 1.5 inter-quartile ranges above the upper quartile in task completion time, mainly because the participants commented extensively on how they solved the tasks or on the usefulness of the interfaces for ED work. For an additional 6 (1%) tasks the only available data were the task completion times.

5.1 Task solutions

The physicians and nurses rated the completeness and precision of task solutions highly for all three interfaces – see Table 1. For the physicians we found no effect of interface on the completeness and precision of task solutions and no interaction between interface and session for the completeness and precision of task solutions, $Fs(2, 7) = 0.48, 0.25, 0.85, 1.21$, respectively (all $ps > 0.3$). Also, there was no effect of session on the completeness and precision of physicians' task solutions, $Fs(1, 8) = 0.002, 0.14$, respectively (both $ps > 0.7$).

For the nurses we, similarly, found no effect of interface on the completeness and precision of task solutions and no interaction between interface and session for the completeness and precision of task solutions, $Fs(2, 7) = 1.46, 1.58, 0.71, 0.06$, respectively (all $ps > 0.2$). There was no effect of session on the completeness and precision of nurses' task solutions, $Fs(1, 8) = 0.31, 1.31$, respectively (both $ps > 0.2$).

In addition, there were no differences between physicians and nurses in the completeness and precision of task solutions, $Fs(1, 16) = 0.51, 0.92$, respectively (both $ps > 0.3$), and no interactions between profession group and any of interface, session, and both.

On this basis we contend that the tasks were solved equally well with the three interfaces, in the two types of session, and by the two profession groups.

Table 1. Task solutions, $N = 618$ tasks

	SDOF		Colour		Blocking	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Physicians						
Completeness of solution	14	9	14	15	13	10
Precision of solution	13	8	13	13	12	11
Nurses						
Completeness of solution	20	13	16	11	15	9
Precision of solution	21	14	17	13	14	9

Note: The completeness and precision of solutions were rated on a scale from 0 to 100 with lower numbers indicating more complete/precise solutions

5.2 Task completion time

Table 2 shows the task completion times. For the physicians there was a significant effect of interface, $F(2, 7) = 8.83$, $p < 0.01$, with Bonferroni-adjusted pair-wise comparisons indicating that Blocking was faster than SDOF ($p < 0.05$) and approached a significant improvement over Colour ($p = 0.06$). Unsurprisingly, there was also a significant effect of session, $F(1, 8) = 9.32$, $p < 0.05$, with lower task completion times for physicians' individual than shared sessions. We found no interaction between interface and session, $F(2, 7) = 1.51$, $p = 0.3$.

For the nurses there was a significant effect of interface, $F(2, 7) = 15.30$, $p < 0.001$, with Bonferroni-adjusted pair-wise comparisons indicating that Blocking was faster than SDOF ($p < 0.001$) and Colour ($p < 0.05$). Unsurprisingly, we also found a significant effect of session, $F(1, 8) = 5.76$, $p < 0.05$, with lower task completion times for individual than shared sessions. There was no interaction between interface and session, $F(2, 7) = 1.77$, $p = 0.2$.

We found no difference between physicians and nurses in task completion time, $F(1, 16) = 0.59$, $p = 0.5$, and no interaction between profession group, interface, and session, $F(2, 16) = 2.65$, $p = 0.09$.

In an interest to uncover the degree to which the participants utilized the possibility of working in parallel during the shared sessions we calculated, for each participant pair and each task, the longer of the two participants' task solution times from their shared session and divided it by the sum of their task solution times for the same task in their individual sessions. Analysis of these ratios showed no significant difference between the three interfaces, $F(2, 7) = 0.75$, $p = 0.9$. However, we found that the mean ratios exceeded 100% for all three interfaces. That is, the time spent by the physician and nurse on solving one task each in their shared session exceeded the sum of the times they spent solving a task each in their individual sessions. Thus, despite the possibility of working in parallel during the shared sessions these sessions were slower than solving the tasks completely sequentially, as in one individual task followed by the other individual task.

To uncover what might cause this increase in task completion times we turned to the videos. The videos showed that participants took turns at the EW to a much larger extent than we anticipated beforehand. We registered only 15 incidents of simultaneous use of the EW by both participants. The video analysis also showed more social interaction during the shared sessions in terms of talk amongst the participants regarding their tasks and insights about how to use or improve the EW. These interactions occurred throughout the shared sessions and also while the participants solved the tasks. Table 3 shows an example with a high degree of interaction among the participants during a shared session.

Table 2. Task completion time (in seconds), $N = 624$ tasks

	SDOF		Colour		Blocking	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Physicians						
Individual	35.6	4.9	40.0	12.5	28.3	11.2
Shared	59.3	20.2	50.3	20.1	47.1	13.7
Nurses						
Individual	38.5	14.0	35.7	11.3	25.5	10.2
Shared	53.5	14.6	57.5	18.8	34.2	11.3

Table 3. Example transcript of a video recording from a shared use session

Utterances:	**Actions:**
	00:06:21 Start of task - Physician starts out using the EW system.
00:06:44 - 00:06:53 **Experimenter:** Remember to use the filter buttons if you feel they could help [solve the task] **Physician:** Yes. But there…	
	00:06:54 Physician continues using the EW to

solve task

00:07:15 - 00:07:28 **Nurse:** Can I ask a question? Because it actually says something there - "Waiting for". It's not all there. Does it mean that the patient journal is finished or what does it say - "Patient journal is"? **Experimenter:** It says: "Patient journal is ordered". It should have said "Waiting for patient journal" but [that option was not available]. **Nurse:** Oh okay.

00:07:29 Physician continues using the EW to solve the task

00:07:41 - 00:08:25 **Experimenter:** Remember [Nurse] if you feel you can solve your task be simply viewing [the EW] then you are welcome to do so. **Nurse:** I'll just cut in here. **Physician:** Go right ahead. **Nurse:** And that was the one reported as a [triage level] two. But is that then one [of the patients] in the hallway? I am not quite sure… What did you do there? **Physician:** I don't know. I am not used to (using the touch screen). I am used to using the mouse. **Nurse:** I want to use the mouse. **Experimenter:** I can use the mouse. You are not allowed. But you are right [Nurse] – it is that patient. **Nurse:** It was her? Oh okay…

00:07:53 Nurse approaches the EW and starts using the system. Nurse takes over from the physician

00:08:08 Physician fiddles with the EW system's scrollbar causing a generic pop-up box to appear

00:08:14 Experimenter closes pop-up using mouse and keyboard

00:08:20 Nurse leaves the EW system

00:08:21 Physician continues using the EW system to solve task

00:08:35 Physician leaves EW system

00:08:35 – 00:11:12 **Physician:** So… I'll say that I would… **Nurse:** Offhand you need more information than what is currently on the EW [to solve the task]. **Physician:** Yes. **Nurse:** It requires that you've spoken with other [staff members] and received some feedback. So it is not only the EW that dictates the solution. **Physician:** I would also like to provide a partial answer. **Experimenter:** Okay. There are these… **Physician:** But our tasks are not related?

00:08:39 Nurse uses the EW system

00:08:43 Nurse leaves EW system

Experimenter: No not at all. And there are these [TLX and usability forms]… So if you feel that the tasks have not been solved completely – and that also includes missing external information – you can mark that in these. **Physician:** Oh okay. But if this were a [live situation] then the screen would look different. I would know how long they had been working and I would know when to expect that they were ready and when I could use their resources. I can't see that from this because it doesn't really say anything. I can't see how long they've been

00:10:46 Physician approaches the EW and starts scrolling the list of patients

working so I can't see when they'll be finished. That makes it difficult for me to solve the task. **Experimenter:** Okay. Sorry to interrupt but have you finished your tasks? Yours is I guess? **Nurse:** Well offhand yes but I am not sure it is the correct answer. Because someone with chest pains could be very very sick so the nurse can't leave. It could also be someone not that ill for example. And you would know that in real life. **Physician:** I would say that if I knew… There are a lot of patients admitted and quite a few reported as well but if all [staff members] currently working are finishing off they could take the next group [of patients] and then it would probably be all right. Some of them are critically ill and there are two yellow down here. So under all circumstances I would enquire an update on how far they are. I should of course check to see if all the physicians available are occupied. I would know that if I had out them to work myself.	
	00:11:12 Physician resumes task solving. General/small talk during task solving
	00:12:05 Experimenter approaches EW and helps solve technical problem
	00:12:23 Physician continues using the EW to solve task
00:13:53 – 00:14:08 **Physician:** So I would say… **Experimenter:** You don't have to write down the answer… **Physician:** Yes. **Experimenter:** If you feel you have the answer then please let me know, so I can stop the timer? **Physician:** Yes. **Experimenter:** Good. Then you get this [TLX and usability form] to fill out.	00:13:52 Physician leaves EW system
	00:14:09 Task stopped

Table 4. Mental workload as measured by TLX, N = 618 tasks

	SDOF		Colour		Blocking	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Physicians						
Mental demand	25	19	22	17	21	15
Physical demand	21	19	16	9	14	7
Temporal demand	26	18	23	15	22	16
Effort	25	19	22	15	19	14
Performance	19	15	19	16	17	15
Frustration	29	23	22	18	17	15
Nurses						
Mental demand	20	11	18	12	16	10
Physical demand	16	12	16	12	12	8

Temporal demand	26	13	22	12	17	9
Effort	20	11	19	12	15	9
Performance	18	16	19	14	15	10
Frustration	23	14	19	12	13	8

Note: The TLX subscales were rated on a scale from 0 to 100 with lower numbers indicating less demand/less effort/better performance/less frustration

5.3 Mental workload

Mental workload was generally modest – see Table 4. A multivariate analysis of the mental workload of physicians and nurses showed a significant effect of interface, Wilks' $\lambda = 0.41$, $F(12, 54) = 2.49$, $p < 0.05$, with Bonferroni-adjusted pair-wise comparisons indicating that overall mental workload was lower with Colour than SDOF. Bonferroni-adjusted pair-wise comparisons of the individual TLX subscales showed that temporal demand was lower with Blocking than SDOF ($p < 0.05$), that effort was lower with Blocking than SDOF and Colour (both *p*s < 0.05), and that frustration was lower with Blocking than SDOF and Colour (both *p*s < 0.01).

There was no effect of session on overall mental workload, Wilks' $\lambda = 0.52$, $F(6, 11) = 1.69$, $p = 0.2$, no interaction between interface and session, Wilks' $\lambda = 0.58$, $F(12, 54) = 1.40$, $p = 0.2$, and no effect of profession group on overall mental workload, Wilks' $\lambda = 0.77$, $F(6, 11) = 0.54$, $p = 0.8$.

5.4 Overview

The clinicians rated their overview of admitted patients, reported patients, and staff on duty as medium – see Table 5. For physicians and nurses combined there were significant effects of interface on the clinicians' overview of admitted patients, reported patients, and staff on duty, *F*s(2, 16) = 8.49, 5.59, 6.38, respectively (all *p*s < 0.01). Bonferroni-adjusted pair-wise comparisons indicated that the overview of admitted patients and staff on duty was better with Colour than with SDOF and Blocking (all *p*s < 0.05) and that the overview of reported patients was better with Colour than SDOF (p < 0.05).

Table 5. Overview, $N = 618$ tasks

	SDOF		Colour		Blocking	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Physicians						
Overview of admitted patients	51	30	40	30	39	25
Overview of reported patients	52	30	42	27	43	26
Overview of staff on duty	48	30	42	31	39	25
Nurses						
Overview of admitted patients	73	20	43	31	60	27
Overview of reported patients	67	19	43	29	56	25
Overview of staff on duty	69	24	41	32	55	27

Note: The overview dimensions were rated on a scale from 0 to 100 with lower numbers indicating better overview

We found no effect of session on the clinicians' overview of admitted patient, reported patients, and staff on duty (all ps > 0.1) and no interaction between interface and session for any of the three overview variables (all ps > 0.6).

For the physicians the effect of interface on the overview of admitted patients approached significance ($p = 0.07$), whereas there was no effect of interface on the physicians' overview of reported patients and staff on duty (both ps > 0.1). For the nurses there were significant effects of interface on overview of admitted patients and staff on duty (both ps < 0.05), whereas the effect on the nurses' overview of reported patients approached significance ($p = 0.08$). Thus, the effects of interface on overview for the physicians and nurses combined were driven by the nurses to a larger extent than by the physicians. We found no interactions between interface and profession group for any of overview of admitted patients, reported patients, and staff on duty (all ps > 0.09).

5.5 Ease of use

The clinicians rated the three interfaces easy to use – see Table 6. For the physicians there was, however, a significant effect of interface on ease of use, $F(2, 7) = 4.46$, $p < 0.05$, with Bonferroni-adjusted pair-wise comparisons suggesting a non-significant trend toward Blocking being easier to use than SDOF ($p = 0.1$). We found no effect of session on ease of use for the physicians, $F(1, 8) = 0.94$, $p = 0.4$, and no interaction between interface and session, $F(2, 7) = 0.18$, $p = 0.8$.

For the nurses there was no effect of interface on ease of use, $F(2, 7) = 1.64$, $p = 0.2$, no effect of session on ease of use, $F(1, 8) = 1.27$, $p = 0.3$, and no interaction between interface and session, $F(2, 7) = 0.65$, $p = 0.5$.

Table 6. Ease of use, $N = 618$ tasks

	SDOF		Colour		Blocking	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Physicians	23	18	20	17	16	13
Nurses	22	15	18	12	16	11

Note: Ease of use was rated on a scale from 0 to 100 with lower numbers indicating more ease

5.6 Interface ranking

For the individual sessions, the participants significantly preferred the Blocking interface, $\chi^2(2, N = 17) = 12.82$, $p < 0.01$. As much as 6 physicians and 6 nurses preferred the Blocking interface, 2 physicians and 3 nurses preferred the Colour interface, and no participant preferred the SDOF interface; 1 physician gave no preference.

For the shared sessions, there was no preference for one interface over another, $\chi^2(2, N = 16) = 4.63$, $p = 0.1$. A total of 5 physicians and 4 nurses preferred the Blocking interface, 3 physicians and 2 nurses preferred the Colour interface, and 1 physician and 1 nurse preferred the SDOF interface; 2 nurses did not report a preference.

5.7 Comments from participants

The participants gave several reasons for their preference ranking. In general, the participants favoured the Blocking interface because they were used to working with this interface. However, they also expressed that the Blocking interface was good for isolating information when that was desired:

> *"I much better like the one we have now [blocking].... Because it removes something then I don't have a totally confusing screen where I have to scroll up and down. If I only want to see the "Reported patients" then it is nice that I can do that."*

The participants also stated that both the Colour-coding and SDOF interfaces were good for keeping an overview of the entire information space and that this overview was lost when using the Blocking interface:

> *"I especially think the [blurred] one where you don't - and also the other [colour-coded] one in principle. It's just a visual thing. But that you don't lose the overview when you filter something away. That it doesn't just go away. That you still have a sense of how many patients there are. I think that is nice."*

However, the participants also pointed out that the Colour-coding and SDOF interfaces required a lot of scrolling when the list of patients became very long and that displaying all patients on the same screen could be quite frustrating:

> *"Moreover, I think they are quite frustrating. Both the colour solution and the blurring solution because you have so many on the screen that it becomes impossible to maintain an overview."*

Some participants stated that they disliked the SDOF interface because it made them feel disorientated or try to focus on the parts of the interface that were blurred:

> *"The one where it is blurred - I found that one a little strange. You tried to focus on the parts that were blurred."*

Finally, several participants expressed that they would normally not work in parallel when more users were present at the EW. Instead, they would wait for each other to complete their tasks and then release the EW to the next user in line:

> *"**Physician**: It's hard to use the board simultaneously because the tasks are different.*
>
> ***Nurse**: Yes*
>
> ***Physician**: It would be hard to solve tasks at the same time as you, [nurse name]*
>
> ***Nurse**: But that is often the way it is [physician name], right? We stand and wait for [each other] to be finished*
>
> ***Physician**: Yeah, that's just the way it is. We stand and wait...*
>
> ***Nurse**: So that's just how our everyday life is."*

6 Discussion

There are four main findings of this study. First, participants solved tasks faster using the Blocking interface (except that for the physicians the improvement of Blocking over Colour merely approached significance). Second, participants perceived that their overview of patients and staff was better when using the Colour interface than the Blocking and SDOF interfaces. Third, among the two cue-based techniques the SDOF interface was more mentally demanding to use than the Colour interface. Fourth, participants virtually refrained from using the EW simultaneously and instead waited for each other to complete their task and release the EW to the next user. We discuss these four findings in turn.

6.1 Blocking is faster

The Blocking interface was faster than SDOF for physicians and nurses and faster than Colour for nurses. For the physicians the improvement of Blocking over Colour approached significance. While participants took longer to solve tasks during shared than individual sessions, the relative advantage of Blocking over the two other interfaces was unaffected by whether participants worked individually or in pairs. The faster performance with Blocking is corroborated by the lower temporal demand perceived by participants when using Blocking compared to SDOF and the lower perceived effort compared to both SDOF and Colour.

The most plausible reason for the faster performance of the Blocking interface is that this interface considerably reduces the amount of scrolling required to overview the information displayed because the filtered-away information is removed. For example, applying the filter for a specified nurse removes all patients not assigned to the nurse and, thereby, moves the nurse's patients to the top of the list. In this way the focal information is presented on its own and thereby becomes easier and faster to perceive and retrieve. It may contribute to this increase in ease and speed that the Blocking interface maintains the relative order of the items that comprise the focal information.

Another reason for the faster performance with Blocking may be that by removing filtered-away information the focal information is collected in one region of the interface. By collecting the focal information in one place it may be easier for the user to avoid distractions from other information compared to Colour and SDOF in which the focal information can comprise several regions interspersed by non-focal information. It appears that previous work on the possible cost of temporal separation (Baudisch et al., 2002; Hornbæk et al., 2002; Kobsa, 2001; Nekrasovski et al., 2006) has focused on zooming rather than filtering and thereby on visiting relevant regions of a display one region at a time rather than on possibly providing access to multiple relevant regions at a time. Our work suggests that the possibility of collecting scattered focal information in one place may be an advantage that should be considered in assessing temporal-separation techniques.

A related reason for the faster performance with the Blocking interface may be that it provides a tighter visual coupling between the filter buttons and the resultant action of applying one of these, thereby making it immediately clear for the users what happens as a result of applying a filter. This may reduce user confusion when having to differentiate between focal and contextual information displayed by the EW and thereby improve user performance. A final reason for the faster performance with the Blocking interface may be that participants are familiar with this interface because it is the interface of the EW they use in their daily work in the ED. Among the participants who preferred the Blocking interface several mentioned their familiarity with this interface as an explanation.

6.2 Colour-coding supports overviewing

In contrast to the performance times, participants held a better overview of the admitted patients and the staff on duty with the Colour interface than the Blocking and SDOF interfaces. The Colour interface also provided participants with a better overview of reported patients than the SDOF interface. The main reason for the improved overview with the Colour interface appears to be that this interface, and the SDOF interface, did not remove information from the EW. Several participants commented that with the Colour and SDOF interfaces they could maintain an overview even when they applied filters, whereas with the Blocking interface their overview tended to suffer when they applied filters because the non-focal information disappeared.

While the temporal integration of focal and contextual information in the Colour interface improved participants' overview, the amount of scrolling required to navigate the list of patients was not reduced because the focal information remained in its original positions in the list. In addition to frequent scrolling, this also entailed repeated visual scanning of the patient list to skip over the non-focal patients when participants were shifting their attention back and forth among the focal patients. This way, it appears that the Blocking interface optimizes an efficient, undisturbed focus on the focal information, whereas the Colour interface optimizes context awareness while solving tasks with the EW.

A possible way of combining the advantages of the Blocking and Colour interfaces could be to colour-code and resort the patients so that the focal information is relocated at the top of the list and in immediate view while still displaying the remaining information. This eliminates the need for scrolling the full patient list to locate the focal information and preserves an overview of the contextual information. The idea is somewhat akin to how split menus collect the most relevant items at the top of a menu for easy access (Sears and Shneiderman, 1994). A frequent argument against split menus is that the changing location of items slows down selection because it conflicts with users' location knowledge (Fischer and Schwan, 2008). We contend that location knowledge is largely irrelevant in a case like the EW because the content of the patient list is continually changing as new patients are added and discharged patients deleted. The fast performance of the Blocking interface supports that dynamically changing the patients' position in the list does not slow down users. Findlater and McGrenere (2004) find that a split menu in which the users individually and dynamically determined which items to put above the split (as would be the case if item resorting is used for filtering) performed well and was popular with the users. Several of our participants suggested resorting as a possible improvement of the EW interface. For example, one participant commented:

"I was thinking… For example - when you select [physician name] - it would be nice if they [patients] moved to the top so you could see them right away. Then it doesn't matter if the others are coloured or blurred. But it would be really nice if they were automatically moved to the top."

6.3 SDOF is mentally demanding

The SDOF interface imposed higher overall mental workload, as measured by TLX, than the Colour interface. This finding shows, in combination with the reduced overview when using SDOF compared to Colour and the absence of a difference in task completion times between these two interfaces, that the Colour interface was the more usable of the two cue-based techniques. Compared to previous studies, our results for SDOF are less positive. One possible explanation for this difference is that previous studies (Giller et al., 2001; Kosara et al., 2002a, 2002b; Schrammel at al., 2003) have mainly tested users' ability to locate unblurred objects quickly and accurately, whereas our study investigates users' ability to assess a situation by deriving information from multiple unblurred areas and relating it to blurred contextual information. Also, Giller et al. (2001) and Kosara et al. (2002a) made their evaluations with participants who had "very good eye sight", which may benefit SDOF compared to the older and visually more average participants in our study.

One reason for the higher mental workload associated with SDOF than Colour-coding is probably that some participants tried to read the blurred information and found this to be unpleasant and difficult. Kosara et al. (2002b) similarly find that users do not like to look directly at blurred objects and argue that if they do it is an indication that the system is badly designed. We contend that for multi-user visualizations, such as the EW, it is a feature of the design that the blurred information remains distinguishable, especially for the users not currently in charge of navigating the visualization. Thus, we are interested in ways of making the blurred information less unpleasant and easier to look at. An obvious possibility is to reduce the level of blurring. In the SDOF interface the colour indication of the triage level is easily told even when blurred and the names of attending physicians and nurses may also be recognizable because users have good knowledge of their colleagues' names and thus need few cues to be able to recognize them, but the remaining fields of information are difficult to make out when blurred (see Figure 5). However, reducing the degree of blurring increases the risk of creating confusion about whether information is blurred or not. Previous work (Giller et al., 2001; Kosara et al., 2002b) provides little guidance on the degree of blurring required to avoid such confusion. Another way of making blurred information less unpleasant and easier to read could be to darken rather than blur non-focal information, as in the Spotlight system (Khan et al., 2005).

The SDOF interface may benefit even more than the Colour-coding interface from the idea of resorting the patients when a filter is applied so that the focal information is relocated at the top of the list while the remaining patients are still displayed. The resorting would imply that all the focal information would be in one place, producing a visual effect of one unified focal region surrounded by a blurred contextual region. We speculate that with one unified focal region, rather than multiple scattered focal regions, a lower degree of blurring will suffice to tell blurred from unblurred information. Further empirical work is however required to investigate whether this speculation has merit.

6.4 Users work in turns

In the shared sessions, participants' collaboration in their use of the shared EW was restricted to deciding which participant solved her or his task first and which participant waited for the other to be done and release the EW for the other participant. We registered only 15 instances of simultaneous use of the EW across the 18 tasks solved by each participant in each of the 9 shared sessions.

An important part of the reason for the virtual absence of simultaneous use was that the physician and nurse in a pair had individual tasks, rather than a shared task, and that their tasks required looking into different parts of the information on the EW. Only one participant at a time could navigate the shared EW and make changes to its content. We had however expected that participants would be able to make some progress on their task by simply looking at the EW, also while the other participant was operating it. We had also expected that participants would negotiate access to the EW on a subtask-by-subtask basis rather than a complete task at a time. According to several participants the absence of simultaneous use is not an artefact of the study but the way in which they use the EW in their daily work at the ED.

In relation to a tabletop interface Shen et al. (2002) found that users quickly accepted the impossibility of simultaneous interactions by multiple users though they initially expected to be able to make simultaneous interactions. The absence of simultaneous use of the EW in the clinicians' daily work may reflect a similar acceptance that the EW does not support such use, thereby masking that support for simultaneous use would be useful. In addition, Shen et al. (2002) provided each user with a separate region on the tabletop to ensure unobstructed access to viewed information even when another user interacted with the interface. This way of improving the support of simultaneous use may also be considered for the EW but it comes at the cost of less screen real-state for shared information. We suspect that simultaneous use of the EW occurs with some frequency in the participants' daily work, even if only implicitly and not in the fashion we envisioned. Simultaneous use may, for example, be restricted to situations in which the secondary users need neither apply filters nor change the contents of the EW and, thus, can accomplish their full use of the EW by looking over the shoulder of a colleague. Our experimental tasks did not include such use of the EW. Our results point, instead, to the need for collaborative visualizations to support users who work independently, whether they do it temporarily or as a more fixed approach to their collaboration.

We concur with statements from other researchers (Bederson et al., 1999; Isenberg et al., 2011) that the nature of collaboration in front of shared displays is insufficiently understood. We, for example, find that the pair of participants in a shared session took longer to solve their tasks than the sum of the task completion times for their individual sessions. Thus, even though the participants organized their shared sessions in a serial manner by refraining from making simultaneous use of the EW their shared sessions involved an overhead compared to the duration of one participant's individual session followed by the other participant's individual session. This overhead must, in some way, be a product of the social situation constituted by the shared session. Our analysis shows that the participants talk together about their individual tasks and about how to use the EW. We speculate that the social situation may also prolong the shared sessions in more subtle ways, such as by increased thoroughness due to more motivation to reach good clinical decisions. Our data on the task solutions do, however, not support this speculation in that the completeness and precision ratings of the task solutions are the same for individual and shared sessions.

We find only one difference between individual and shared sessions: While participants preferred the Blocking interface in the individual sessions, they did not prefer one interface over the others in the shared sessions. This result is our only, weak, indication that the costs of removing contextual information rather than visualizing the application of a filter by adding cues to the focal information may be higher in multi-user situations, where different users may need access to different information, than in single-user situations.

7 Conclusion

The participants in our experiment completed their tasks significantly faster and with less temporal demand and effort when using the Blocking interface. A likely explanation for this is that this interface collects focal information in a single region of the EW display, thereby eliminating distractions from surrounding information as well as the need to scroll the entire list of patients. The Colour-coding interface provided the participants with the best overview of the EW information. However, because the Colour-coding interface keeps the focal information in its original position when a filter is applied the amount of scrolling needed to navigate the EW is not reduced. As suggested by some participants, a combination of colour-coding and moving the focal information to the top of the patient list may combine the advantages of the Colour-coding and Blocking interfaces.

The SDOF interface imposed higher mental workload compared to the Colour-coding interface. Also, the SDOF interface provided a reduced overview and was not significantly faster or slower compared to the Colour-coding interface. We conjecture that a unified unblurred focal region, for example created by resorting the information, may be easier to locate than multiple unblurred scattered foci amongst blurred contextual information. However, we also conclude that the SDOF interface showed less promise in this study than in previous studies.

Finally, we found that the participants almost completely refrained from working in parallel, probably due to a combination of the tasks solved in the shared sessions and participants' normal way of using the EW in their daily practice. We urge researchers to focus more on investigating the uses of visualization techniques for work situations where users may not directly collaborate with each other but instead share access to a system through a common artefact.

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