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Published in:
Proceedings from The 16th Scandinavian Conference on Health Informatics 2018 Aalborg, Denmark August 28–29, 2018

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

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Abstract

Patient handovers from prehospital to emergency departments (ED) can be complex; involving critical patient care under the influence of high stress levels and carries the potential for loss of important contextual information. An intuitive and easy access to this information, can advantageously help ensure patient safety. The aim of this study was to design a dashboard prototype that visualizes data for the clinicians in emergency departments in acute care. Through observations at an emergency department, a dashboard design was conducted and evaluated. Six clinicians from two different emergency departments and three peers with experience from healthcare, were used as evaluators of the dashboard, by a cognitive walkthrough using a case-based simulation. This study found that the evaluators perceived the visualization of the patient information at the dashboard, as easily manageable and sufficient. Visualizing important contextual patient information at a dashboard, can be rewarding to the clinicians in the ED.

Keywords:

Data visualization, Emergency Medical Services, Emergency Department, Clinical Decision-Making, Dashboard, Design.

Introduction

Prehospital information involves contextual information about the incident location, patient status, vital signs etc. [1,2]. Information can both support the clinicians at an emergency department and ensure patient safety, if properly used [1,3]. The complex and dynamic situations in patient handovers from prehospital to emergency departments put high demands for fast decision making about further procedures and treatments [1]. Decision making processes are challenged by high levels of stress. High levels of stress are a psychological factor that may impact the ability to transform information to actions [1]. Hence, decision making relies on easily accessible contextual information, which should be visualized intuitively "at a glance" [1,4,5].

Visual simplistic projecting of data facilitates information processing to be faster [1,6]. The visualization of data can be efficiently displayed by a dashboard design, the design promotes interrelations between data. Today, information about the patient can be given in writing or orally to an emergency coordinator, or directly presented in a complex information system [3].

The aim of this study was to design a dashboard prototype that simplistically visualizes and prioritizes data for clinicians in emergency departments in acute care. The design was further evaluated to consolidate the possible effects of the design.

Materials and Methods

The study consisted of two phases:

1. Designing the electronic dashboard.
2. Evaluation of the clinical dashboard

Phase 1: Designing the clinical dashboard

To investigate the needs for a simplistically design of the dashboard prototype and to form the design process insights into everyday practices were obtained by qualitative observations. Analysis of the workflow provided an intuitive understanding of possible solutions, as well as knowledge of how the clinicians currently uses prehospital information. In addition, a detailed description of the physical conditions framed the workflow.

The observation was conducted in an emergency department (ED) by two observers, over the course of one day and was conducted as an observational study with the possibility of elaborate questions to the clinicians. The observation and dialogues were used as possibilities for optimizing data placement in the dashboard design.

The dashboard design was conducted on the basis of *the good design principles* as described by Wiklund et al. [7] in comparison with the results from the field studies and outcomes from other studies [2,4–6,8,9]. Based on this, the results were 20 requirements (see table 1) which were set in the user interface and content which became the basis for the design.

The prototype was designed using interactive mockups in the prototype tool Justinmind Prototypes (Ver 8.3.1).

Phase 2: Evaluation of the electronic dashboard

The prototype was evaluated by a cognitive walkthrough, which involved descriptions of the workflow utilizing case-based simulation [7]. During the walkthrough an in-depth description of the prototype was presented, thereby

increasing the motivation and rational thinking of the evaluators [10].

The evaluation consisted of three stages:

1. Case presentation. The evaluators were asked to indicate the relevant information.
2. Dashboard was displayed. The evaluators were asked to select which data was relevant, as well as what alternatives could be desired.
3. Opinion regarding; access to data, design and whether the dashboard appeared to be easy or difficult to use.

The procedure was the same for all evaluators, and each research team member had the same role in each evaluation. The dashboard was presented in the same manner to all evaluators. Firstly, the data panels were presented, secondly navigational options and at last a header containing data which was not relevant in acute treatments of emergency patients.

Evaluators

Nine evaluators were selected, to evaluate the dashboard. Three evaluators from ED A (EDA), in which the field studies where held. Three evaluators were also selected from the Department of Health Science and Technology, Aalborg University, Aalborg, Denmark (peers), as well as three evaluators from ED B (EDB) which is located in another region. A total of nine evaluators were selected, all with a bachelor's degree within health science and at least two years of health care experience. The evaluators from the two emergency departments were expected to provide important information, concerning the how design was experienced, and whether the data displayed on the dashboard harmonized with the workflow and the information needed in emergency medicine.

Results

The trauma room had installed in it a big screen which was visible to all attending personnel. This is ideal for showing the latest data but was currently only used for showing pictures from the accident scene.

Twenty requirements to the dashboard were constructed, as illustrated in table 1. The requirements are based on the observation findings, outcomes from other studies and the principles as described by by Wiklund et al [7]. The dialogue with the clinician concluded that notes from the emergency respondent, vital signs and pictures from the accident scene was of highest importance.

The twenty requirements were utilized in the design of the dashboard design.

The dashboard consists of 3 graphical parts:

1. Data panels consisting of six panels shown in figure 1.
2. A navigational cluster in which the user can shift between interfaces.
3. A header in the upper part of the user interface which contains multiple kinds of data.

Table 1- Requirements for the electronic dashboard design

Requirements for the electronic dashboard design			
1	Must fit multiple monitor sizes.	11	Data must be shown close together on the user interface in panels.
2	Alerts for incoming critical patient's must remain visible.	12	There must be consistency in the chosen design i.e. same placement of controls with same features throughout the prototype.
3	Important data should be visible on dashboard.	13	Icons and titles must have relational meaning to each other.
4	Panels containing new data should be placed at the top of screen.	14	Navigation should be through a few buttons placed in a cluster.
5	If data exceeds screen size only vertical scrolling should be promoted.	15	The dashboard must show as much data as possible, so navigation is minimized.
6	Login periods should be prolonged.	16	Patient identification must be placed in a header that is visible at all times.
7	The critical and important data should be visible on dashboard.	17	Titles should be meaningful to the user.
8	Critical data must be emphasized.	18	Navigational buttons should be both icons and titles.
9	Continuously synchronization of data with timestamp.	19	Overview should be simplified with few panels containing data.
10	User interface must be compatible with multiple platforms.	20	The graphical user interface should be aesthetically pleasing.

Walkthrough of the data panels

The arrangement of the panels is sorted by its content and relation to each other (see figure 1, in Danish). The six prioritized panels contain:

1. **Patient** - The panel contains patient data such as allergies, previous diseases, diagnosis and identification-related data
2. **Assessment and treatment** - The panel contains Airway, Breathing, Circulation, Disability, Exposure (ABCDE), as well as treatments performed by the prehospital unit.
3. **Vital signs & observations** - The panel contains observations and measured vital signs that are critical for the treatment of the patient. These are divided into columns so that they are clearly separated from each other.

4. **Pictures** - The panel contains images from the scene of injury and of the patient.
5. **Notes** - The panel contains all notes taken by the pre-hospital unit.
6. **Injuries** - The panel contains a diagram of the patient's injuries.

The panels facilitate visualization of the user interface and sought-after data is quickly and intuitively accessible. Most recent data are prioritized to the top of each panel, ensuring uniform data presentation across all panels. Each value/ observation has its own column to provide an overview. This minimizes the possibilities for misinterpretation of data. Clinical decision support is solved by gathering data into few panels where relational data is gathered in the same panel. i.e. ABCDE is shown with patient treatment.

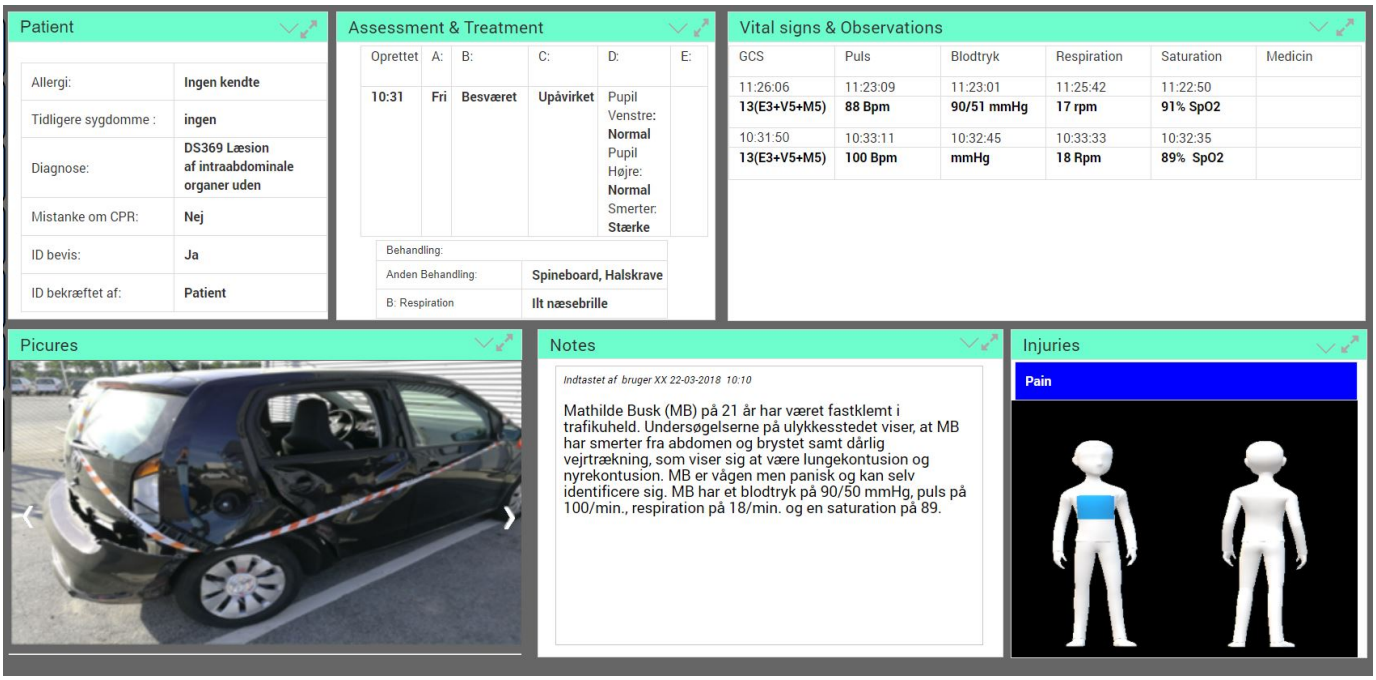

Figure 1- The figure shows the six data panels used to visualize data

To meet the requirements concerning information density, the panels have clear borders which gives the user a reading direction and keeps the design from looking cluttered. Information are therefore easily distinguished from each other. The amount of data generated in the prototype has not filled out the panels, therefore scrolling has not been required. Attempts have been made to create a high degree of internal consistency by placing features in the same place across all interfaces and keeping the design as uniform as possible. This applies more specifically to the features "expansion" and "minimize" of panels.

Evaluation findings

Evaluators' perception of the dashboard was noted for each individual during the cognitive walkthrough. The evaluators had a predominantly positive image of the dashboard.

- **Patient panel** - Few comments on this panel. A single evaluator from EDB commented that it was good to know if a patient's identity was confirmed by themselves, so that the clinician was prepared for the actual condition of the patient.
- **Assessment and Treatment** – The evaluators had some remarks, and as a peer expressed it, it is difficult to comprehend so much text in one panel. An evaluator from EDB made the point that the dashboard design puts pressure at the prehospital units, filling the ABCDE scores.
- **Vital signs and observations panel** - Multiple evaluators appreciated the presented values in columns as designed in the prototype, so that development could be followed. Two evaluators indicated that they would like to concurrently see the values on a curve. When asked whether they preferred the values shown numerically or placed in a curve, all stated they would prefer the current numerical representation. One evaluator pointed out that, critical values could be marked red to draw the clinician's attention.
- **Pictures panel** – Evaluators from EDA were surprisingly not excited about pictures from the scene of injury. This was especially interesting as they currently used the pictures. Evaluators from EDB understood the idea and thought well of it. The peers group having no domain experience, needed an explanation of why the images were of importance. A single evalua-

tor from this group thought the picture was big and her gaze were drawn there.

- **Notes panel** - Notes from prehospital units are currently used by EDA but not by EDB. The benefits of notations from the prehospital was acknowledged by both departments.
- **Injuries panel** – All evaluators were pleased with the injury picture. Especially by the possibility to expand the injury picture, so a description of the damage could be seen. One evaluator made the point, that labels could be difficult to differentiate, if a multi trauma with many types of injuries were shown.
- **General Overview** - All evaluators felt that the dashboard provided a nice overview of relevant clinical data. One of the peers felt like there was too much information in the dashboard but had no experience within the domain of emergency medicine, and therefore lacks the insight into what information is considered being important in trauma situations.
- **Other comments** – Evaluators from EDA appreciated that only data fields containing information were shown in the dashboard, this eliminates noise in the overall impression of the dashboard. Evaluators from EDB suggested easier access to the information system. Their suggestions included a longer login period and a joint user, so they did not have to spend time on logging into the system. A single evaluator from EDB also wanted the screen in the trauma room to be split into two, so the notes (as they received by telephone from the prehospital units) could be displayed at the same time as the dashboard.

Discussion

The use of a dashboard improves the ability of health professionals to effectively find information and improves the sharing of information [5]. The results of this evaluation support this. The use of data panels containing relevant contextual data has proven to be beneficial for the clinicians. Most evaluators found the data easy to find.

The results show that dashboard designs can provide a good overview of complex data and how this data should be distributed across a dashboard used in emergency departments. This is supported by other studies (9,11,12]

The study design was conducted in a user centered approach. The field study provided knowledge about users, their workflows, and their challenges with the current use of prehospital patient information. Based on this, a prototype dashboard was prepared to meet the needs of the clinicians. The design process was iterative, alternating between data collection from field studying and involvement of relevant outcomes from other studies

The study involved multiple iterations concerning relevance and inspiration, but only one design iteration, which can be seen as a limitation. This design iteration involved relevant users from an emergency department, the involvement of relevant users, who have the possibility to provide feedback, is positive for the use of a design, as well as users acceptance [13]. The involvement of users from the emergency departments is seen as an advantage in this study, due to their greater knowledge in the domain of emergency medicine and the various work procedures. It is essential that continuous involvement of end users right from the beginning of the design process and preferably with the same facilitators [14].

The field study identified that the trauma room settings were ideal for the use of a dashboard design and a dialogue with the attending nurse led to the conclusion that notes from the prehospital respondent, vital signs and pictures from the accident scene were of highest importance and thus became vital parts of the data panels.

- **Vital signs and observations** - It can be seen as important that data is presented, in both numeric values and with visual illustrations [1]. In this study, it was not possible to present vital signs visually by a curve on the main screen, but as numerical values arranged in columns. Data should not require a cognitive transformation to be understood by the user, as data may otherwise be misunderstood in stressful situations [1].

The cognitive walkthrough of the prototype found that the clinicians preferred numerical data, with the possibility of accessing a visualization as needed. The evaluators found the data as sufficient with vital signs arranged in columns and arranged chronologically with the latest measurement at the top. Data can be presented in multiple ways, as an evaluator suggested could the data fields alert the user if a value exceeds a limit. However, additional studies would be required, as more abnormal values would cause more red markings, allowing abstraction from other panels, which are also important in the acute situations [7].

- **Notes** -Throughout the cognitive walkthroughs of the dashboard, the use of the contextual data in the dashboard was explained by the same approach, but evaluators' perception of affordance did not seem to be the same. Affordance is the way in which objects are perceived by the evaluator's own habits and assumptions. Obtaining affordance can be met by an intuitive design, where the user is not in doubt about the application [1,15,16]. Affordance was not achieved especially by one evaluator. The evaluator did not perceive that the dashboard interaction was with prehospital units under the "notes" panel but would like to have it simultaneously display the emergency department's own notes from their electronic health records. A reason for this could be that the dashboard title *notes* did not appear to have an intuitively meaning for this evaluator.
- **Pictures** - While evaluating the prototype, one evaluator found that the pictures from the accident site appeared to be a focal point. This is consistent with the cognitive mindset of user interface design, where

the eye first sees the graphics, then highlighted text and finally the body text [17,18]. Despite the relevance not found in the literature and similar studies, the cognitive walkthrough showed the importance of having pictures in the data panels. However, two factors that may be related to accident pictures; estimated accident rate and damage mechanism [2]. Pictures from the accident site describe the kinetics of the accident, which serves the purpose of the two factors. However, a description of the two factors imposes higher demands on prehospital units than taking pictures, and time management is likely to be necessary.

In conclusion, this study sought to design and evaluate a simplistically prototype dashboard that visualizes data for the clinicians in emergency departments in acute situations like traumas through an analysis of clinicians' requirements and needs in combination with *good design principles* by Wiklund [7]. The overall positive evaluation shows that contextual information displayed in a dashboard is appreciated by the clinicians and is useful in critical situations.

Limitations

The cognitive walkthrough was chosen as an evaluation technique because the aim of the study was to design a dashboard visualizing the relevant contextual patient data, in correlation with the workflow at an ED. The cognitive walkthrough showed to be ideal. However, the evaluations were conducted under artificial conditions, away from the environment in which the dashboard is expected to be used. It was not possible to test the dashboard under trauma treatment conditions i.e. in trauma room. Alternatively, the evaluation could have been conducted as a usability study, where two parallel, simulated and real-life workflows are performed, starting from the incoming trauma patient for treatment at the trauma room (19). This approach would seem more genuine for the clinicians and the dashboard could be tested under conditions that seem more realistic. At the same time, the current use of prehospital data and the prototype could be assessed in relation to each other.

Acknowledgments

Thank you to the involved Emergency Departments for the possibility to conduct our qualitative observation studies.

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