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Remote design of a pediatric intensive care unit dashboard in time of pandemics

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Abstract. To support the pediatric intensive care unit with the COVID-19 pandemic, we followed a user-centered design process to create a dashboard in a context where direct access to users was impossible. To this end, we applied contextual inquiry, user interview, requirement definition, iterative design with user validation and usability testing in a remote fashion. Being unable to be physically present at the hospital limited our understanding of the context of use, extended the duration of the study and limited the number of interviews and testing sessions. However, we were able to benefit from the experience of our team members, adopt an efficient decision-making method to select appropriate requirements and use remote moderated usability testing to conform our design process to an aggressive timeline.

Keywords: remote usability evaluation, user-centered design, medical dashboard, covid-19, pediatric intensive care unit.

1 Introduction

In Quebec, the COVID-19 pandemic exacerbated hospitals' condition. Healthcare personnel worked with an added pressure due to limited human resources, highlighting the need for efficient personnel management. At Sainte-Justine hospital (Montreal, Quebec) Pediatric Intensive Care Unit (PICU), the tools available to manage patient care were inadequate to deal with the pandemic. In 2017, the PICU developed a digital dashboard showing bed occupancy and medical staff on-duty on a large-screen television. However, the dashboard was unable to meet the needs brought by the pandemic: it did not manage the growth in the number of overflow beds, as the visualization was fixed to 32 rooms, and there was no information on zone separation between COVID-19 positive and negative patients. The dashboard also showed usability issues related to situational awareness, since it did not offer any trend information on staff load and nurse-patient ratios. A new digital dashboard was necessary to deal with the possible overflow of hospitalizations caused by the COVID-19 pandemic.

We partnered with Sainte-Justine hospital to develop a new visual dashboard that would meet the PICU medical staff's needs to face the COVID-19 pandemic. To this

end, we followed the User-Centered Design (UCD) methodology prescribed in ISO 9241-210 (2019) [1]. All activities were conducted remotely, as the dashboard design happened during the shelter-home order and we were unable to go on-site for observations. Completely remote UCD activities with short deadlines in a medical setting posed a challenge that was not specifically documented in ISO 9241-210.

In this study, we present the UCD activities aimed at developing a dashboard in a completely remote context where access to users was limited. First, we provide a review on PICU and critical care management dashboard characteristics and describe the ISO 9241-210 process. Second, we present the main UCD design activities that were conducted. Third, we conclude with recommendations for the application of a UCD process in a completely remote context.

2 Literature Review

2.1 PICUs characteristics

Efficiency of PICU relies on a quick and accurate communication of critical information between doctors, nurses and respiratory therapists [2]. PICU are characterized by a higher average nurse-to-patient ratio than in other ICUs, usually one nurse for one or two patients [3]. Since the risk of respiratory exhaustion is faster in children than in adults, having an efficient nurse bedside supervision is critical [4]. As bed occupancy increases and the number of available staff members becomes limited, the situational awareness decreases due to the demand in cognitive workload [5]. Efficient management of the PICU's resources is key to assure on-time healthcare services.

2.2 Critical Care Management Dashboard

A dashboard is a visual display of important information that has been consolidated on a single screen to be monitored at a glance [6]. Dashboards were first implemented in businesses as a competitive tool to monitor performance [7]. Since the 90s, they started to be increasingly present in healthcare establishments [8].

Hospital dashboards aim to meet the needs of strategic, tactical or operational resource management in hospitals [9]. However, a unified view of resource management and clinical management of patients is rare [10]. This leads to a situation where the hospital's resource management is not aligned with care management activities in the hospital's units. Therefore, in order to find a solution to the lack of technological integration of clinical and administrative resource management in the pediatric intensive care unit of a hospital, we developed a critical care management dashboard. To this end, we used the methodology prescribed in ISO 9241-210.

2.3 ISO 9241-210

ISO 9241-210 is an UCD approach that aims to improve the usability of interactive systems with defined requirements capture and user involvement throughout the design cycle [1]. Its use for the design of medical equipment showed to improve the device's overall usability and user performance [11, 12].

After considerate planning, the iterative approach consists of the following 4 main activities with their expected information outputs (in parenthesis):

1. Understand and specify the context of use (output: as-is scenario, personas)
2. Specify the user requirements (user needs, user requirements)
3. Produce design solutions to meet these requirements (scenarios of use, low- to high-fidelity prototypes)
4. Evaluate the design against requirements (usability test report, field report)

On-site observation and interview with end-users, such as contextual inquiry and usability evaluations, are preferred methods for capturing the context of use and the user requirements [13]. However, we were unable to go on-site as the design phase occurred during the stay-at-home order when the pandemic started. We therefore adapted the UCD activities to a remote setting.

3 Methodology

Since the intention was to offer the dashboard to the hospital in time to face the pandemic, an aggressive timeline was elected to complete all activities within 2 months. The size of the team, an efficient allocation of the resources and a good communication between its members permitted to address such a timeline.

The design team was composed of graduate students in User Experience (UX) programs and were responsible for defining the user requirements, designing the prototype and conducting usability evaluations. IT personnel from Sainte-Justine were responsible for implementing the prototype and integrating it with the hospital's digital record. The PICU staff that intervened in the design process were representative of the people working in the unit as it was composed of doctors, nurses, beneficiary attendants and administrative personnel.

Together, we worked on our main usability objective for the new dashboard: to improve the healthcare workers' situational awareness [14]. To this end, we followed the structure of the ISO 9241-210 closely, while adapting the activities to a remote context. Fig. 1 illustrates the UCD process that was carried out during this study with its main activities and outputs.

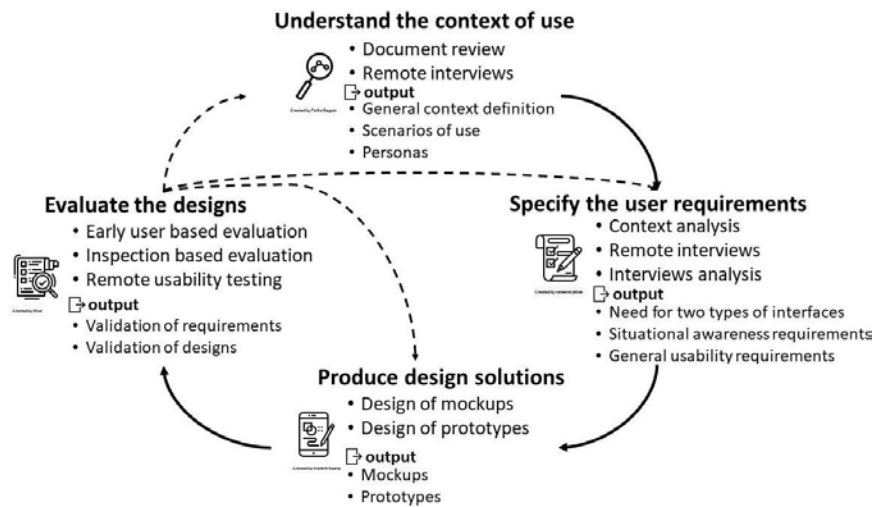


Fig. 1. UCD Process main activities and outputs

3.1 Understand and specify the context of use

To understand and specify the context of use in a pandemic context, the research team relied on two methods: document review and remote interviews.

The document review was based on a previous on-site evaluation of the existing digital dashboard done in 2019. It gave the design team an overview of the hospital's existing digital dashboard system and challenges that users were experiencing. The output of this work included: a definition of the context; list of the users and their role with the dashboard; review of usability problems with the existing dashboard and a proposition of design solutions to fix them. These information were the only data available captured directly on-site prior to the pandemic, all other information was captured remotely.

We conducted remote semi-structured interviews that lasted from 30 min to one hour. We followed an interview guide prepared to cover the research main goals: work organization, effects of COVID-19, existing tools in the unit and situational awareness requirements. We used a teleconference software (i.e., WebEx) to conduct and record the interviews that were then transcribed and categorized. 11 healthcare professionals took part in these interviews (6 from Sainte-Justine and 5 from other Quebec healthcare institutions). At the end of the interviews, the team presented an iteration of the dashboard.

3.2 Specify the user requirements

Usability and situational awareness requirements were first identified through an analysis of the context including the main tasks of the healthcare professionals related to the dashboard. They were then completed with more remote interviews which were also used to confirm that the requirements were aligned with the objectives identified

at the start of the project. The users continued to specify their requirements throughout the design process as the interviews were carried out. About one month in the project, those were starting to be steady and seemed reliable.

3.3 Produce design solutions to meet user requirements

A user interface design tool (e.g. Adobe XD) was used to produce the design solutions shared on a common drive with the rest of the research team. In order to take into consideration the whole user experience while meeting user requirements, the production of design solutions started in the early phase of the project with the development of mockups. At first, they were based on the documentation review and refined following benchmark research, user interviews, and daily multidisciplinary team meetings.

Then, a more precise definition of the context of use and requirements allowed to produce concrete design solutions. These mockups were developed having in mind a scenario of a typical day in the PICU and multiple solutions were explored. At this point, the software developer and the IT personnel of the hospital started developing the backend structure of the dashboard, while consulting with interface designers. This helped optimizing the workflow and making sure that the interface design was in concordance with the backend capabilities. Within a span of two months, mockups and prototypes were created, revised and validated with further interviews resulting in mature interfaces that were ready to be implemented.

3.4 Evaluate the designs against requirements

The mockups and prototypes were subject to three types of evaluation: early user-based evaluation with mockups, remote inspection based evaluation with mockups and user-based evaluation with prototypes. Early user-based evaluation was done with the first mockups during the interview to help us understand the context and specify the requirements. Remote inspection based evaluation was done in two ways via screen sharing. The mockups were reviewed on a daily basis by the main team during meetings and also on a weekly basis by another Montreal hospital's design team that was also developing an interface to help with hospital resource management.

When a mature design was obtained, a moderated remote usability testing was used to identify persisting usability issues and to evaluate the design against situational awareness requirements. 6 individual tests were completed with 5 participants from Sainte-Justine hospital. The group was composed of pediatricians, intensive care doctors, a respiratory therapist and one head nurse. One participant was interviewed twice within a week to validate some of his ideas and modifications to the dashboard. Each session lasted one hour. The tests consisted of situational awareness tasks questionnaires that the users answered for both the old and the new dashboards followed by an open discussion on the efficiency of the proposed design. Using a teleconference software, the screen of the interviewer was shared to give the user access to the dashboard interface, questions were asked verbally and the session was recorded with the user's permission.

4 Results

The context specification allowed the team to define the dashboard as a tool mainly used to know where a specific room or a specific person is in the unit. It can be used by everybody in the PICU, either workers, patients or their relatives. During a shift, there are typically around 20 people who will be relying on the information provided by the dashboard. As such, the dashboard must display its content in a way that relevant information is quickly available for up to 16 different types of users (doctor, nurse, beneficiary attendant, parents, medical consultant, etc.). Based on the understanding of this context, the team elaborated scenarios of use and personas.

The understanding of the context along with the evaluation of mockups generated a document of over 80 pages. The report included requirements related to the context of use, general usability issues and the objective of improving the situational awareness of the PICU workers. The analysis of the requirements along with the evaluation of different mockups by the users and stakeholders enabled the team to produce the interface presented in Fig. 2.

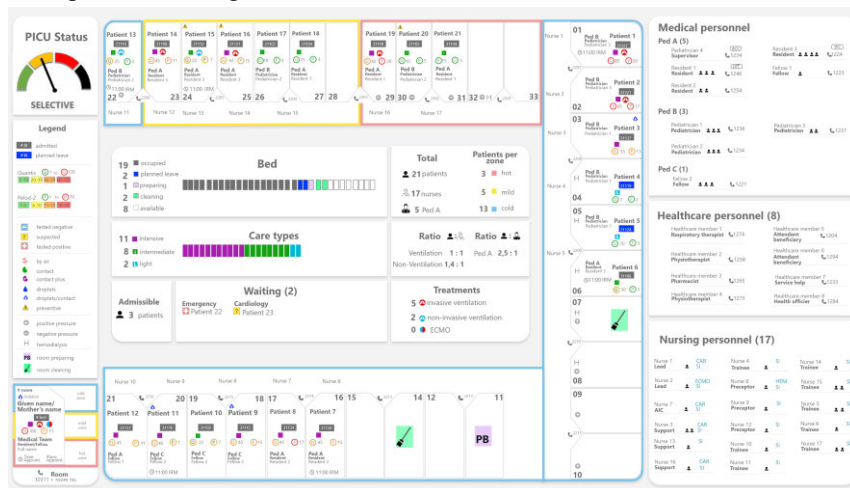


Fig. 2. Overview of the medical dashboard

5 Discussion

The results show that conducting the ISO 9241-210 process remotely is feasible. We successfully identified personas, defined scenarios and user requirements, as well as designed, tested and validated prototypes with the users. We were able to apply user-centered methods in time of pandemics for the design of a medical visual dashboard.

However, we experienced two main constraints. First, being unable to be physically present at the hospital limited our understanding of the context of use of the dashboard already in place and of the way the PICU operates. For instance, access to informal

interactions between staff and observation methods such as contextual inquiry were not possible. Second, working remotely offers limited direct access to the users. We were unable to commute to their workplace and conduct interviews between their breaks. Instead, we had to plan the interviews in advance and make sure that they had the adequate equipment to complete an interview or remote testing. This extended the duration of the study and limited the number of interviews and testing sessions.

Nonetheless, three elements helped the team complete the design of the dashboard in these circumstances. First, a member of the team had worked on the previous iteration of the dashboard. Her work provided valuable information, such as identified users of the dashboard, which helped with the understanding of the context. Second, limitations related to user requirements specification were addressed by giving precedence to requirements that increased situational awareness offered by the dashboard. Some requirements were “nice to have” but would not have been possible to implement within the framework of the project. Third, the moderated usability tests proved useful given the circumstances. The fact that the questionnaires was oriented toward situational awareness encouraged the users to focus on accomplishing the tasks and acted as a visualization exercise. Even though the test was done remotely, this goal-oriented questionnaire helped the users focus on using the dashboard in its actual environment.

A next avenue for future research would be to investigate alternative methods to gather information faster in remote settings (e.g. video recording, diary logs, unmoderated user testings, etc.).

6 Conclusion

The COVID-19 pandemic raised the urgency for efficient dashboards in Quebec hospitals to better manage personnel and patients. We were able to follow an UCD process remotely during the lock-down and delivered design solutions to address such needs in a completely remote way. The dashboard is currently being implemented in the PICU of Sainte-Justine and will be subject to follow-up evaluations to confirm that it has met the goals defined at the start of the project. Furthermore, a journal paper detailing our approach to design a dashboard that increases situational awareness in a medical context will soon be published.

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