Abstract

Work in intensive care units requires interaction with several medical devices and interpretation of dynamic information from several sources. The aim of the current study was to gain understanding of the work domain to support the development of a holistic information environment and further analyses of risky situations. A total of 18 hours of bedside observations at an intensive care unit and interviews with three experienced intensive care unit nurses were conducted in order to receive input data for the modelling of the work domain. The domain was modelled in an abstraction hierarchy, as according to the first phase of the cognitive work analysis framework. The results show that the ultimate purpose of the work carried out in an intensive care unit is keeping patients alive while gaining time for treatment, but also to perform treatment and relieve symptoms. The purpose is represented at the top level of the model, and lower levels include functions as supporting the patients’ vital functions and avoiding secondary complications. With this work domain analysis as a basis, three different design challenges identified can be dealt with systematically.

Introduction

The Swedish Accident Investigation Authority (2013) recently conducted an investigation on an accident resulting in the death of a patient in an intensive care unit at the Karolinska University Hospital, Sweden. A patient who had an external pacemaker implanted after surgery was after four days transferred from one division to another within the hospital. At the time of arrival, the patient was connected to the telemetric surveillance equipment. When the patient was registered in the system, the staff failed to indicate the presence of an external pacemaker, and there was no barrier in the interaction dialogue in the system checking for such an omission. Since the pacemaker was not marked explicitly, the presence of its pulses was difficult to discriminate from the patient’s own heart beats, i.e., the pulses from the pacemaker were interpreted as the patient’s own heart beats by the surveillance equipment. This in turn led to situations of cardiac arrest not being appropriately discovered by the surveillance system. During visual inspection of the patient by the night staff, the patient was found dead. The Authority concluded that factors at two different levels of the organization contributed to the evolvement of the accident. Deficits deducible to management level, that is to say latent errors at the blunt-end, resulted in unclear instructions regarding the telemetric surveillance equipment, in
turn creating uncertain conditions during transfer between divisions as well as when shifting staff. Despite the lack of clear instructions staff was forced to decide by themselves, since time did not allow consultation with colleagues or management. The other factor pointed to by the Authority was deficits deducible to the interaction between staff and the telemetric surveillance equipment, that is to say event-related errors at the sharp-end. The staffs’ use of the telemetric surveillance equipment was not in accordance with the instructions since the alarm system resulted in a number of documented false alarms. This in turn resulted in reduced attention among staff, with the consequence that a correct alarm was rejected. The hypothesizes in the current project are that the following three challenges have to be met to ensure a better work environment where mistakes and errors like the ones identified by the Authority are reduced: (1) The design of single technical apparatus has to be adequate when it comes to usability and interaction; (2) a more the holistic design approach is needed with respect to the work environment where the users perform their work tasks; (3) a proactive safety culture that encourages learning from mishaps and lapses needs to be developed.

In order to investigate how the three challenges can be met, a long-term goal of the intensive care unit project discussed here is to employ a bed-side approach and produce data in order to document as much in detail as possible of actions, events and behaviours allocated to the interaction between the nurses and patients, as well as between nurses and the technical equipment. The assumption is that a bed-side approach for human factors research will support the development of a better understanding of the work conditions in intensive care units. Without a proper understanding of the dynamic decision making processes going on in an intensive care unit, it is probable that the important actions and series of events are overlooked.

The work domain analysis described in the current paper is a part of a first exploratory phase which will define the future direction of the intensive care unit-project. The aim of the work domain analysis is to gain knowledge about the intensive care nurses work domain to be able to address the different challenges mentioned above in a better way.

Even if the design of each and one of the technical apparatus is according to usability standards, the holistic work environment might suffer from usability flaws if the apparatus and softwares not are integrated, ad hoc implementation is therefore not appropriate from a sociotechnical systems design perspective. It is therefore important to adopt a systems perspective when working with improvements of the intensive care unit and from this reasoning a need for understanding the intensive care work is of great importance.

Work domain analysis in intensive care units

The work domain analysis is the first phase of the cognitive work analysis framework (Rasmussen & Peijtersen 1994, Vicente 1999), which is a framework for analysing complex systems. The work domain analysis phase identifies and describes the possibilities and constraints on work conducted within the work system, independent of situations and can therefore be used as a way to deal with
novelty according to Vicente (1999). A work domain analysis is usually modelled in an abstraction-decomposition space which divides the system into five levels of system decomposition, represented in horizontal direction, and five levels of abstraction in vertical direction (Vicente, 1999). The five abstraction levels are from the overall purpose of the system at the top level, to the physical components of the system at the bottom, and the functions of the physical components of different abstractions in the levels in between.

Methods from the cognitive work analysis framework have successfully been used in many application domains and are often used to support interface design, according to a review by Read, Salmon, and Lenné (2012). Health care and even intensive care unit’s is an area where the cognitive work analysis framework has been used. For example Effken et al. (2011) conducted a cognitive work analysis by interviewing health care managers, to better understand environmental constraints and the implications for a decision support tool. Miller (2004) describes a work domain analysis modelling the intensive care unit patient, which further is used as a basis for information design for different media, by Miller et al. (2009). Gorges et al. (2013) modelled a work domain analysis for paediatric intensive care unit, which was used for rapid prototyping of a mobile patient monitoring application.

The current paper reports a work domain analysis with a bed-side perspective and a focus on the work conducted by intensive care nurses at an intensive care unit, because a good understanding of the work domain are useful in the development of a representative information environment. Therefore the focus is on understanding and modelling the sociotechnical system and work domain of the intensive care unit nurses, as opposed to the patient (as by Miller, 2004) or with a wider focus on organizational factors (as by Gorges, 2013).

Method

The work domain analysis of an intensive care unit, from a bed-side perspective, has been modelled based on information achieved through an observation study (figure 1), and through interviews and participatory analysis made by three subject matter experts. The subject matter experts’ have 12 to 16 years of experience working as specialized nurses at the intensive care unit. One of them (Camilla Fröjd) is co-author of this paper.
Figure 1. Illustration of the workplace in the intensive care unit.

The modelling of the work domain was a continuous process moving from a focus on collecting data towards reviewing the modelling of the work domain, see figure 2. The work domain has been modelled iteratively during and between the data collection sessions and the expert reviews in an abstraction hierarchy. The abstraction hierarchy includes five levels and system decomposition has also been included where it provides clarification. The names of the abstraction levels are developed by Rasmussen as reported by Reising (2000), and also described in Jenkins et al (2009) as the following: The top level contains the purpose of why the system exist, and is called the functional purpose. The second highest level is called values and priority measures, and can be seen as how the functional purposes can be measured. The middle level, the purpose-related functions, is the functions necessary to achieve the functional purposes described on an abstract level. The second lowest level is called object-related processes and is the functions of the physical components of the system, or why they exist. The lowest level of the abstraction hierarchy is called physical objects, and contains the physical components of the work system.
The data collection started with a three hour introductory visit at the intensive care unit, guided by two of the subject matter experts. Here the basic layout of the intensive care unit, equipment, work routines, and tasks were described.

The data collection continued by interviewing the two subject matter experts separately during totally five hours divided into three sessions. The interviews were semi-structured, and the interview questions were based on the questions suggested by Naikar, Hopcroft, and Moylan (2005). The abstraction hierarchy was modelled during and between the interviews, and was used as a base for the later interviews. In that way the subject matter experts could be asked to provide more information about how to fulfil the different functions or purposes described in the abstraction hierarchy, or why the physical components exist or what they can be used for.

More data were collected during an observation study that took place at the central intensive care unit at the University Hospital in Sweden. The observations took in total 18 hours distributed over two work shifts, first a day shift and then a night shift. Two to three different work teams were observed during each work shift, and questions about why tasks were performed were asked when the work situation allowed it. The notes taken during the observations were later translated into nodes and connection between nodes in the abstraction hierarchy.

In the review session, three subject matter expert were interviewed. They separately reviewed the nodes in the abstraction hierarchy and their connections, and the abstraction hierarchy was updated according to their feedback. All review sessions took in total ten hours divided into four work shifts.
Results

Functional purpose

The functional purpose of the work domain is in the abstraction hierarchy described as; “Treat, relieve symptoms, and gain time for treatment and the effect of treatment” (see figure 3). The functional purpose of the intensive care unit, the overall purpose of why the system exists, from the perspective of the worker in the system is to keep the patient alive while the patient receives the lifesaving treatment. Other units at the hospital have the specialization of treating different injuries or diseases, and therefore a physician from another unit is assigned the patient depending on the patients’ needs. However, the border for the actual treatment of the patients’ injury or disease and the intensive care is not a sharp edge, and some of the treatment is also carried out by the intensive care unit. What is characteristic for the intensive care unit is that patients need more support of the vital functions to stay alive than can be given at other hospital units. An additional purpose of the intensive care unit is to relieve the patient’s symptoms.

Values and priority measures

The three values and priority measures and their connections are visualized in Figure 3. The value and priority measure “Person centred care” is perhaps not an obvious part of gaining time for treatment or treat a patient’s disease or condition. It is anyways modelled as connected to the functional purpose (instead of described as a functional purpose itself) because the patient’s privacy and wellbeing is an important part of how the intensive care is conducted and defines how well it is performed.

The two other values and priority measures are directly connected to keeping the patient alive and enable treatment of the patient’s disease or condition, or to not cause other damage because of the intensive care itself. These values and priority measures are “Prevent secondary complications” and “Support the patient’s basic & vital functions”. Both values and priority measures are further decomposed into categories of secondary complications or the patient’s body functions that might need support, respectively.
Purpose-Related Functions, Object-Related Processes and Physical Objects

The purpose-related functions, and their connections to the values and priority measures, can also be seen in Figure 3. Those are the functions of the work system, described on an abstract level, which in this system mean that they are functions described from a care or medical perspective. The object-related processes’ are instead described from a technical perspective, which is more related to the medical technology or physical objects of the work system. The object-related processes’ and the physical objects are not included in Figure 3 due to space limitations.
Examples of functions in the intensive care work domain are to interpret the patient’s clinical status, interpret equipment status, and perform intensive care treatment. Those functions require interaction with several medical devices, and interpretation of information from several sources. Examples from the abstraction hierarchy in full is that the purpose-related functions “Interpretation of patient’s status” are supported by the object-related processes “Monitoring of vital signs (physiological data) & information about patient status”, which is among other physical objects implemented through blood gas measurements and other analysis results, x-ray, and patient data presented on a monitoring display. To interpret the patient’s status also examination of the patient and the information provided from the nurse that worked the shift before is very valuable. Interpretation of equipment status regards for example that the ventilator settings fit the patient, and that all infusion pumps distribute the drugs as appropriate. The purpose-related functions related to the implementation of IC prescription and treatment, as for example “Keep the patient’s blood pressure” and “Remove harmful substances”, are implemented by many technical functions where one of them regards administration of drugs to the patient (object-related process) implemented with for example infusion pumps (physical object).

Discussion

The future work concerns meeting the three challenges mentioned in the introductory section: (1) Design of single technical apparatus has to be adequate when it comes to usability and interaction; (2) a more holistic design of the work environment that supports the users in performing their work tasks; (3) a proactive safety culture that encourages learning from mishaps and lapses.

Constraints imposed on the work in the sociotechnical system are identified and modelled in the abstraction hierarchy, from the physical objects, as medical technology, to the higher purpose of gaining time to treat the patient’s injuries by for example supporting the patients’ vital functions. Higher level goals for intensive care unit could instead be expressed with a focus on the whole organization, but for the intensive care nurses’ work domain the higher level goals on a patient level are central, and therefore is the bed-side perspective important for the understanding of the nurses work domain and to be able to support an holistic design, which is mentioned earlier as challenge one and two. The model of the work domain contributes to an understanding of the work conducted within the work system, as well as information requirements and functions needed, which can be used to support development of an interface design integrating the different parts of the sociotechnical system. Therefore an understanding of the work domain is useful to support interface design (challenge 1) and especially the focus on the holistic work design (challenge 2) because the visualization of the relations between important domain functions. But further analyses are needed to be able to support the development of the interface design. Analysis that investigate the control tasks need to be conducted and possible strategies to complete the work tasks, which are a continuation in accordance with the cognitive work analysis framework.

The focus on the intensive care nurses work domain was chosen because of the need to gain a larger understanding of the nurses work domain, and bring the knowledge
through to design and in the continuation of the project. Further, the work domain analysis can be extended to also include data from interviews with physicians working within the intensive care unit, which would be a useful complement because the functions in the work domain connected to physicians are different from the functions connected to the nurses. Therefore, the physicians' input would be from another perspective, and could give other requirements for the system design.

Regarding the third challenge about supporting development of a proactive safety culture, the domain analysis did not give direct input. In the future work, that will also include safety culture aspects, the understanding of the work achieved through the domain analysis will be used when discussing risks for incidents with nurses using the Collegial Verbalization method (Erlandsson & Jansson, 2013; Jansson et al., 2013; Jansson, Erlandsson & Axelsson, 2015; Jansson, Olsson & Erlandsson, 2006) and when analyzing those from a system perspective. The future work is also to include a workshop study with the nurses at the intensive care unit, to increase the learning from incidents and abnormalities.

References


