Using Cognitive Modeling for Requirements Engineering in Anesthesiology

Constanze Pott
University of Groningen
c.m.pott@rug.nl

Joost le Feber
University of Twente
j.lefeber@utwente.nl

Abstract

Cognitive modeling is a complexity reducing method to describe significant cognitive processes under a specified research focus. Here, a cognitive process model for decision making in anesthesiology is presented and applied in requirements engineering. Three decision making situations of anesthetists are distinguished, which depend on the state of the patient. For every decision making situation, different requirements of information supply to support decision making of anesthetists can be defined without additional input of the anesthetist. We developed a prototype of a decision support system for familiar situations and define the specifications of a system to support urgent situations. More research about presenting relevant information is needed to support the third decision making situation, diagnosing.

1. Introduction

When trying to develop decision support systems in anesthesiology, system developers are confronted with difficulties, making the use of traditional methods for requirements engineering almost impossible. Anesthesiology is a complex and dynamic work environment where highly trained experts suppress vital functions of the patient (i.e., breathing) in order to enable surgery. Knowledge about human physiology is still limited and modeling the problem space (i.e., the patient) is difficult because of its complexity. Furthermore, the patient can get into a sheer unlimited number of states. Therefore, it is almost impossible to define the problem space, a precondition in more traditional approaches.

2. Cognitive modeling

In our study we used cognitive modeling to develop decision support systems in anesthesiology. To gain insight into the mechanisms of diagnosing and to differentiate between different decision making situations, we distributed a questionnaire among anesthetists by email in 2001. We received 245 responses from 29 countries. The results of this survey were integrated into the cognitive process model.

2.1. Improving situation awareness

Situation Awareness can be described as the "big picture" of a situation. Cognitive psychology provides a large body of evidence that a person's internal representation of a situation is not a direct mapping of the outer world. Because of high workload or low alertness, the situation awareness of anesthetists may be impaired, i.e., their decision making might be based on wrong assumptions. The goal of our research is to develop a decision support system to improve the situation awareness of anesthetists in order to facilitate and improve their decision making. This is done by presenting information complying with the instantaneous information need of anesthetists. This need changes with different cognitive decision making processes of the anesthetist, which depend on the state of the patient. The state of the patient is either a maintenance state where most actions can be anticipated, or a repair state where diagnosis and treatment are necessary. In the maintenance state, the need for decision support is low. Our survey revealed a high need for decision support in the repair state. To handle the complexity of the repair states of the patient, we divided them into three subgroups: familiar, urgent, or requiring diagnosing.

2.2. A model of decision making in anesthesia

Our cognitive process model focuses on perioperative decision making tasks (between induction and emergence of anesthesia) and distinguishes between maintenance and repair tasks. We focused on repair tasks, which are triggered by an unexpected change of some of the patient's variable values (see fig. 1). If an unexpected change is detected, situation awareness makes the anesthetist decide whether the new values are acceptable for the patient. If they are not, situation awareness has to be updated. If the newly perceived state of the patient is familiar to the anesthetist, s/he

Proceedings of the 2005 13th IEEE International Conference on Requirements Engineering (RE'05)
0-7695-2425-7/05 $20.00 © 2005 IEEE

applies the typical treatment for this situation. Otherwise, s/he has to estimate the urgency of the problem, i.e., how life threatening the situation is to the patient.

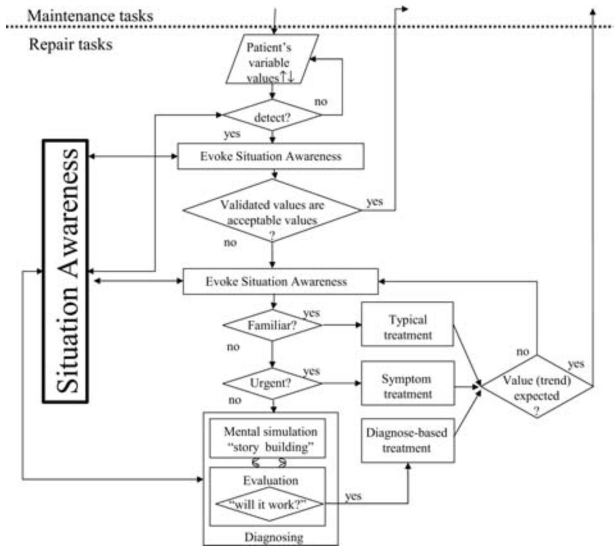

Figure 1. A cognitive process model of decision making in anesthesiology.

In urgent situations, when time for proper diagnosing lacks, symptom treatment is applied following the rule "treat first what kills first". If the situation of the patient is neither familiar nor urgent, extensive cognitive processes of decision making take place to develop diagnosis-based treatment. After the treatment, the patient's variable values are re-evaluated. If the values (or at least their trends) develop as expected, the anesthetist returns to maintenance tasks. Otherwise situation awareness is evoked again.

3. Implications of cognitive modeling for system development

The main outcome of cognitive modeling is the distinction of three different decision making situations, which depend on the state of the patient. The model in figure 1 enables reduction of the complexity of the system where different requirements are defined for the different situations.

3.1. Implications for familiar situations

In familiar situations, decision support is needed to identify "repair tasks" in low vigilance situations, or to prevent the anesthetist from misinterpreting the state of the patient. For familiar situations, the problem space can be defined properly. Depending on the measured patient data from the monitoring devices, we developed a decision support system for familiar situations. This system estimates and presents the probability and improbability of a set of diagnoses that span most of the anesthesiological daily practice to improve anesthetists' situation awareness.

3.2. Implications for urgent situations

For urgent situations, a system will be developed identifying life threatening situations of the patient automatically. This system can moreover be seen as an improvement of already existing alarm systems including more information about the state of the patient. For this system, the absolute parameters from the monitoring devices have to be converted into relative parameters, e.g. the measured blood pressure (a number) will be split in 5 categories from low, low normal, up to high. This splitting depends on the individual patient's per-operative data, e.g. age, weight, state of health. If a patient has variable values in the high or low categories, most probably the patient is in an urgent state. In contrary to existing alarm systems, variable values will be validated automatically by cross-checking, reducing the probability of simple measurement faults.

3.3. Implications for diagnosing situations

For diagnosing situations, more research is needed about the presentations of information. For unfamiliar, not urgent states of the patient, the amount of data that can be processed by the anesthetist has to be investigated. Moreover, the grouping of information according to sub-systems within the patient, e.g. circulation, should be studied on their implications for improving situation awareness of anesthetists.

4. Discussion

Cognitive modeling of decision making processes enabled us to specify the essential needs of anesthetists during surgery and to analyze the context of the future product despite its complexity. It allows us to build systems that respond to the anesthetist's changing needs, which depend highly on the state of the patient. Based on information from monitoring devices, our system can estimate the need for information of anesthetists. Moreover it can identify the diagnosing situation, where only human expertise is feasible. As anesthesiology is a good example of a complex, dynamic and unlimited context, the promising results of our research can also be applied to similar contexts.

Proceedings of the 2005 13th IEEE International Conference on Requirements Engineering (RE'05)
0-7695-2425-7/05 $20.00 © 2005 IEEE