## A PC-Based Display for Anesthesia Monitoring

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### Abstract

In current practice one of the anesthesiologist's main tasks is to monitor the physiological variables of a patient. Several displays at several locations around the patient provide the data. In the meantime the anesthesiologist has another task, namely to observe the patient and to keep an anesthesia record, which is usually hand-written.

The number of measuring points and the complexity of the operations has increased so that during periods of high per-operative activity the workload imposed upon the anesthesiologist has become rather high. The research project was aimed at assessing the current status of anesthesia monitoring systems, to perform a task analysis and to make an initial design for a new anesthesia monitoring display using existing hardware configurations.

### Introduction

The more sophisticated technology gets the higher the amount and the greater the accuracy of possible measured physiological parameters becomes. On one hand this has the advantage that the patient's condition can be monitored more accurately during the operating procedure and this may lead to greater patient safety. On the other hand however, if the anesthesiologist wants to keep track of all these parameters he should either have more eyes available or he should be provided with a more comprehensive monitoring system. With a higher amount of measured parameters available also the amount of alarms will increase which will again pose more pressure on the anesthesiologist. The anesthesiologist has to locate and interpret the alarms and take action.

In current practice the anesthesiologist has to monitor the patient's physiological parameters by means of several displays at several locations around the patient. In addition he has to watch the patient and keep a handwritten anesthesia record. This has made the task of an anesthesiologist a rather complex one to perform and one that, certainly during periods of high per-operative activity, causes a high workload for the anesthesiologist. Therefore it is desirable to improve the situation leading to an improved workload situation for the anesthesiologist.

A fairly high amount of effort has been put into developing monitoring systems that support the anesthesiologists in decision making [6,11], but very little research has been done on data presentation aspect of monitoring systems. We believe that this aspect of monitoring systems can help reduce the anesthesiologist's workload and in that way ultimately contribute to the safety of the patient [2,8,9,10,11,12]. This research project was aimed at looking into the possibilities of reducing the anesthesiologist's workload by improving the data presentation of the anesthesia monitoring system.

## Methods

This research project consisted of three main parts. First existing literature on monitoring systems was reviewed. Then a task analysis was performed and an initial PC-based design concept for a new anesthesia monitoring display was developed. The third part consisted of recording and interpreting the results.

### Literature Review

The literature on anesthesia monitoring systems was reviewed. This was done in order to get insight in the currently available monitoring systems, but also to provide ideas for possible research directions. The results from the literature review point out that three main problem areas exist in currently used monitoring systems [11].

While a lot of effort is being put into research in the physical and functional integration of monitoring systems [6,11], we decided to aim our research at improving the data presentation and user-interface of the currently used monitoring system. At the same time we addressed the physical integration of the different monitoring systems currently used.

## Practical Work

A task analysis was performed and a PC-based concept for a new monitoring userinterface was developed. After the initial PC-based design concept was developed it was tested by means of another task analysis to verify whether or not the concept is useful.

### Practical Work: Task Analysis

In order to find out what requirements have to be met in order to improve the data presentation of the currently used system a task analysis was performed. The results of the literature review were used to set up a task analysis using structured interview techniques, which is typically used for pre-design data collection [7]. Sixteen anesthesiologists at the department were interviewed.

The structured interviews were conducted based on six issues that followed from the literature [1,3,4,5,11]. The interviews were set up in an open-ended manner in order to leave room for discussion and individual input from the anesthesiologists. To initiate a discussion on each of the six issues addressed we made design proposals based on our findings in the literature [11] and on the basic principles of human factors [5]. The anesthesiologists were confronted with our proposal concerning each issue and asked for their opinion. The interviewer rated their opinion. The ratings for the different anesthesiologists on each issue were added up and an average was calculated. This average was used to decide whether or not it was useful to implement a proposal in the design.

After the initial design concept for the new display was developed this was evaluated by using structured interview task analysis techniques again. We used the same criteria as before to validate our design. This time we left room for suggestions from the anesthesiologists concerning the design.

### Practical Work: Design Concept

Using the results of the task analysis and the basic principles of human factors [5], the new, PC-based monitoring interface concept was designed. The concept was developed using Borland Delphi 2.0; an MS-Windows based graphical programming environment.

Several design ideas were proposed based on both literature and task analysis. Since we were developing an initial concept for a new PC-based monitoring interface we implemented several displaying ideas and tested the usefulness.

In order to evaluate the design we constructed a simulated anesthesia case. We constructed a database of the different measured variables and read the database into the program as if it were a real patient's data. The simulated case lasts about one hundred minutes but in order to show the anesthesiologists the most important features in a limited amount of time we speeded it up to about 10 minutes.

# Results

The results of our research are the following. First there are the results from the review of the literature. Secondly there are the results from the task analyses based on which we designed and validated the new PC-based display. The structured interviews after the display was designed also provided us with useful suggestions for future research. Thirdly there is the display design.

### Literature Review

The review of literature reveals that three main problems exist in currently used monitoring systems [11]:

- 1. The currently used monitoring systems are not physically integrated
- 2. The currently used monitoring systems are not functionally integrated
- 3. The data presentation and user-interface on currently used monitoring systems are not comprehensive

Further the literature review points out that using graphical display techniques and appropriate coloring can improve the data presentation [1,3,11]. Also standardizing and integrating the different monitors used seems useful. The literature showed us that six different issues should be addressed in order to be successful at improving the user-interface of an anesthesia monitor [1,3,4,5,11]. Those issues are:

1. **Human factors:** The new interface has to be easy to operate. Therefore it is necessary that the design of the new interface is comprehensive and intuitive so that it will not impose information overload on the anesthesiologist.

*Proposal:* Design the interface in a graphical manner using colors and icons to increase intuitivity and comprehensibility. The idea is to design an MS-Windows based interface in order to benefit from the graphical advantages provided by this kind of interfaces.

2. **Controls:** Controls on current monitors are mostly hardware bound, which has a major disadvantage in the fact that the operator is forced into an incomprehensive menu structure. Also the insight into the menu structure is hard to get.

*Proposal:* Make the menu structure more comprehensible using the possibilities an MS Windows-based interface offers. Use a pointer device, such as a mouse or track-ball, and design the interface in a way that the hardkey-functions of the current systems can be operated with a single pointer device using MS-Windows based menus and controls.

3. **Display:** Currently available displays may have a high resolution, however, most of the currently used interfaces do not use graphics and colors to the full extent or are monochrome displays. Also current monitors hardly use graphical displaying methods such as icons or buttons etc. The only graphical information displayed is waveforms, trends are available.

*Proposal:* Try to develop a display presenting as much information as possible using minimum amount of pictures and characters; minimalistic approach. The basic idea of this minimalistic approach is to obtain well-organized display layout.

4. **Configurability:** Different anesthesiologists might want a different layout of their interface. In the current design it is possible to adjust the display layout but that is hard to do.

*Proposal:* Make the new interface easily adjustable to personal wishes of the anesthesiologists by using an MS-Windows based interface. Also make it possible to save personal preferences using a user ID.

5. Alarms: Current alarms are often very incomprehensible due to the small variety of alarm sounds and the low prioritization that is applied. Also many false alarms appear.

*Proposal:* The current alarms might be improved in two ways: using graphical information and using sounds; e.g. alarms could cause a color change of some kind and different, easy distinguishable sounds could be used.

6. **Standardization:** Current monitoring devices are mostly specialized machines, which are not compatible with other devices. This has several disadvantages. One of them is that such devices are often expensive. Another is that if devices have to be upgraded or enhanced, it has to be done using devices of the same manufacturer.

*Proposal:* Use a PC to acquire and display the data. The advantages of this are: 1. PC is extremely modular and compatible with a huge variety of hardware. 2. PC is very cheap. 3. With PC it is easy to implement graphical displays with color

and high resolution. 4. Sounds are easy to generate using MIDI or some other sound format.

### Task Analysis

The results of the task analysis provide us with two main requirements for the new system. First, anesthesiologists are of the opinion that the more information they have available the better. Therefore the first main requirement is that all the information available on current systems should also be available on the new system. Secondly, different anesthesiologists generally have different opinions on what information is the most important and has to be displayed continuously. Therefore the second main requirement is a high degree of configurability.

The results from the structured interviews before the display was designed show us that our proposals on the six different issues will improve the current situation. They also show that our results from the literature review are valid. The average ratings for the different issues are stated in table 1. The rating is as follows: 1 - 1.5: Big worsening, 1.5 - 2.5: Worsening, 2.5 - 3.5: Neutral, 3.5 - 4.5: Improvement, 4.5 - 5: Big Improvement.

Table 1         Final results of the structured interviews						
	Analysis of the Proposals			Evaluation of the Design Concept		
Issue	Rating	Average	Result	Rating	Average	Result
1	68	$4.25\pm0.77$	Improvement	73	4.56 ± 0.51	Big Improvement
2	77	$4.81 \pm 0.40$	Big Improvement	78	$4.88\pm0.34$	Big Improvement
3	66	4.13 ± 0.62	Improvement	65	4.06 ± 0.57	Improvement
4	75	$4.69 \pm 0.48$	Big Improvement	76	$4.75 \pm 0.45$	Big Improvement
5	71	$4.44 \pm 0.51$	Improvement	63	3.94 ± 0.68	Improvement
6	70	$4.38 \pm 0.50$	Improvement	70	$4.38 \pm 0.50$	Improvement

The display was evaluated using the structured interview technique again. We interviewed sixteen anesthesiologists at our department. The results from the structured interviews after the display concept was designed show us to what extent the six mentioned issues improve the display (Table 1). The results show that we implemented the proposals effectively because as can be seen from table 1 the anticipated improvements based on our proposals and the actual improvements based on the design concept are similar.

The evaluation reveals that the new display will improve the workload situation of an anesthesiologist and therefore could ultimately contribute to the safety of the patient.

#### The Display Design Concept

The new display takes into account the results from the task analysis. For evaluation and practical reasons, the data presented on the new display has been restricted to the following physiological variables: heart rate, temperature, blood pressure, oxygen saturation, EKG, pulse-oximeter waveform. The data is grouped and presented in a graphical way using basic human factors principles. This provides a more comprehensive way of assessing several important and frequently used features, such as, adjusting alarm limits and modifying screen layout. The display design concept is shown in figure 1.

It can be seen from figure 1 that several different displaying techniques are being used in the design concept. Improvements can be categorized in the six issues addressed:

• *Human Factors:* The display design concept is graphically oriented which enhances intuitivity and therefore the ease with which the system is operated. Besides numerical values and waveforms figure 1A shows additional graphics designed to draw the attention to the appropriate part of the screen in order to speed up the interpretation of the data presented.

• *Controls:* We avoided the incomprehensive menu structure the currently used systems have by using an MS-Windows based menu. Also we made frequently used controls accessible from the main screen. Figure 1A shows the slide-controls for adjusting the alarm limits as well as the MS-Windows based main menu through which the controls can be accessed in a more conventional manner. As many controls as possible will be accessible from the main screen in the future.

• *Display:* By using graphically oriented display techniques we made the display more user-friendly and increased intuitivity. Also we made the display better organized by using display-units displaying all the information on a certain variable. In the future the display-units can be customized to the individual preferences of the user and can be placed anywhere on the screen.

• *Configurability:* Using display-units not only make the display better organized but it also improves configurability. By introducing a user ID we made it easier for the anesthesiologist to set up the system for a case. The user has to input his user ID into the system when he starts monitoring. Figure 1B shows the "log-on"-screen that will appear on starting the program. The "Users"-menu also contains an item to change the current user.

• *Alarms:* Using colors in combination with graphics to indicate an alarm situation draws the attention of the anesthesiologist to the appropriate place on the screen and therefore helps the anesthesiologist interpret the alarm situation faster.

• *Standardization:* By using a standard PC as a basis for the system we created a potential for a system that is inter-connectable with several other systems and information sources.



# Discussion

The structured interviews after the display concept was designed provided us with suggestions for future research. The results that came from our interviews are presented below organized in suggestions concerning the six issues addressed.

### Human Factors:

- In order to work with a system everything needs to be clear and legible, also when looking at the screen from a distance.
- Text on the screen needs to be clear and unambiguous in order for good interpretation to be possible.
- Using a graphical format like gauges is nice because the exact value is not as important as a general impression of an estimate of the value.

### Controls:

- Future systems will become more and more intelligent and might even recognize emergency situations and come up automatically with visual cues or suggestions.
- The different monitoring systems currently used should be integrated into one system.

### Display:

- Trends need not to be displayed continuously but a good trending system is desirable. Make a trending system that is as easy to configure as the display itself.
- Maybe not use a color display but a grayscale display with colors only in case of an alarm situation to prevent confusion.

### Configurability:

- Make colors configurable because people who suffer from color blindness will have problems distinguishing colors.
- Using the user ID will not only serve the anesthesiologist but will also be able to serve as a way of recording who has been using the system.
- Besides the personal preferences concerning the display layout it would be nice to have a number of personal presets for different types of cases.

#### Alarms:

- For indicating alarm situations use blinking color change instead of just a color change.
- The sounds used for indicating an alarm situation might be digitized speech instead of just beeps and buzzes.

#### Standardization:

- Make the system connectable to other systems and information sources. For example: Patient information system, Laboratory information system, Knowledge bases.
- Implement a knowledge base that supports the alarm system and that way maybe prevents false alarms. A knowledge base can also be used for decision support for the anesthesiologist.
- Knowledge bases and case logging are not only useful for evaluation purposes but also for educational purposes.

However, our most important finding in this research is that it is required to have knowledge from all the fields involved in this development in order to make significant further achievements. This is a requirement because that way it will be possible to look at the system from different perspectives. Fields involved in this research are anesthesiology, engineering, designing, programming, ergonomics and probably even more. Knowledge from just one of those fields won't be sufficient. We found that operating in a multi-disciplinary development-team is required for achieving significant results in this research.

Our findings underscore two aspects. First of all that redesign of monitoring interfaces is important, and that these changes can be made without requiring major hardware overhauls. Secondly that in order to be successful in designing a new anesthesia monitoring system it is important to have knowledge from all the related fields available.

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