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PATIENT MONITOR USER INTERFACE WITH MULTIPLE INPUT DEVICES

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<p>This thesis work describes the development process of a new patient monitor user interface. The input devices of this interface are a touch screen and the traditional control wheel. The touch screen design is in a prominent role because it is a new feature in the products of GE Healthcare. The final result of this work is a user interface that has been validated for hospital work.</p> <p>The theoretical part of the thesis discusses different input devices and their applicability to medical equipment. Touch screen studies and design guidelines are emphasized because the practical part of the thesis deals mostly with a touch screen user interface.</p>		
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<p>Tässä diplomityössä kuvataan uuden potilaanvalvontamonitorin käyttöliittymän suunnitteluprosessi. Käyttöliittymän syöttölaitteina on kosketusnäyttö ja perinteinen ohjauspyörä. Kosketusnäytön suunnittelu on työssä merkittävässä roolissa, sillä se on uusi ominaisuus GE Healthcaren tuotteissa. Tämän työn lopputulos on käyttöliittymä, joka on validoitu sairaalakäyttöön.</p> <p>Diplomityön teoriaosassa esitellään erilaisia syöttölaitteita ja pohditaan niiden soveltuvuutta lääketieteellisiin laitteisiin. Kosketusnäyttö tutkimuksia ja suunnitteluohjeita on painotettu, koska työn käytännön osuus koskee suurelta osin kosketuskäyttöliittymää.</p>		
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Abbreviations and definitions

Digit field	Area on patient monitor screen where numerical values of one measurement parameter are displayed
ECG	Electrocardiogram, a waveform representing heart functions
GE	General Electric Company
GPRS	General Packet Radio Service, a packet-based wireless communication service that provides continuous connection to the Internet for e.g. mobile phone and computer users
HCI	Human-computer interaction, the study of interaction between people and computers
ICU	Intensive Care Unit
ID	Identification
Measurement parameter	a value measured from the patient that represents the patient's state of health, e.g. ECG, NIBP, SpO ₂
NIBP	Non-invasive blood pressure, measured normally with an arm cuff
OR	Operating Room
Patient monitor	a device which continuously or repeatedly measures and indicates the value of a variable from the patient to the operator
PDA	Personal Digital Assistant
SpO ₂	Blood oxygen saturation in arterial blood

UI	User Interface
Usability	The effectiveness, efficiency, and satisfaction with which users can achieve tasks
Waveform field	Area on patient monitor screen where a waveform representation of one measurement parameter is displayed
WLAN	Wireless Local Area Network

1 Introduction

GE Healthcare needs to develop a touch screen user interface for their patient monitors. Many competitors have already introduced touch screens and they have become popular among users because they are fast and simple to use. Not having a touch interface is a significant competitive disadvantage for the company.

In the future patient monitors will become more versatile and offer more functions than just monitoring patient vital signals. Among the first applications there will be a web browser and e-mail client that will require a mouse and a keyboard for efficient use. The work done in this thesis is the beginning of the user interface development part of the product development process of a new patient monitor model that has a touch screen, mouse and keyboard as input devices.

The design work is done with a user-centered approach in order to produce a user interface that does what the user needs without disturbing the more important task of caring for the patient. ISO 9241 standard defines usability as the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments. In this case we want medical personnel to achieve the goal of giving the best possible care to their patients in hospital environments.

1.1 Objective and scope of the thesis

The first objective of this thesis is to find out what is the level of existing research on using different input devices and in particular touch screens. The new patient monitor will have a mouse, a keyboard and the traditional control wheel as input devices in addition to the touch screen. The advantages and disadvantages of having multiple input devices will be considered based on existing research and usability tests. Some future input devices and interaction methods and their applicability to medical devices in different use situations will also be considered.

The second objective of this thesis is to design the touchable look and feel for the interface and to ensure that the usability of all input devices is at an acceptable level. This will be done through usability testing. The touch screen will be emphasized because the company has not designed monitors with touch screens before. Design of the touch interface will not start from scratch but will be more like a transformation of the old control wheel operated interface into a touch interface.

This thesis does not aim at evaluating and improving the current menu structure, work flows or other functionality of the device. The underlying design and functions have been developed in earlier projects where usability issues have been taken into account. However, if issues related to the current design arise they are reported and improvements suggested.

1.2 Structure

This thesis can be divided into two parts, a conceptual part and a practical part. Chapter 3 forms the conceptual part where the ground rules for user interface design and input device usage are set. Chapter 3 covers the existing research on using multiple input devices and touch screens and presents some guidelines for UI design. Chapter 4 forms the practical part where the development process of the new UI is described. Chapter 5 concludes the work with a description of the resulting final user interface and a summary of the most important points about different input devices and their use.

2 Background

This chapter provides background information on the product that will be designed, its users and the environment where it will be used. The information on the hospital environment and users is based on my own hospital visits and interviews with users as well as GE internal reports on hospital visits made by other people. The use scenario is based on my knowledge of hospital work and its relevancy has been checked by a nurse.

2.1 *Company*

GE Healthcare is a unit of General Electric Company and it is headquartered in the United Kingdom. It develops and manufactures medical imaging and information technologies, medical diagnostics, patient monitoring systems, disease research, drug discovery and biopharmaceuticals. GE Healthcare employs more than 42,000 people worldwide. GE Healthcare Finland Oy was formed when GE acquired the Instrumentarium Corp. and its patient monitoring division Datex-Ohmeda. Datex-Ohmeda has traditionally had a remarkable market share in Finland, around 90%. Worldwide GE Healthcare has a market share of around 30%, which makes it one of the two largest players in the industry along with Philips.

2.2 *Process*

Figure 1 depicts the GE Healthcare Finland usability engineering process. The process used in this thesis follows this general process rather well. The usability engineering plan has been written for the entire product but starting from the second step of the right side column all phases are carried out in this thesis. Research on users, environment and tasks is done in the beginning in order to get a general idea of the needs and requirements for a patient monitor. The results of this work are described shortly in this chapter. General usability goals were set so that the new UI should be at least as easy and fast to use as the control wheel

operated UI. More specific goals were set for each usability test round separately. A new interface was designed and it was evaluated with usability testing. The interface was modified according to the test results and after the last test round the final UI was specified.

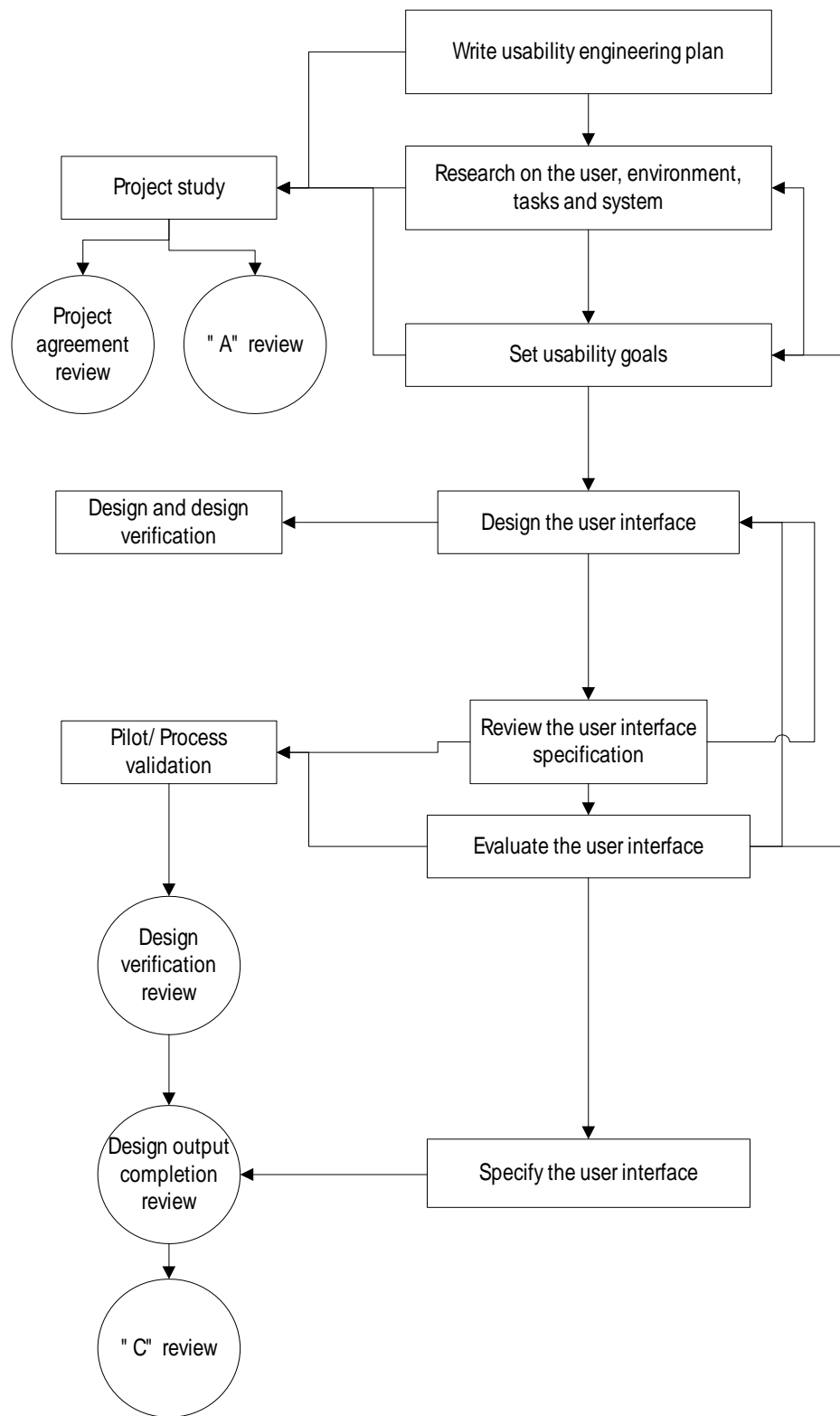


Figure 1 The GE Healthcare Finland usability engineering process diagram.

2.3 Product

Patient monitoring products are used in operating rooms, critical care units, emergency rooms and other hospital sites where the patients need to be monitored. The monitor can be used to follow patient's heart rate, blood pressure, breathing rate, blood oxygen saturation, inhaled and exhaled gases, brain activity, depth of anesthesia and other clinically significant parameters. High-end patient monitors, such as the anesthesia monitor in Figure 2, are modular and support the full range of parameters provided by the manufacturer. Different measurement modules can be attached to the monitor frame depending on which parameters are needed. Up to two dozens parameters can be measured simultaneously. On the other hand low-end patient monitors are smaller in size and have a fixed limited parameter set. They are often portable and might not even have a color display. There are two different versions of the patient monitor software, one for operating rooms (anesthesia or ANE monitor) and one for intensive care units (ICU monitor). The two software versions are very similar for the most part. The most significant differences are: operating room versions can measure anesthetic agents in exhaled gases, muscle relaxation and depth of anesthesia, which is not needed in intensive care where patients are not anesthetized. Critical care versions have a longer memory of parameter trend data because patients can stay in the ICU for several days while a surgery cannot last that long.



Figure 2 The Datex-Ohmeda anesthesia monitor is the flagship of the product line.

The results of this study will be first used in the design of a new patient monitor model that is scheduled to be released in the latter part of year 2006. The monitor will be portable, have a large color touch display and it will include most of the same features as current monitoring products. The new monitor model will be very similar to the current Compact Monitor that is displayed in Figure 3. Later on, the touch screen interface will most likely be used in other products as well.



Figure 3 The Compact Monitor is a current model that is very similar to the new one.

2.4 Input and output types

The most important input into a patient monitor comes from the patient not from the user of the monitor, that is to say the registered nurse (RN) or medical doctor (MD). The vital signs of the patient are continuously measured with different sensors and cables and the data is given to the monitor that displays the data. The sensors and cables can be thought of as the patient interface while the main subject of this study is the user interface, that is, the interface to the nurses and doctors.

Typical user input into a patient monitor can be divided roughly into three categories: entering alphanumeric data, performing functions and changing settings. Alphanumeric data can be patient name, ID, age, height, weight, given medications, performed or planned treatment and procedures and names of the medical personnel. Data can be entered at the bedside or from a remote location over a network.

Functions that can be performed on the patient monitor include initiating measurements, calibrating and zeroing sensors, creating and printing reports and screenshots and uploading patient data from the hospital network. Many of these functions require some physical contact with the patient or equipment, such as applying a sensor, injecting medication or opening a calibration switch, so they cannot be performed remotely.

Settings that can be changed include parameters that are shown on screen and in trend views, alarm limits and volume, measurement intervals and data display formats among others. Settings can technically be changed remotely but in practice it could cause a risk to patient safety, e.g. if one nurse by a remote station changes alarm settings and another nurse by the bedside does not know what settings are valid.

Typical output from a patient monitor comes in three forms: displayed on screen, printed on paper and audio. The most important output is the numerical and graphical real time data displayed on screen. Vital signs of the patient are measured and the results are displayed in a convenient form for the physician to interpret. Paper printouts can be produced automatically at pre-set times or when there is an alarm situation. Alarms can be indicated by a sound, by a blinking light and by a message on screen. Audio feedback can also be given on each heartbeat (pulse beep sound) and when a measurement is running or finished.

2.5 Users

The users of patient monitors are nurses, doctors and possibly other medical personnel. The technical and computer skills of users vary greatly according to their education and personal interests. The patient is the center of attention for medical staff and the monitor gets little attention. Monitor usage can be as light as simply attaching the modules and cables and occasionally checking the screen to make sure all values are normal. On the other hand the monitor can be used more intensively to enter patient data, laboratory data and care notes, to check parameter trend data, change alarm settings and to view the data of patients at other bedsides when the monitors are networked. For these reasons the patient monitor has to be intuitive and easy to use by occasional users and also efficient and quick for experienced users.

Medical staff needs to know and remember a large quantity of information to perform their duties. In addition to the vast medical knowledge they need to master the use several technical equipment, including the central monitoring station, IV pumps, ventilator, anesthesia machine, imaging equipment, blood sample analyzer, defibrillator, ECG analyzer and others. Ideally all these equipment have intuitive interfaces so the users don't have to stop and think about using them but can concentrate their effort on caring for the patients.

2.6 Environment

A typical hospital environment is very crowded. There are several machines around the patient and multiple measurement cables between the patient and the machines. The patient monitor can be located e.g. on a shelf above the patient's head or in a special suspender that brings the monitor closer to the nurse. It is possible that the monitor is located so high up or behind other equipment that it cannot be reached from the bedside. This is one reason why there needs to be an alternative to the touch screen input. Many monitors do have some sort of remote controller in the form of a small keypad of equivalent. Typical examples of an operating room and intensive care environments are shown in Figures 4 and 5 below.



Figure 4 Operating room setup. This is the working area of anesthesia doctors and nurses. The patient monitor is located high up on a shelf where it can be hard to reach for a shorter person.



Figure 5 In intensive care units nurses often need to control the monitor from both sides of the patient bed and they have a remote controller for this purpose.

2.7 Use scenario

John Doe is going to have a stomach operation and nurse anesthetist Betty is preparing the operating room for surgery. Preparations related to the patient monitor include switching the monitor on, attaching the required measurement modules and checking that all cables, lines and tubes are available. Betty sets the monitor to a specifically configured intestines-mode to activate applicable settings for the surgery and enters the patient name and ID into the monitor. Another nurse comes in with John who is still awake but drowsy from medication. The nurses attach the ECG cable, SpO2 probe, Entropy sensor etc. and when the anesthesiologist arrives John is ready to be put to sleep. The anesthesiologist administers the appropriate medications and intubates John (sets a breathing tube down his throat) so that a machine can do the breathing for him. John breathes a

mixture of air, oxygen and anesthetic agent that keeps him unconscious. He is also given intravenous medication to relieve pain and to relax muscles and stop reflexes so he will not move during the operation. The nurse anesthetist supervises the effects of all this medication throughout the surgery on the patient monitor screen to make sure that John is safe. The anesthesia must be deep enough to ensure that the patient knows not what is happening, feels no pain and does not move. On the other hand the anesthesia must not be too deep so that the patient will wake up at the desired time and will not feel nauseous after the operation. The waveforms and digits on the patient monitor screen are the most important signals of depth of anesthesia that the caregivers follow continuously.

All goes well during the operation and John is taken to the recovery room to wake up. The same patient monitor is used in the operating room, during the transport and in the recovery room. For transport the patient monitor is attached to the patient bed with a special mounting device. On the way to the recovery room Betty helps John breathe with a balloon-like manual resuscitator and in the recovery room John is again attached to a mechanical ventilator. The nurses watch over John and a few times the patient monitor alarms for low oxygenation but the nurse just silences the alarm because it is nothing serious. After the fourth alarm the nurse gets frustrated and adjusts the alarm limit to a lower value. When John is sufficiently conscious he gets to breathe for himself and both the nurse and the patient monitor make sure that he does not fall back to sleep and stop breathing.

Only a short while later the monitor starts alarming that John is not breathing. The nurse tries to wake him up but with no success. The problems with John's breathing are so severe that he is taken to the intensive care unit to be attached to a mechanical ventilator, again with the monitor attached to the bed. At the ICU the patient case is reset in the anesthesia monitor and all patient and trend data is downloaded to the ICU monitor from the hospital network. The nurses at the ICU have not seen John before and they check the downloaded data to learn about John's operation and current condition.

At the ICU a nurse cleans the incision wounds again and while doing this she moves around the bed a lot. The monitor is on one side of the bed and on the other side there is a remote controller that the nurse uses to silence a false alarm and start a blood pressure measurement. When the doctor comes to check in on John on his round he talks to the nurses, checks how John looks on the outside and looks at the trend data on the monitor to see if John is healing as planned.

3 Technology review

This chapter describes the different input devices used in patient monitors and presents some ideas for future input devices. Touch screens are explored in more detail because the next part of this study will be mostly touch interface design.

3.1 Pros and cons of using multiple input devices

Having multiple input devices means that there are several alternative devices that can be used to enter data into the monitor. At any one time there can be multiple input devices attached to a monitor, or only one input device, that is most suitable for the environment and tasks, can be selected.

Using multiple input devices takes up more workspace and interrupts workflow when users have to switch between devices. More initial effort is needed in order to learn to use several input devices instead of just one. Using several input devices is still justified by their unique features that make certain tasks far easier than with alternative devices. E.g. a keyboard is generally better for typing than a mouse but a mouse is again better for selecting objects in a graphical user interface. For drawing a stylus is likely to be the best choice, even a mouse can be used but a keyboard is next to useless for this purpose.

Having several alternative input devices for the same function can be advantageous as users have different preferences based on their prior experiences and they are pleased to have freedom of choice. Sometimes devices fail and the alternative input device can be used to get work done while waiting for a replacement. Also if an application is used in several very different use environments it can be beneficial to have different input devices for each of these environments.

3.2 Typical input devices in medical equipment

In patient monitors there is rather limited need for user input – vital signs of the patient are the most important input. In an extreme situation the medical staff makes no input directly to the monitor. In a short surgery input may not be needed and in an emergency room there may be no time for it. Some input device is still needed and here are introduced the common alternatives.

3.2.1 Measurement cables and modules

The most important form of input to a patient monitor are the vital signals that are measured from the patient, via cables and input modules so that no user action is needed after the cables are attached. E.g. heart and brain activity are measured as electronic signals from the patient's skin, blood oxygen saturation is measured by a non-invasive infra red finger probe and examples of exhaled gases are taken from the ventilation system and analyzed. However, attaching all the cables in the first place can take quite some time. E.g. a Swan-Ganz catheter is used for measuring blood pressure in the pulmonary artery in the heart and it takes about forty minutes to thread the catheter through an incision in the carotid artery into its correct place in the heart. The results of all measured parameters can be shown on the monitor screen in a convenient form for the clinician to interpret and decide upon the appropriate care procedures. Figure 6 shows an example of a measurement module and a cable.



Figure 6 Measurement module for ECG, SpO₂, NIBP, invasive blood pressures and temperature and a 12-lead ECG measurement cable.

3.2.2 Touch screen

Patient monitors are used in numerous different contexts and the requirements on input devices vary. Quite often a touch screen is sufficient to satisfy the need for input. Most tasks that need to be performed are simple enough to be done with a few touches and the occasional typing can be done with an on-screen keyboard. In many cases touch screens are complemented with some keys on the monitor frame. At the very least a power on/off switch is required.

3.2.3 Keyboard and mouse

Attaching a physical keyboard to the bedside monitor can be a good idea if much alphanumeric input is needed. This kind of input can include patient name and identification information, laboratory results, given medicine, performed procedures and other care information. A mouse could be used as a remote controller for a touch screen that is situated high up or behind other equipment, too far to touch. Mice and keyboards become even more important when in the near future patient monitors are equipped with web browsers, patient data management tools, x-ray viewers etc. These tools have traditionally been PC applications that are used with a mouse and keyboard.



Figure 7 The Datex-Ohmeda anesthesia record keeper keyboard for patient monitors includes all the same function keys as the patient monitor, special anesthesia-related function keys, qwerty-keyboard keys, numeric pad and the control wheel.

Standard keyboards and mice may not be rugged enough for all hospital settings, they require a lot of desk space and they are hard to keep clean and sterile so they cannot be used as the only possible input devices. Of course special, more robust keyboards have been designed for medical equipment but this often means that comfort of typing is compromised. This can be tolerated when not too much typing is needed and many users hunt and peck for keys anyway (Wiklund, 1995). An example of a dedicated patient monitor keyboard is depicted in Figure 7 above.

3.2.4 Wheel and keys

The wheel is a common and well-liked input device characteristic of medical equipment. The wheel needs to be accompanied by some keys that initially open the menus that are then scrolled by turning the wheel. The wheel is the green, round knob that can be seen in the keyboard in Figure 7 and in the remote controller in Figure 8. In current Datex-Ohmeda monitors most actions are initiated and selections made by pressing the wheel on the desired menu item. Text entry is done with the wheel by scrolling a list of characters and pressing the wheel on the desired character. A wheel can also be used in a remote controller together with some keys as seen in Figure 8 below. Interviews with medical staff have indicated that wired remote controllers are preferred. This is because wireless



Figure 8 A remote controller to a Datex-Ohmeda monitor.

devices can easily get lost or misplaced and it is not directly obvious, which monitor is controlled by a given remote controller.

3.2.5 Centralized input

In an intensive care unit all input may be done through a central station that is connected to all bedside monitors. The trend is that bedside monitor usage decreases and central station usage increases. Central stations are standard PC's that have keyboards and mice for easy input and more computing power and storage space than traditional bedside monitors. Working with a PC sitting at a desk is usually more ergonomic than walking and standing and reaching for the monitors in odd places in the crowded hospital environment. Using a central station also makes it possible to keep an eye on all the patients while working on the information of any one. Today central stations are only used to enter alphanumeric data such as patient name and identification information, laboratory results, given medication, performed procedures and other care information. Initiating measurements and other procedures cannot be done from a central station but need to be performed at the bedside.

3.3 Emerging technical possibilities

These future ideas are new input devices that have been mentioned in literature and they would bring some new and useful feature to patient monitoring.

3.3.1 Touch-sensing input devices

Touch-sensing input devices do not directly use the touch as an indication of position or selection like touch screens or pads. They are used in the same way as traditional devices such as mice or trackballs but they incorporate a touch-sensor that knows whether the user is touching the device. If the device is touched, even if it is not moved, clicked or used in any way, an “on-demand interface” is brought up. Thus when the user is touching the e.g. mouse, the selectable options or menus are shown and when the touch is released the menus are again hidden in order to free more screen space for the actual document that is being viewed. (Hinckley & Sinclair, 1999) In medical equipment screen space it is at a premium. It is important that the patient’s vital signs are always visible and preferably in a large font. Menus and such should cover as little screen area as possible. With a touch-sensing input device this could be achieved by displaying menus only when the input device is being touched. Currently a similar function can be achieved by having only one touch button that can be used to open a larger menu on screen. When the user has finished working he can again close all menus. In addition menus that are left open for a certain amount of time can be closed automatically. E.g. a touch screen keyboard that is used for entering patient name can cover up almost the entire screen, which can be tolerated for short periods of time but the keyboard should be closed when it is not being used. With a touch-sensitive input device the user would not have to open and close menus explicitly.

3.3.2 Projection keyboard

Projection keyboard technology can in the future find its way into the medical field. Electronic perception technology is used to project the image of a keyboard

onto a convenient surface by a tiny light source and a perception chip in the same device senses the user's finger movements in real time. A projection keyboard is indestructible, space-efficient and extremely configurable. In a medical environment a projection keyboard has special advantages because it can be projected on a surface such as stainless steel that is easy to keep sterile and endures liquids and chemicals. (Advanced Input Systems, 2005)

3.3.3 Voice control

Voice control can in time turn out to be a useful input to patient monitors. In some cases it would be advantageous if the physician didn't have to look away from the patient and move his hands to the monitor to check a value. The same idea also works the other way around: the monitor could produce audio feedback of the state of the patient. This is a complicated issue because it is hard to distinguish which events are important enough to cause the monitor to state them aloud. Too much audio feedback can be considered irritating and in a noisy environment some important information might be missed. (Wiklund, 1995) However, output is not the subject here. Some demos of voice control to medical equipment have been built but their reliability is not at a sufficient level or voice can only be used to initiate some functions (Sanjo & al. 1999). When dealing with a person's health or even life it is of vital importance to interpret all commands correctly and in a timely manner. A common problem with automatic speech recognition systems is the difficulty of interpreting the speech of different people with different voices and accents (Deng & al. 2004). This is problematic in the global market for medical equipment because software needs to be localized to several different languages and other than native speakers are bound to use the equipment. Also a noisy environment degrades the performance of automatic speech recognition and silence is by no means guaranteed in a hospital. There is also a privacy issue about spoken commands. Doctors may not want others to know what they are doing no matter how self-confident and professional they are.

3.3.4 Context information

Context information can in the future become an important form of input into medical equipment. This could reduce the number of steps that users have to make in order to perform their duties. Manual interface navigation would be reduced if context information could be used to predict what data is needed and what action is the most likely to follow. User identification could be done automatically by recognizing an approaching person by an RFID wristband or by fingerprints. Also patients could be recognized this way and when a given patient returns to the hospital, his medical records could be retrieved from the hospital network automatically. Context information could cause the monitor to change operating mode automatically if it is moved to another department or used for a different purpose than previously. Different alarms and conditions are of importance in different phases of an operation and the monitor could behave differently in the intubation phase, in the middle of the operation and in the end when the patient is waking up. Human errors can be decreased by equipment that prevents the administration of incorrect medicine to patients. This type of solution is already in use in medicine dispensers where the users types in a patient ID and the dispenser only opens drawers that contain medicine prescribed to that patient. There is no real context information involved, though. Some of the context aware solutions may still have a long way to go before all reliability and confidentiality issues are solved. (Bardram, 2004)

3.3.5 Mobile devices

Mobile devices can today be used for viewing patient data over a network. A mobile remote viewing system can run on a computer connected to the Internet, a PDA device with a WLAN connection or on a cell phone with a GPRS connection. Currently these devices can only be used for viewing data but in the future the connection could be bi-directional and a mobile device could serve as a personal remote controller for each member of staff. Then it would be possible to input alphanumeric data e.g. the patient's name or laboratory data to the monitor through

the mobile device. Still not all types of input could be made through a mobile device. The user still needs to be at the bedside for performing functions that need physical manipulation of equipment and changing some monitor settings remotely may be too risky. To the monitor it would not matter what input device is used to enter data to the mobile device, keypad, stylus or something else.

3.4 Selected technology: touch screen

Touch screen has been selected as the first new input device to be brought into GE patient monitoring products because it has many benefits over more traditional input devices. These benefits are explained in more detail in the following section. Another important reason for developing a touch interface is the fact that competitors have touch interfaces in their products and GE is losing deals to these competitors. Having a touch screens is not only a selling point that looks cool in demonstrations, they are also popular among nurses and doctors, the regular users.

When touch screens first appeared to the market in the 70's and 80's they were technically poor with low precision and high error rates. They were of no use in professional applications such as medical equipment. (Potter & al. 1988)

Nowadays touch screens are reliable and pleasant to use and they have become popular in situations where little typing is needed and speed is of importance, e.g. information kiosks and point of sale systems.

3.4.1 Touch screen pros and cons

Touch screens have several advantages over other input devices. Direct touching requires little thinking, is easy to learn, makes hand-eye coordination easier and is faster than pointing with other devices. No extra workspace is taken up by input devices that can get lost in the midst of other equipment and there are no wires to gather dust. Touch screens endure dirt and liquid, are easy to clean and can be used with gloves on. On the down side touch screens may be obscured by the user's hand, get smudged by fingerprints, long term use can cause arm fatigue and

some reduction in image brightness may occur. Touching by a finger is more inaccurate and dragging and sliding is harder than with a mouse. (Shneiderman, 1991; Waloszek, 2000)

A touch screen interface is best suited to applications where opportunity for training is low, frequency of use is low, accurate positioning is not required, little or no text or numerical input is required, desk space is at a premium or the environment may be chemically or otherwise "aggressive" (Waloszek, 2000). Several of these conditions apply to hospital environments. Part of the staff can be trained to use new equipment by the manufacturer but many users are only given short advice by their co-workers. There are always new employees and substitutes who receive no training. There are several devices from different manufacturers that all have a different interface and it is hard to remember them all, especially when some functions are needed infrequently. The need for text input at the bedside is very limited and the patient monitor is used only for short task with two or three clicks at a time. The hospital environment may be very crowded and even "aggressive" when strong cleaning chemicals are used.

3.4.2 Touch technologies

There are several different technologies used to recognize touches on screen. The most essential technologies are resistive, capacitive, surface acoustic wave and infrared touch screen. (Elo Touchsystems, 2005)

Resistive touch screens consist of a normal glass panel that is covered with a conductive and a resistive metallic layer, which are held apart by spacer dots. The voltage on the resistive layer is +5 V while the voltage on the conductive layer is zero. When the screen is touched, the conductive coating on the coversheet is pushed against the coating on the glass, making electrical contact. The voltages produced are the analog representation of the position touched. Because the touch is registered through physical contact, the screen can be touched with any object of any material. A resistive screen can be tightly sealed for cleaning and liquid drops

do not produce touches or harm the screen. The optical performance of resistive screen is relatively low because of the metallic layers. The layers can be damaged by sharp objects which makes resistive screens not suitable for public access systems exposed to vandalism. Resistive technology is the most commonly used, most likely because of its low price, and it is also used in medical applications.

Capacitive touch screens consist of a uniform conductive coating on a glass panel. Electrodes around the panel's edge distribute a low voltage across the conductive layer creating a uniform electric field. A finger touch draws current from each corner of the electric field. The controller calculates touch location coordinates by measuring the current and transmits it to the computer for processing. Strengths of the capacitive technology include a fast response time, good optical performance, durability and a tolerance for surface contamination. Capacitive touch screens work only with a conductive, grounded pointing device like a finger so in environments where gloves are required this is not an appropriate solution. Capacitive screens need frequent calibration.

Infrared touch screens generate a grid of light across the face of the screen and check for interruptions to that grid. The screen can be touched with any object that absorbs infrared light. The screen can be sealed to be water tight, it can be used in direct sunlight, it provides the best optical performance and scratches to the surface do not affect performance. The drawbacks with this technology are that the screen may sometimes react before it is physically touched, it is more difficult to integrate, needs a larger bezel, has a larger power consumption and is more expensive than the other technologies. Infrared screens are used in medical applications.

Surface acoustic wave touch screens send sound waves across the screen surface to look for interruptions caused by touch. The screen can be touched with any object except small and sharp objects such as a pen. The optical performance is as good as with an infrared screen and the screen is durable and vandal resistant. The

drawback with this technology is that it is affected by liquids and dirt that absorb the waves and cause “dead zones” on screen. It cannot be used in outdoor applications that are exposed to bad weather. Surface acoustic wave touch screens are also used in medical applications.

3.4.3 Touch interface design principles

This section describes design guidelines and principles that apply to user interface design in general and touch interface design in particular.

General

General user interface design principles apply to touch screens as well any other interface and they have not significantly changed over the years. The following seven principles with a large set of accompanying design guidelines were put forward by Dumas in 1988.

- Put the user in control.
- Address the user’s level of skills and experience.
- Be consistent in wording, formats and procedures.
- Protect the user from the inner workings of the hardware and software.
- Provide online documentation.
- Minimize the burden on the user’s memory.
- Follow the principles of good graphics design.

Nielsen’s (1993) ten usability heuristics comprise many of the same ideas.

- Use simple and natural dialogue.
- Speak the user’s language.
- Minimize user memory load.
- Be consistent in all aspects of the interface.
- Provide timely and accurate feedback.
- Provide clearly marked exits.

- Provide shortcuts for more experienced users.
- Provide good and informative error messages.
- Prevent errors from happening.
- Provide sufficient help and documentation.

Ergonomics

Arm fatigue caused by extended touch screen use can be reduced by tilting the screen in a different angle than traditional computer displays. Tilting the screen to a 30-degree angle from horizontal has been identified as a good choice (Sears,1991). Patient monitors are usually not used for a long time but they can be located high up or behind other equipment so that they are difficult to reach. The ideal solution would be to have the display attached to a free moving pivoted bearing so that the user can adjust the height and angle of the display. This cannot be done with a portable monitor where the display has to be attached to the measurement modules in one compact package.

Buttons

Touch buttons in finger-operated touch screens need to be large enough to touch accurately even with larger fingers. There also needs to be some space between them to prevent one touch hitting two buttons. In practice large enough is something in the order of 2 cm per side and some space in the order of 3 mm (Waloszek, 2000).

Touch screen buttons give no audio or haptic feedback of their own. It is a good idea to use three different looks for indicating the state of buttons:

1. default look
2. "will be activated" look that signals that the button is being pressed down and an action will be initiated when the button is released
3. "has been activated" look that signals that a touch has been registered and that the corresponding action is initiated.

The difference between these three looks needs to affect the entire button, not just

some part of it, and be significant enough to notice even when a finger is on the button obscuring part of it from view. In practice these three different looks are most intuitive when the button is made to look like it is in 3D. Auditory feedback can also be useful in some applications. (Waloszek, 2000)

When the screen is not viewed directly from the front but from one side or from lower or higher there may be a consistent bias between where users want to touch and where they actually do touch (Sears,1991). This bias has to be taken into account when designing the interface. Patient monitors are situated in varying locations and it is not possible to forecast the sort of bias that will occur. Therefore we need to be prepared for bias in all directions. In practice the touch buttons need to be big enough and there need be enough empty space between them.

Finger input

There are some special considerations related to finger input in addition to the need for adequate size. Long fingernails can cause accidental touches next to the place where the intentional touch was made. Unintentional touches can also follow from tracing a line of text with a finger when reading carefully or when pointing at something for another person to look at. Shaking hands can cause double clicks, which could be removed by filtering. It is common for users to touch lower with a finger than they would with a mouse pointer. This is most likely because the finger would cover the screen element from view and users want to see that they are touching the right element. (Miller, 1999)

In a hospital environment people often wear rubber gloves and the touch screen must work even with gloves on. They also use other objects than a finger to touch the screen. The eraser end of a pencil is a good stylus but sharper objects such as the sharp end of a pencil can damage the display. Having a screen that does not respond to touches with a sharp object would discourage their use. These factors need to be taken into account when choosing the touch screen technology. A resistive touch screen registers all touches with all objects and materials but can be

damaged by sharp objects. A capacitive touch screen must have a conductive input, usually a finger with no rubber glove, in order to register a touch. The surface acoustic wave touch screen allows a touch with almost any object except hard and small objects like a pen tip. Infrared touch screens are rugged and register touches with almost any object. In this respect the infrared or surface acoustic wave touch screen would be the best choice for a patient monitor.

Dragging

Dragging on a finger operated touch screen display is not recommendable and scrollable views such as web pages are not a good choice. Multiple window interfaces in Windows style are not practical on touch screens. In stead views should be changed with some form of tabs or page buttons. (Waloszek, 2000)

Panning on a touch screen by pushing the background has been found superior in performance and user preference in comparison to panning by touching the side of the screen and panning by pushing the view/window. (Johnson, 1995) This has no implications in our case since there is no need for panning in patient monitors.

Placing of interface elements

The area that a person sees can be divided into the upper visual field and lower visual field. Studies show that pointing on a touch screen is faster and more accurate for items in the lower visual field. Visual search and object recognition on the other hand are more efficient in the upper visual field. (Po & al. 2004) These results support the design choices made in patient monitors - touch buttons are placed in the bottom of the screen and the alarm message area in the top of the screen. Having the buttons in the bottom of the screen also means that the user's hand will cover as little as possible of the screen.

3.5 Expected benefits

Benefits that are expected from introducing new input devices into patient monitoring products include the following. A touch screen, where you can touch directly on the element that you want to manipulate, provides a more intuitive user interface and more direct access to features and menus. Touch screens are easy to use even for computer-illiterate users and pointing with your finger is natural while learning to use a new input device, such as the control wheel, can take some time.

Having the alternative of using the touch screen, control wheel, mouse or keyboard provides more flexibility and room for choice according to personal preference and use environment. When more features are added to patient monitors, e.g. browser and x-ray viewer, the traditional control wheel is no longer enough. One significant benefit is also the image issue – GE will be seen as being at the forefront of technological development, or at least even with competitors.

4 Developing the new UI

This chapter describes the development process of the new user interface starting with a short description of the methods used, continuing with limitations to the design, analysis of other touch screen systems and making the prototype and ending with results of usability tests.

4.1 Methods

The first task before starting to work on the new user interface was to get familiar with the old interfaces and company design guidelines. This meant using the products and reading documentation. The next phase was benchmarking other similar products with touch screens. This entailed expert evaluations that were targeted to find good design solutions as well as bad ones. The most important method in the development of the new UI was usability testing with prototypes. The prototypes and usability tests are described in more detail in chapters 4.4. and 4.5.

4.2 Design limitations

Designing the new touch interface cannot start from an empty paper. Older monitor versions have a certain look that is distinctive to the manufacturer and this brand-look should be conserved to some extent. On the other hand something fresh, new and modern should be brought in so that the UI does not look old-fashioned. GE has a set of design guidelines that should be followed in new products and consistency with other related products would be beneficial as well. Of course, all of these limitations cannot be fully followed at the same time.

4.2.1 Current products

Current GE and Datex-Ohmeda products have a different UI look and there is a need to find a unified look after the integration of product lines. Examples of the

GE and Datex-Ohmeda look are shown in Figures 9 and 10. The starting point to the new design was the Datex-Ohmeda look and changes were made when needed. The biggest change is the use of touch screen input. Older monitoring products do not incorporate touch screens and the main interaction methods are keys in the frame and the wheel. The keys open menus on screen and navigation is done with the wheel. Turning the wheel moves a cursor highlight in the menu and pressing the wheel confirms a selection.

Consistency with old products enhances usability because skills can be transferred and less training is required (Nielsen, 1993). A familiar look also gives users confidence and results in less resistance to using new products.

Datex-Ohmeda has a long history in usability engineering and the current Datex-Ohmeda interface is the result of several rounds of usability tests on different versions of the product. Therefore this study will not aim at covering all possible UI issues. The structure, depth and width of menus, choice between drop down menus, check boxes and radio buttons, abbreviations and icons etc. will remain similar to previous products if there is no specific reason to make changes.

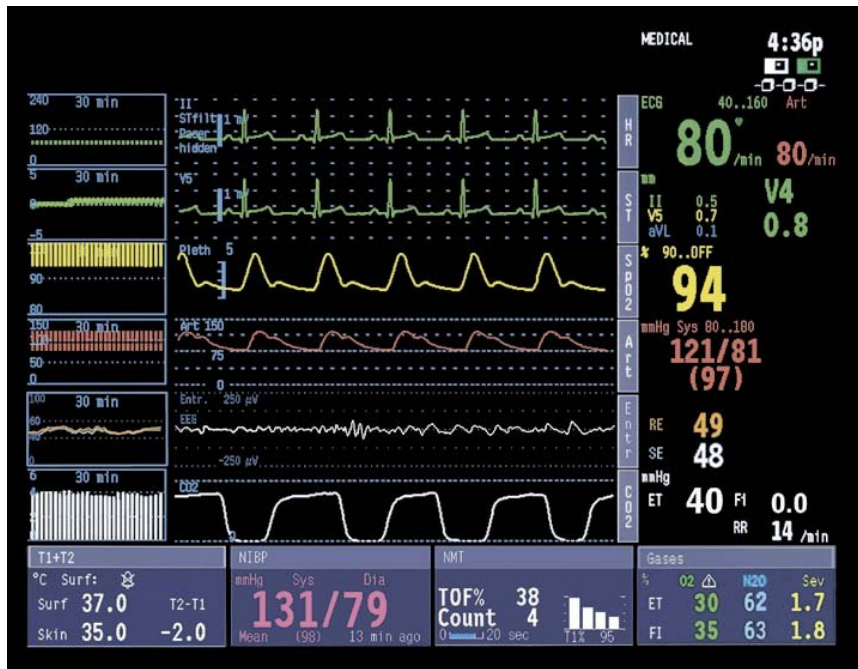


Figure 9 A screenshot of a current Datex-Ohmeda anesthesia monitor.



Figure 10 The Dash portable monitor with the current GE look.

4.2.2 CUI guidelines

GE Healthcare has a set of Common User Interface (CUI) guidelines that should be followed in all products. The mission of the Global Design CUI Initiative is to provide a consistent user experience for all customers. The CUI guidelines include definitions of recommended fonts, colors, UI components and controls, branding issues and more. An example of the CUI look is shown in Figure 11 below.



Figure 11 Examples of regular mouse-operated CUI elements on the left and a touch screen combo box on the right.

The CUI guidelines include a section on finger operated touch screen interactions. The recommendations state that touch screens generally follow all CUI standards but the size of controls is increased as has been done with the combo box in Figure 11. The size of all controls should be at least 36x36 pixels (1,27 cm) and preferably 54x54 pixels (1,90 cm). Spacing of controls also needs to be reconsidered. Users tend to touch slightly below the control which means that increased vertical spacing is required. Spacing between smaller buttons is recommended to be 36 pixels and between larger buttons 9 pixels.

It is recommended that all dragging, sliding and scrolling should be avoided and alternative designs be devised for touch screen applications. Also 'double-click' and 'right-click' are difficult to implement in touch screens and all actions should be activated with a single press.

4.2.3 Centricity Anesthesia patient data management

Centricity Anesthesia is a product family of patient data management tools that is produced by another GE Healthcare subsidiary. Centricity Anesthesia is a PC based database tool that has a touch screen interface that can also be used with a mouse. It runs on a Windows PC and it needs the mouse to ensure that all small Windows components can be selected. In the application itself buttons and such are large enough for touch screen use. The idea is that the touch screen can be used for selecting everything within the application and the keyboard can be taken into to use when entering data. A mouse can be added to workplaces where other applications are used as well. Centricity Anesthesia is a more comprehensive tool than a patient monitor and it has a distinct PC application look to it as can be seen in Figure 12. The Centricity Anesthesia look cannot be copied to patient monitors as such but it is good to bear in mind as an option. Using some of the same elements might be a good idea for consistency's sake.

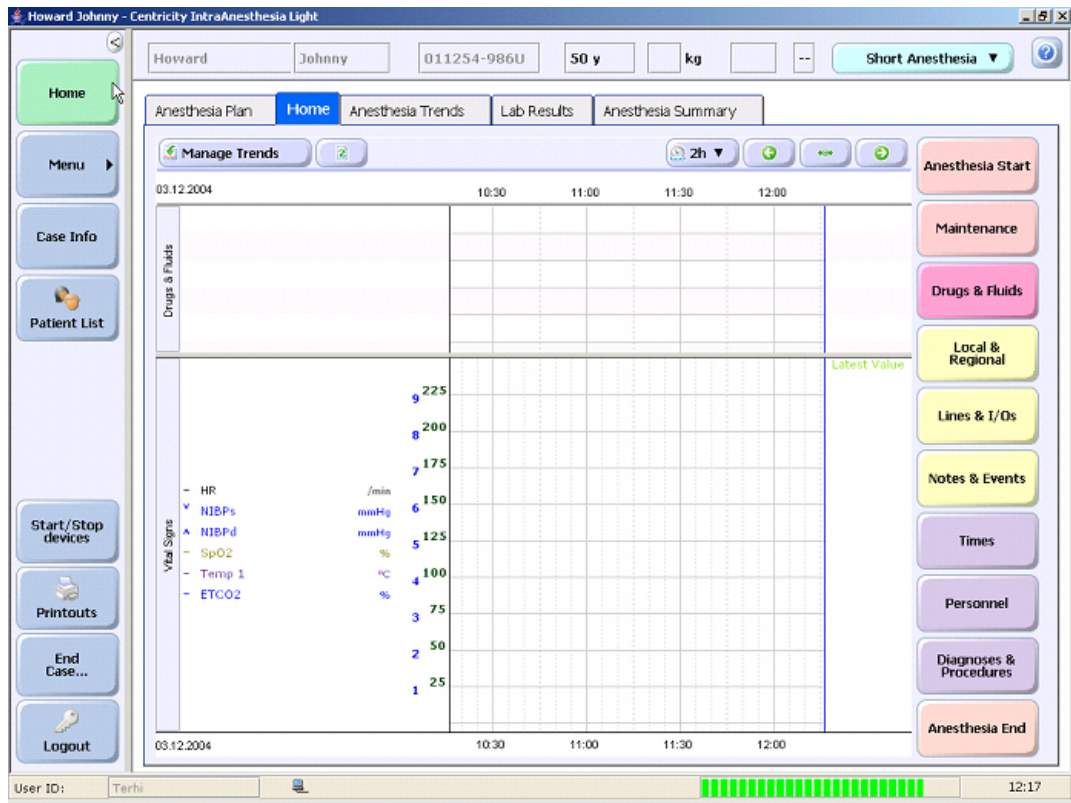


Figure 12 A screenshot of Centricity Anesthesia patient data management tool.

4.3 Analysis of other touch screen systems

The competitors of GE have been swift to adopt touch screen technology. Philips, Spacelabs and Nihon Kohden all have patient monitor models with touch screens available. Nihon Kohden also has a model with optional mouse and keyboard. Dräger Medical has a monitor with a standard PC keyboard but no touch screen. GE needs to adopt these new input methods to keep up with competition and to keep the image of an innovative company. Unfortunately only Philips monitors were available for evaluation because Datex-Ohmeda monitors are most common in Finland. Another relevant device found was Siemens Servo i ventilator. It has a touch screen interface and its features are similar enough to patient monitors to justify a closer look.

4.3.1 Philips MP50

Philips is the biggest competitor of GE in the patient monitoring business. Their equivalent to our new monitor is the MP50 portable patient monitor shown in Figure 13. Three usability experts from GE performed expert evaluations of the MP50. The most important insights from the evaluations are listed here.

- The menu windows do not open consistently to the same place and they are of different sizes. Sometimes they are so big that they cover up important information, e.g. NIBP and HR.
- You would want to move / drag menu windows like on a computer screen, since this is a touch screen, but you cannot. Drag and drop functionality in general would be nice.
- In several menus there are options both in the menu window and in the bottom of the screen. It is hard to notice that there is important functionality at the bottom when you are looking at the window and your hand blocks the bottom of the screen from view.



Figure 13 The Philips MP50 patient monitor.

- There are several inconsistencies in the functionality, e.g. 'Print reports' button opens a menu named 'Reports', touching a black area usually opens a screen setup menu but not always, alarm limit adjustments looks different when you do it in parameter setup menu and when you do it alarms setup menu, some menus are closed automatically after a value has been selected while some do not etc.
- When you are using the wheel and you close a menu window you don't know where the focus is.
- Turning the wheel with normal screen on, the focus goes through all empty areas on screen when you scroll which makes it slower to get to the parameter you want to configure.
- You can easily lose track of the wheel focus when it moves between the lower menu and the menu window. It seems that sometimes the highlight is nowhere and pressing the wheel does nothing.
- It seems to be impossible to go everywhere and do everything with the wheel.

- When you open a submenu from the bottom menu, there is no 'previous menu' button. You have to know to press the 'main screen' button. This way you also lose the menu path where you were before the last choice. It is unnecessarily hard to e.g. change alarm limits after changing alarm volume when you have to select 'main screen' in between.
- Menus or individual items in menus are not disabled when they are not available because e.g. some measurement is not used or there is no printer connected.
- There are annoyingly long delays in some functions e.g. loading 10 min trends in alarms setup or displaying a printer error message.

4.3.2 Siemens Servo i

Siemens is not directly involved in the patient monitoring business but they do manufacture several other medical devices. The Servo i ventilator has a touch screen, some keys and a control wheel on the frame and mechanical switches for gas flow control. The device can be seen in Figure 14.

The studied ventilator is not based on latest touch screen technology, which is evident by the heavy pressing needed to get a reaction. Touching with a fingertip does not suffice. Pressing rather hard with a fingernail is the best way to use the device.

For patient data input a qwerty-keyboard is shown on screen. The key size of 1,2*1,2 cm seems rather small. However, users responses in the first usability tests of our paper prototype indicate that keys of this size are sufficient. Also in this case the key size is appropriate when in any case you get better results by using a fingernail to press the screen.



Figure 14 Siemens Servo i ventilator (from <http://www.nagelnetwork.com/Maquet/maquetServoiBeta.htm> checked 30.06.2005)

Value adjustment works in a way that might not be obvious at first glance. First you have to select the value to be adjusted by touching it on screen. Then the value can be adjusted with the control wheel but there are no touch buttons for this. This is a fast way to do the task after you get used to working with the two input methods intermittently, e.g. left hand touching screen and right hand turning wheel. Still it would be best to offer both adjusting with the wheel and with touch button arrows.

Some gas flow setting adjustments feature a kind of color-coded progress bar. This bar indicates by green color that the value is in the safe and natural range and by red that the value is in an unsafe range. White is used for 'out of range'. This type of color-coding could be considered for e.g. alarm limit adjustment in a patient monitor.

4.4 Making the prototype

The process of developing the new touch screen based user interface started with a paper prototype that was a modified version of the current non-touch UI. A subset of the screens in the real product was captured as screen shots. These screens were modified in Photoshop to accommodate use by touching. In essence the first prototype looked like the current monitor with larger menu items and buttons. General and GE touch screen design guidelines, competitors and GE's touch screen based products and other touch screen systems were kept in mind as background information to help in the design of the touch elements.

The functionality of the prototype is such that by touching the digit field of a parameter you can open the setup menu for that parameter. Digit fields are the numeric areas at the bottom and on the right side of the screen. What would happen by touching the waveform field was left as a question for the users to answer. Menus that are not related to any one parameter can be opened through the touch button bar at the bottom of the screen.

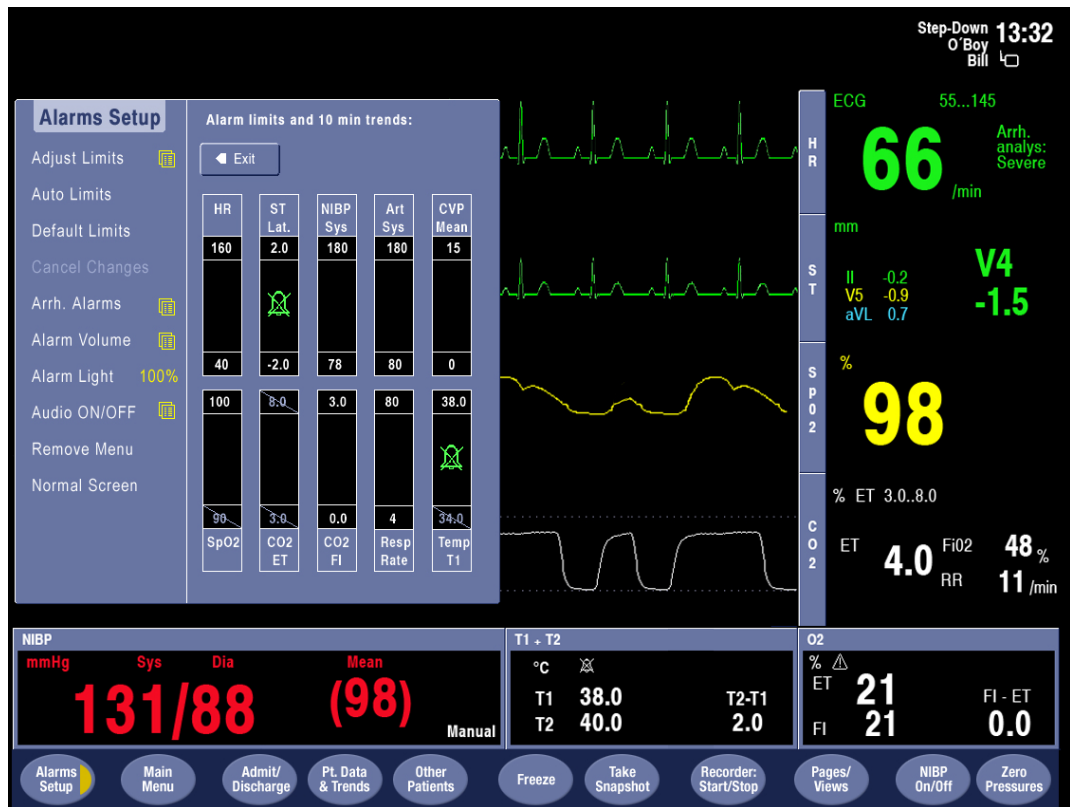


Figure 15 The *Alarms Setup* menu in the first prototype.

Two areas for special interest were the *Alarms Setup* and *Trends* -menus that are shown in Figures 15 and 16 respectively. In the *Alarms Setup* menu you can set alarms limits for all parameters, e.g. when the patients heart rate is faster than 120 beats/min the monitor will alarm. The desired parameter is touched in the menu shown in Figure 15, which opens a new menu where the alarms limits can be adjusted with up and down arrows. There were two different alternatives for these arrows and users were asked which alternative they preferred.

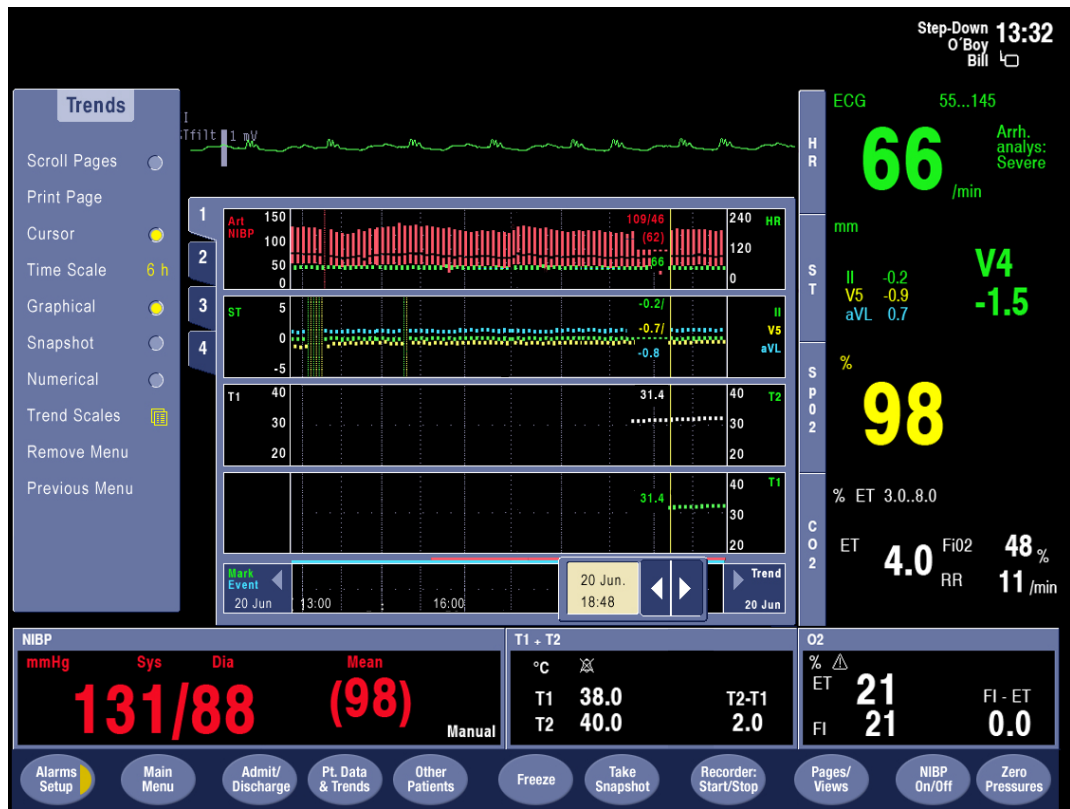


Figure 16 The *Graphical Trends* page in the first prototype.

The *Graphical Trends* page in Figure 16 shows a graphical representation of the patient's vital signs for the past six hours. The time scale of the trend can be changed in the menu on the right and this function was one of the tested features. There are four pages of graphical trends with different parameters on each page. The pages can be changed with the numbered tabs or by touching the *Scroll Pages* item in the menu. The yellow vertical line in the trend graph is a cursor that shows the numerical values of all trended parameters at the time. The cursor can be moved to a different time with the arrow widget at the bottom of the trend graph. There are also numerical trend pages that show the same trend data in numerical form.

In current patient monitors, there is always an advisory prompt text in the bottom left corner of each menu. When the control wheel focus is on a menu item, the text

describes the functionality of that menu item. This type of feature would be hard if not impossible to realize in a touch screen because there is no focus or cursor that moves on screen. Throughout the three usability test rounds the users were asked if they missed the prompt text or felt like they needed some help using the monitor.

Usability tests were performed on the first prototype to find out more about user expectations. Based on these test results the prototype was modified and a new test round was performed on the second paper prototype. After some more changes to the design, the third test round was performed on a partly functional prototype implemented with PowerPoint and visual basic.

4.5 Evaluation of the prototype with usability tests

This section describes the goals and results of the three usability test rounds that were performed on prototypes of the touch interface. The first two tests were performed with a paper prototype and the third test with a limited functional prototype implemented with PowerPoint and visual basic.

4.5.1 First test round

The first test round concentrated on the touch screen part of the user interface because there was little prior experience on touch screens. Within the touch screen the focus was on the *Trends* and *Alarms Setup* –menus because they are among the more complex parts that are used often in the product.

The aim of the test was to get early feedback from users and hear their ideas and expectations of touch screen monitors, in the manner of concept exploration. We wanted to find out what parts of the UI will need to be changed and in what way when we include a touch screen in the product. We also wanted to find answers to the following more precise questions.

- How do users feel about the advisory prompt texts in menus? Do they need or want them?
- How should the scrolling arrows be placed in the trend pages to make them as intuitive as possible?
- Do users understand the logic of scrolling the trend cursor, changing pages through tabs and changing the trend time scale?
- How should selections be confirmed?
- How should alarm limit adjustment work?
- Which areas are conceived as touchable and what is expected to appear by touching them?
- How large should the touchable areas be?
- What is expected to happen if you accidentally touch a different area of the screen while working in some menu?
- What is good and bad about touch screens? (The test users were accustomed to using touch screen monitors in their work.)

The usability goals were that users understand the logic of the product and are able to perform all test tasks. The goals were rather indefinite because at this stage we still wanted to explore the concept of touch screens and get acquainted with nurses' mental models and expectations.

The tests took place in Etelä-Karjalan Keskussairaala (South Karelia Central Hospital) in Lappeenranta, Finland, on June 14th to 15th 2005. The six test participants were nurses from cardiac monitoring and intensive care units and they had prior experience of using touch screens in their work. Prior experience of touch screens was important because it would be very hard to imagine that a paper prototype is a touch screen if you have never used a real touch screen and know what it is like.

Every test session proceeded as follows. First the user was asked to sign a non-disclosure form and fill in a background questionnaire. After this the user performed tasks and answered questions about the UI. The tests were recorded on video and notes were typed on a laptop computer.

The very general usability goals set for this test round were fulfilled for the most part. Users seemed to understand the functioning logic of the product and they were able to perform the tests tasks with a little assistance with the terminology. It is impossible to tell how much assistance would have been needed if the prototype had been in Finnish. The prototype was in English, which turned out to be a small problem. We got answers to the questions that we had set before the tests. These answers were kept in mind when designing the next prototype. The most important findings of these tests are listed below.

Touch screen

All test users were used to touch screens in their daily work and they liked using them. They all preferred using touch screen functionality to keys or wheels. They said that touch screens are good, modern, robust, quiet and fast when you can access everything directly. The only down side is that they get smudged with fingerprints if you have sweaty or dirty hands or have just put on hand lotion. It is important that the technical performance of the screen is good and that it registers even light touches with a fingernail.

Tabs

Five out of six users said that the tabs were a good and quick way to change trend pages and that they didn't necessarily need another way to do it as well.

Unfortunately only one user recognized them independently while the others had to be instructed to try them. That one user had seen tabs in computer programs, the others did not remember seeing them before. One user said that she would prefer changing pages with arrows. The tabs can be seen in the *Numerical Trends* page in Figure 17.

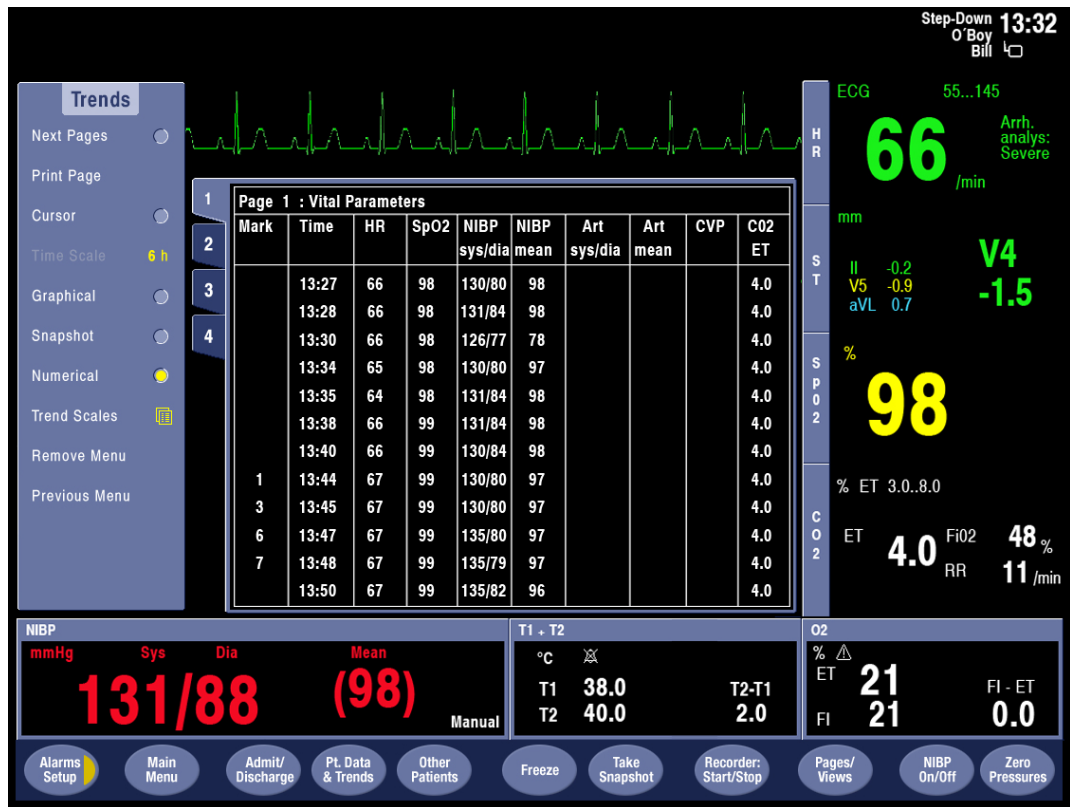


Figure 17 The *Numerical Trends* -page used in the first usability tests. There is no cursor for scrolling because users were asked to tell their opinions about suitable cursor behavior.

The trend page tabs could be labeled with longer names to make them easier to notice and understand. Ideally the label would tell the user which parameters are on that tab but obviously there is not enough room for that. The tabs could read e.g. 'Page 1' instead of plain numbers to make it clear that these are different pages. The 'Pages' could also be written only once on top of the area where the tabs are.

Confirming selections

The confirmation of selected values should work consistently everywhere in the UI, e.g. in trend time scale and alarm limit adjustment. The users preferred not having to confirm selections so that all changes would take effect immediately and remain in effect after exiting the menu. This would reduce the number of times

they have to make selections on screen. However, they would also accept the use of a confirm button.

Selectable menu items

The menu items that can be selected to change a value, e.g. for changing trend time scale, should be made to look like they can really be selected to change the displayed value. This could be done by adding the word 'change' to the name and by adding small arrows next to the value 6h to indicate that the value can be changed, that it is not only displayed as information.

Accidental touches

When you are working in one menu, e.g. adjusting alarm limits, and you accidentally touch another area on screen, e.g. ECG digit field, what should happen? The users would not be surprised if this would cause the *Alarms setup* menu to be closed and the *ECG* menu to open, most of them even expected this to happen. They would simply go back to where they were and finish what they were doing. One user said that she would expect nothing to happen since the *Alarms setup* menu is active and thus the rest of the screen should not react to touches. That would however cause a problem when you really want to leave the *Alarms setup* menu and go to the *ECG* menu because the screen would not register your touch. The users said that these kind of accidental touches are not very common. With this in mind it would be better to have the entire screen active all the time.

Digit fields

All users said that by touching a digit field you should get to the menu of that parameter. Combining all answers, this parameter menu should include all applicable settings, trends, alarm limits and possible measurement start/stop functions.

The users said that they didn't want one digit field to be split up into smaller areas that would have different functions, e.g. alarm limits, unit, label. They don't want

to tinker with many small areas that are hard to touch accurately. There was one reason to believe that they were saying one thing and doing something else: some wanted to start a manual NIBP measurement from the text 'Manual' in the NIBP digit field.

All in all, it would be best to make a digit field into one touchable area that takes you to the parameter menu where you can access all functions for that parameter. The NIBP measurement quick button should be placed close to the NIBP digit field but not inside it.

Waveform fields

Touching a waveform field was a point where the users were not as unanimous as with touching a digit field. Touching a waveform might do nothing at all, return to normal screen, stop and enlarge the waveform, print the waveform or open the parameter menu (same as digit field). The general attitude was that "anything goes, we will get used to it".

There are already quick ways to get back to normal screen (key in the frame), to get into the parameter menu (digit field) and to print the waveform (touch button) so there's no pressing need to have a second way to do these things. Stopping and enlarging the waveform would be a new feature and new features were not supposed to be added to this version. So this leaves the choice that nothing happens.

Another alternative would be to adopt the solution of a competing product (Philips) where touching a waveform opens a menu where you can change a different parameter to the field. This could mean that by touching any waveform you could open *Screen 1 setup* menu.

Changes to the prototype

In the second version of the prototype the tabs in *Numerical Trends* were moved to

the top of the trend area. The goal was to find out if the tabs are better noticed in a different location. There was not enough room to write the page names on the tabs in a visible font. The direction of the time-line in *Numerical Trends* was changed to run from left to right so that the numerical trend can be scrolled in the same way as the graphical trend. Double arrows for 'fast-forward' scrolling were added to both graphical and numerical trends.

The look of menu items that can be changed by the users was changed to make them look more editable. Two different versions were made to ask the users which alternative they preferred.

A new menu path to *Demographics* was added to the prototype. This is a menu where you can enter patient's height and weight. The path to this menu is a rather long one and one of the goals with making this menu was to probe users' feelings about deep and narrow versus shallow and wide menus. Another goal was to study the use of a numeric pad for data entry. There were also two separate on-screen keyboards with qwerty- and acb-layouts for the users to choose their favourite alternative and place it on the screen where they want.

Some items in the row of touch buttons in the bottom of the screen were changed because of usability test results from another project. The goal was to find out how this new button set is received. Also the look of the buttons was modified to be more compliant to the GE Common User Interface guidelines. The second prototype was done in Finnish because the use of English language was a problem for some test users.

4.5.2 Second test round

The second test round still concentrated on the touch screen part of the user interface. Text input and trend menus were of special interest because an on-screen keyboard is a new feature and the trend menus were modified a lot since the last tests. We also studied the combined use of touch and the control wheel.

The aim of the test was to get more feedback from users and hear their ideas and expectations of touch screen monitors. There can be significant differences between different hospitals and departments in the way they use monitors and in the features that are needed. This is why we need feedback from many sources and we need to ensure that the product will be usable for all users. We wanted to find out if we had made the right changes to the UI after the first test round to enhance ease of use and intuitiveness. More precisely, we wanted to find answers to the following questions:

- Were the changes made after the first test round justified in that they help resolve usability issues and do not introduce new problems?
- Does the user interface work consistently?
- How should the interface work when using both touch and the control wheel?
- What type of on-screen keyboard do the users prefer (qwerty or abc) and where should it be positioned on the screen?
- What do users think about the new button row that was designed according to feedback from usability tests in another project?
- Which areas on screen are seen as active and what should happen by touching them?
- Are there any remaining or new usability problems?

The usability goals were that users understand the logic of the product and are able to perform all test tasks. The goals were rather indefinite because we still wanted to explore the concept of touch screens and get acquainted with nurses' mental models and expectations. Since the test was performed with a paper prototype it would have been very hard if not impossible to gather any useful quantitative data.

The tests took place in Oulun Yliopistollinen Keskussairaala (University Hospital) in Oulu, Finland, on August 25th to 26th 2005. The six test users were nurses in neonatal and children's intensive care units and had prior experience in using

touch screens in their work. A different hospital and different departments than in the first test round were selected in order to get a more comprehensive set of test users to evaluate the new UI. The test procedure was similar to the procedure of the first test round.

The results of the tests were good and the general usability goals were met. The users liked the touch screen concept and had no real problems in using the product. This time the prototype was in Finnish and the users had monitors in English at work. This was not such a big problem because it is easy to deduce the meaning of terms in your native language. The most important contribution of these tests was the confirmation that we have made good design choices and we got information on which we can base more decisions. The most important findings of the tests are listed below along with design recommendations.

Trends and snapshot

One of the six users found the tabs for changing trend pages independently. Further three users understood and liked them when they were explained and the two older users said they would prefer to use the menu item *Scroll pages*. In the *Numerical trends* four users noticed the tabs after first seeing them in *Graphical trends*. One user commented that the tabs are better situated on the side of the trend view, not on top, because they would be harder to reach high up. One user also said that the tabs on the side were easier to notice because they catch the eye when reading the view from left to right. Others said that it doesn't matter whether the tabs are on the side or on top. The graphical and numerical trend pages can be seen in Figures 18 and 19.

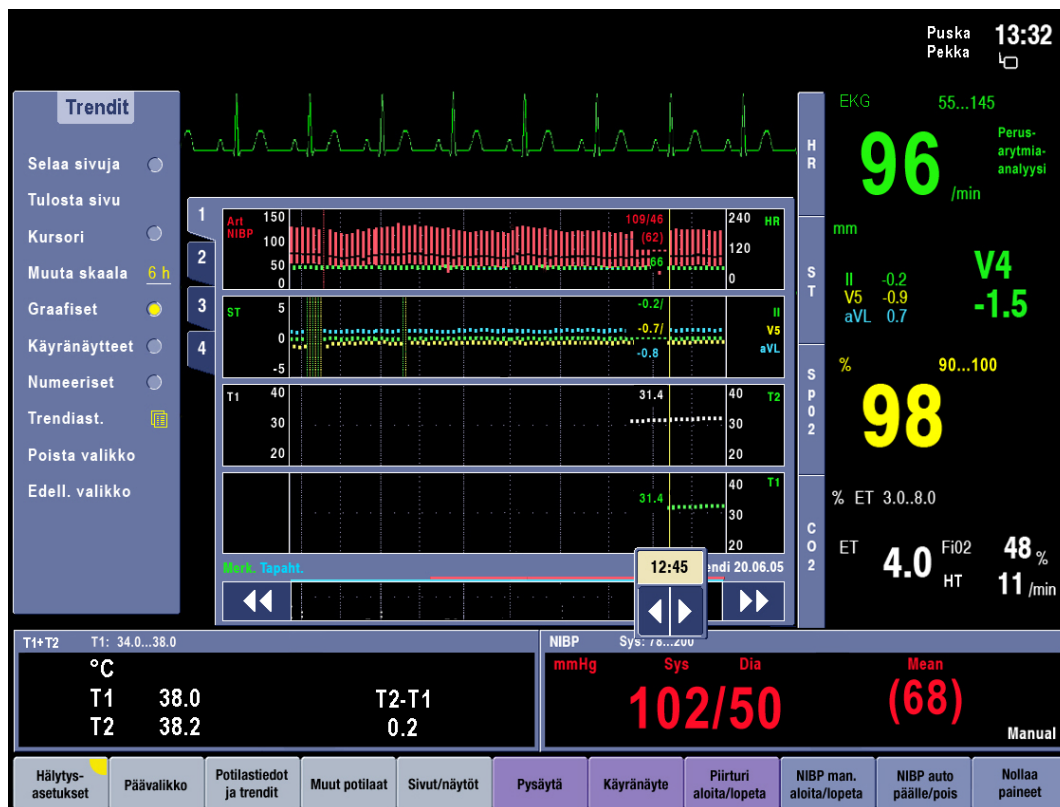


Figure 18 Graphical trends with the tabs on the side.

Two users said that their first intuition for placing the graphical trend cursor was to just touch the trend box at the spot where they want to go. The single as well as the double scrolling arrows were generally well understood. The only improvement suggestion we received was that if the single arrows could be user as a slider there could be a picture looking like a volume adjustment slider instead of arrows there. The cursor can be seen in Figure 19.

The new layout of *Numerical trends* as seen in Figure 20 was well liked and all users said it was clear and easy to read. They had no improvement suggestions. Also the layout of the *Snapshot* view was said to be good as it is.

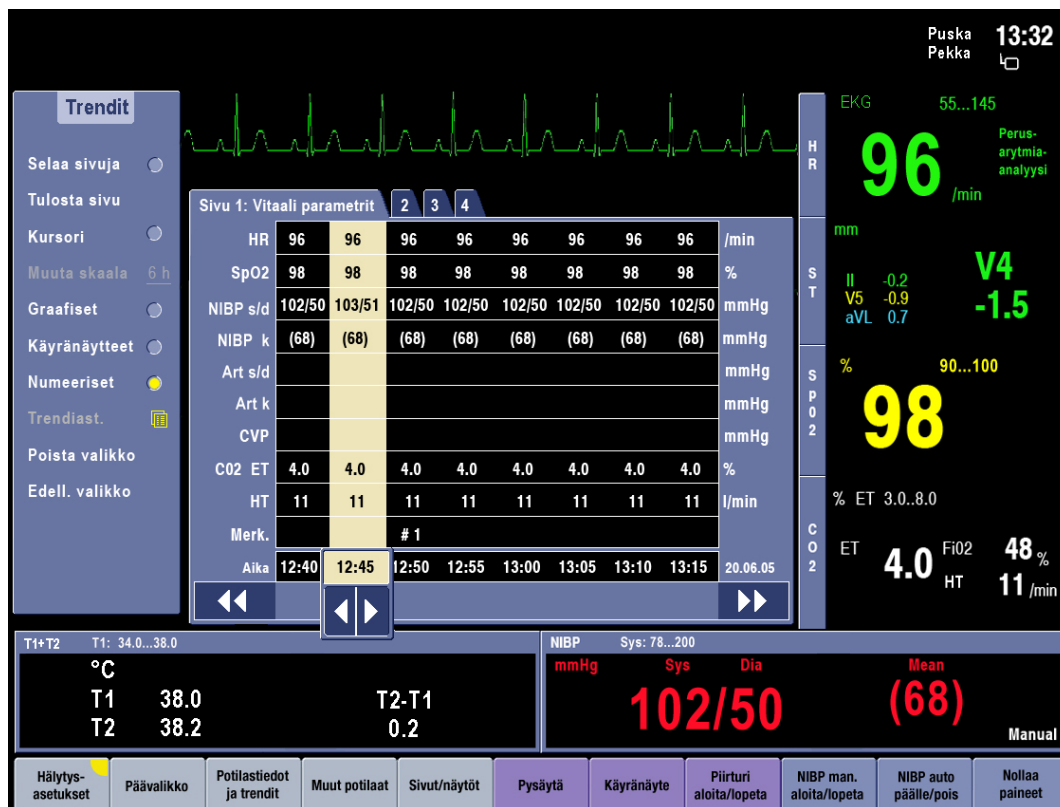


Figure 19 Numerical trends with the tabs on top of the trend area.

Three users found the *Snapshot* item immediately in the trends menu while the other three were unsure where to find it. One said that it does not belong in with the trends since trends are continuous data and snapshots are small pieces of waveforms from here and there. The *Pages/Views* button was one guess where snapshots could be. The meaning of *Pages/Views* was not clear to the users. After the meaning was explained some users still seemed unsure if the function was needed as a fast access button. Two users tried to see the snapshot by touching the *Snapshot* button. ‘Take Snapshot’ might be a better label for it to indicate that it cannot be used to view old snapshots.

No major changes are needed in the trend views. The tabs should be located on the side of the box because they seemed to catch the eye better there and the lower they are the easier they are to reach. The trend cursor arrows are good. The slider-

look can be considered but it may not be needed because the best function seems to be rough placing by pointing directly on the trend view and then using the single arrows for more careful adjustments. Some combination of slider- and arrow-look should be used if it is not possible in practice to move the cursor by direct pointing. The *Snapshot* view is good as it is but we should think about whether to keep the view as a part of trends or move to *Pages/Views* menu or somewhere else.

Admitting a patient and text entry

In general the menu structure of the admit menus seemed quite logical and users found what they were looking for, some after one or two incorrect selections. Deep menu paths were not considered good and the suggestion of combining demographics information to the same menu with name and id info was popular. Some users commented that a deeper menu path is not a big problem in this case since this is a feature that is not used in every case and it is only done once for each patient.

The general opinion was that upon entering the *Demographics* menu the numeric pad should already be open and the focus in the height field. The danger of unintentionally changing values did not seem too big because you still have to confirm changes with OK. After typing in the height and touching OK the focus should directly move to the weight field.

The users said that in the current situation they sometimes enter the name of the patient into the monitor. They were expecting to get a new patient data management system where they would need to identify each patient but then it would most likely be done from a central PC.

Two users preferred a keyboard with the keys in alphabetical order while the other four preferred a qwerty-keyboard. All users said that the keyboard should appear to the bottom left corner of the screen so that it would be easy to reach and not

cover up the vital digit fields in the right. Covering up temperature or even NIBP digit fields is not as bad.

The contents of the *Demographics* menu should be combined with the *Admit/Discharge* menu. When you enter the menu a qwerty-keyboard is open in the bottom left part of the screen and above the keyboard are shown the data fields. The focus is in the first data field, which could be patient's last or first name. After entering data and pressing OK the focus automatically moves to the next field. The field that is being filled needs to be highlighted enough to make sure that the user notices that after pressing OK the field changes. All of the data is confirmed with a *Confirm* button that closes the *Patient data* menu and returns to the previous menu.

Changing and selecting values

Users were asked to change trend time scale and NIBP cycle time and asked questions about changing settings. Three users said that selections should be confirmed by an OK button or equivalent. One user did not want any unnecessary touches but for the selections to become effective immediately. One user supported confirmation but also noted that when the setting does not affect patient safety it could be faster to make the change immediately.

To change trend time scale from 6h to 20min 3 users touched the down arrow and 1 user the up arrow. In the *NIBP cycle* time menu, to change the time from 5min to 10min, 1 user touched the down arrow and 3 users the up arrow. The *NIBP* menu can be seen in Figure 20. It seems that the down arrow should make a time value smaller and the up arrow larger.

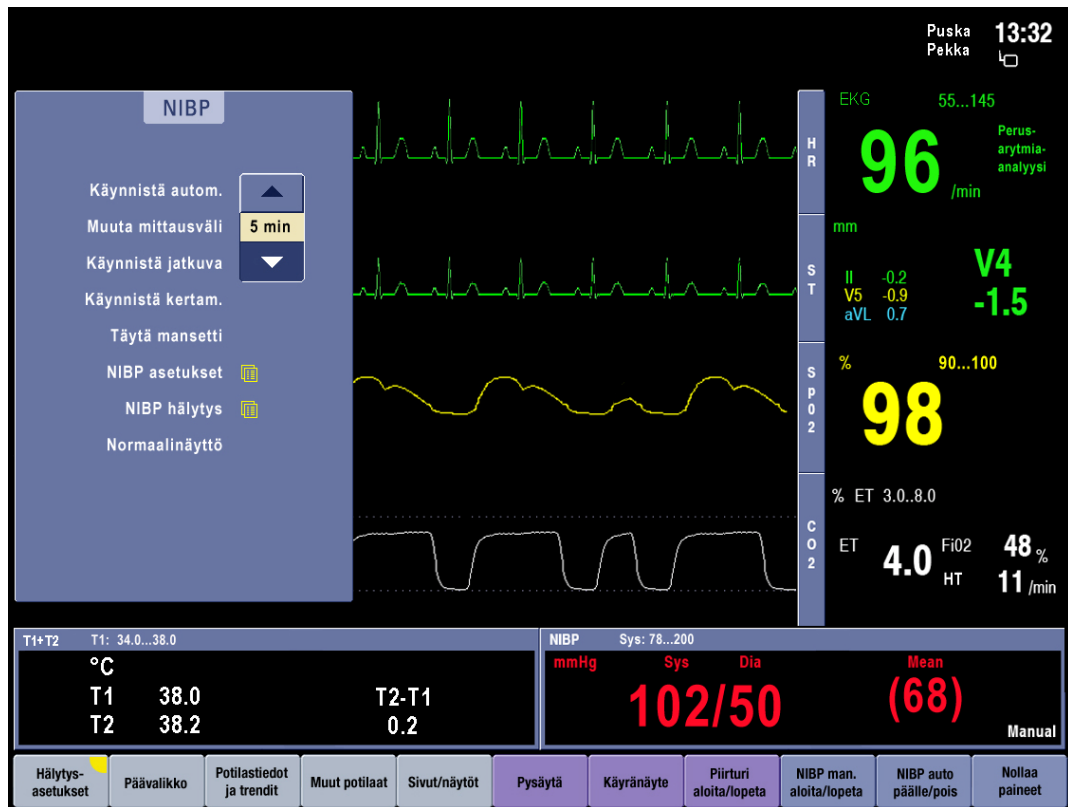


Figure 20 The NIBP menu with the cycle time selection box open.

The two users who answered the question about displaying more than 1 item at a time in the selection list said that it would be nice to know what the other alternatives were. Showing alternatives would help in knowing whether to touch the up or down arrow to get to the desired value and selecting the value from a list would also serve as confirmation so no OK button would be needed.

Users were asked which alternative design they preferred for indicating that a value was editable by the user. The alternatives were a light blue box around the value, looking like a text box, or the value in yellow and underlined as shown in Figure 21. The opinions were divided, three votes for each alternative.



Figure 21 The alternative designs for values that can be changed or edited by the user.

Values that can be entered, edited or changed by users should be indicated by background coloring similar to a text box. This choice is made because colored and underlined text can be mistaken for a hyperlink. When the box or its label is touched, a list of alternatives opens, showing several choices one of which is highlighted to indicate that it is currently in effect. The list can be scrolled up and down with arrows and a selection is made by touching an item on the list. This serves as confirmation and causes the list box to close. The list should be ordered so that shorter times or smaller numeric values are in the bottom of the list while larger values are at the top.

Active areas

All users said that the digit fields should be active and they could be used to get to “the details”. It seemed that the *NIBP* menu that opened from the *NIBP* digit field was pretty much what they expected. Adjusting limits was an important feature and they would like to have direct access to it, e.g. through the alarm limits displayed in digit fields. The digit fields will remain as a shortcut to the parameter menu. If alarm limits are displayed in the digit field, touching them will directly open that parameter’s alarm limit adjustment menu. Otherwise the entire digit field is one area that all leads to the parameter menu.

According to the users the waveform fields could provide access to settings related to them, e.g. size, ECG lead selection, saving a waveform strip. One user said that she would not like anything to happen from the waveform. At least for now the waveform fields will not be active because all parameter settings can already be reached through the digit field and no other functionality is needed. It would also

be a problem if someone points at an interesting part of the waveform and accidentally opens up a menu that then covers up the important spot.

All users said that the touchable areas were large enough. No one thought of touching the alarm flag, the clock, the network symbol or the name of the patient. The button row, menus and digit fields will be the only active areas. Other parts of the screen will not be active. Small pop-up menus should not appear next to the touched spot as in Philips monitors. Menus open always to the same place on the left and are of the regular size.

Control wheel use

All users liked the touch screen and did not see much use for the wheel. One user even asked why there has to be two ways of doing things, it will only cause confusion. Another user said she would use the wheel if she had dirty hands and did not want to smudge the screen.

In the trend views the most popular wheel function was moving the trend cursor. One user remarked that the wheel would be a good way to move the cursor when you want to find an exact spot. When the Trends menu is entered the wheel will first move the cursor. After pressing the wheel the focus goes to the menu.

In alarm limit adjustment the most popular wheel functions was to first change the upper limit. One user said that she would use the wheel instead of the arrows to change the limits because it is lower and easier to reach. When alarm limit adjustment is entered the wheel will first adjust the upper limit. After pressing the wheel it adjusts the lower limit and after pressing once more it moves a focus in the menu.

The users did not think there really needed to be any functionality with the wheel when the monitor was in normal screen. One said that there could be a focus that goes through the buttons and another said that the focus could also go through the

digit fields. When normal screen is on and the wheel is turned, a focus highlight could go through the buttons at the bottom of the screen. Parameters can be found in the *Main Menu* so there is no urgent need for the focus to go through the digit fields. It would only be confusing if the focus jumped from the button row to the digit fields that are lined in two different directions on screen.

In menus the wheel moves a highlight between menu items and for entering text the highlight could go through the keys on the keyboard.

Changes to the prototype

Before the third test round there was a larger change to the way the UI looks. The most notable changes were that the coloring of the menus was changed to a much lighter shade and all menu items were made to look like buttons. This was done in order to make the UI look more modern and more compliant to the GE Common User Interface guidelines.

The tabs in *Numerical Trends* were moved back to the side of the trend view because that seems to be the better place for them. The trend cursor can be placed directly by touching the trend on the spot where the cursor should go. More careful adjustments can then be made with the arrows. The *Snapshot* page was moved from the *Trends* menu into a new *Events* menu that will also contain a new feature called oxycardiogram (OCRG). The OCRG is a new feature that will be studied and developed in another project.

Deep menu paths were not popular so for the third prototype the menu for patient data entry was modified so that there were more data fields in one page together with an on-screen keyboard. The goal was to see user reactions to that and get feedback on the usability of the qwerty-keyboard.

Editable values were indicated by a background coloring similar to a text box. The list of choices was made to show more than one alternative. Selections in the list are done by touching an item and no other form of confirmation is needed.

Each parameter's alarm limits are shown in the parameter digit field in a rather small font. These limits were made to be a fast access to the alarm limit adjustment for that parameter. The goal was to find out if this fast access is appreciated and is the touchable area too small.

4.5.3 Third test round

The goals of the third test round were to check that there are no usability problems in the touch interface for former Datex-Ohmeda monitor and control wheel users. Now there was a real touch screen in use it was possible to try in practice what size of touch elements was considered too small. There were elements of different sizes in the prototype and user reactions to them were observed and answers to questions were recorded. The menu for patient data entry was modified after the second test round so that there were more data fields in one page together with an on-screen keyboard. We wanted to see user reactions to that and get feedback on the usability of the keyboard. As this was only a Power Point prototype the control wheel was not functional but we asked the users how they thought it ought to work to get confirmation to our plans.

The third test round was performed at the GE office in Helsinki on October 10th to 14th 2005. The users were this time from the anesthesia environment, three nurses and three doctors. Again we wanted to get opinions from a different user group after the last two rounds that were done with ICU personnel. The users of this test round use Datex-Ohmeda monitors in their work and their prior touch screen experiences were not considered before recruiting them. The intention was also to have one person from each previous test round to come and see how the UI is evolving and tell their opinions about it. This plan failed because no one from Oulu had time to come to Helsinki and the person who did come from

Lappeenranta had in fact participated in a test in another project. So there was no feedback about the UI evolution but still some comments from a Philips user.

The usability goals were that all users know how to use the monitor and think that it is good and easy to use. These goals were met and no major changes are needed to finalize the UI design. Results of the tests and design change recommendations are unfolded next.

Touchable areas

All users knew immediately that the button row at the bottom of the screen was indeed a row of touch buttons. Six out of seven users realized that the digit fields were routes to the parameter menus. Two of them said that the same menu should also open by touching the waveform fields and one said that the waveform field should open something related to especially the waveform. Four users said that there was no need for anything to happen by touching the waveform field.

One idea that came up was that the touchable areas could be lined with a thin grey line to indicate the borders of areas. This way it would be easier to tell how the screen space is divided into active areas.

All users said that it was a good idea to have direct access to a parameter's alarm limits by touching the limits shown in the digit field. Dividing digit fields into other smaller areas was not supported.

As long as the related digit field and waveform field are always next to each other the way they are in current Datex-Ohmeda monitors, the parameter menu should be opened by touching either one. It is easier and faster to touch a larger area and the area is easier to reach from either side of the monitor.

If alarm limits are displayed on screen, they should be link to alarm limit adjustment. Otherwise regular digit fields should not be divided into smaller areas.

The functioning logic of more complex digit fields such as Gases or VO2 where there is no clear parameter menu to go to, should be considered in more detail.

Patient data menu

The large size of the *Patient data* menu was acceptable to users. The common opinion was that menus are not open for a long time and if patient data is filled in at all, it is done before the patient arrives to the operating room. The on-screen keyboard seems large enough - no one had trouble hitting the correct keys although one user said that they could be larger still. The *Patient data* menu can be seen in Figure 22 below.

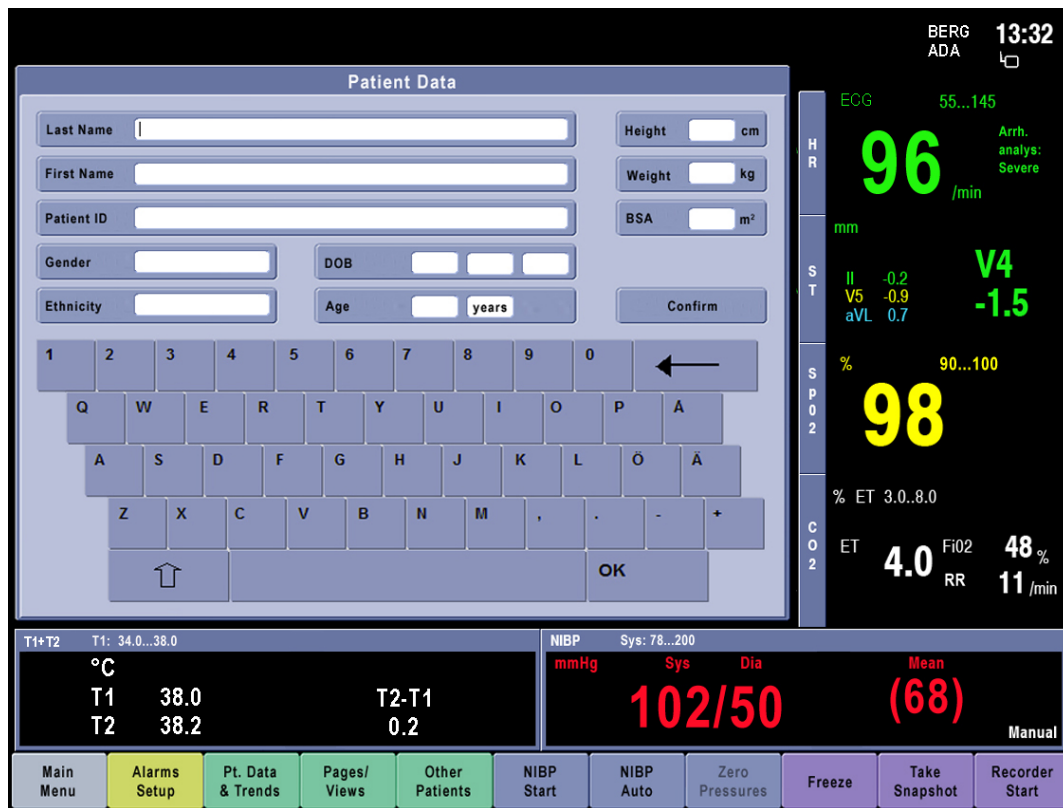


Figure 22 The *Patient data* menu used in the third test round.

Almost all users first tried typing patient's first and last name in the same field. After some thought they said that it is better to have separate fields. In the ideal situation all data fields would be checked for validity before accepting the data. One user suggested that a change in background colour could be used to indicate successfully entered data (e.g. green) and unacceptable data (e.g. red). Fields such as Date of birth should also have some indication of how to fill them (e.g. dd.mm.yyyy).

Some of the patient data fields seemed irrelevant to Finnish users. Date of birth and patient ID are in essence the same information and ethnicity is not of importance. The patient data menu needs to be localized and configured to accommodate different needs and features. Irrelevant and redundant information should be removed.

The users correctly expected the monitor to calculate values like age and body surface area based on previous values that have been input.

The OK and Confirm keys were seen as doing the same thing. The users assumed that all data would be saved no matter when or how they exit the menu. The Confirm key could be replaced by a Previous menu key that several users looked for when they wanted to leave the menu. The correct location for the Previous menu key might be somewhere in the bottom right corner of the menu because that is where the users were looking for it.

Several users did not use the OK key to toggle to the next input field but instead touched the field itself. Both ways of doing it should be supported. The term OK is not necessarily the correct one for this key. One user said that Enter would be a better term for confirming one line of information while OK sounds like it would close the entire menu. Replacing the OK button with an Enter and the Confirm button with a Previous menu button should be considered.

Someone also noticed that the menu was missing a Cancel key that would cancel all input and changes. An individual field can be cancelled by deleting with backspace. A Cancel button should be added.

Graphical trends

The *Graphical trends* were generally easy to use since they had not changed much from old Datex-Ohmeda monitors. Moving the cursor by dragging and changing pages by tabs was intuitive to most users and no improvement suggestions came up. The control wheel was seen as a good and fast way to move the cursor even when a touch screen is available. One user suggested adding page names to the tabs so one could see in advance what will be displayed if a certain page is selected. There is no room for long texts but even three-letter abbreviations or symbols such as a heart or lungs might be useful.

Scrolling a whole screen-full of data with the double arrows was not a total success. No one guessed what the arrows do without trying. After trying and getting some explanation on the behavior, some users said that a fast forward / rewind function is useful while some found it useless and confusing.

Trend time scale selections list should open on top of the menu according to two users. The other five said it should open next to the menu, partly on top of the trends. For both views the reasoning was that the most important data should not be covered up. The function should be the same in all menus and in some menus it may be important to see the other menu selections while changing one selection. Thus the selection lists should open on top of the view on the right and not on top of the menu items in menus such as *Trends* and *ST view* as shown in Figure 23 below.

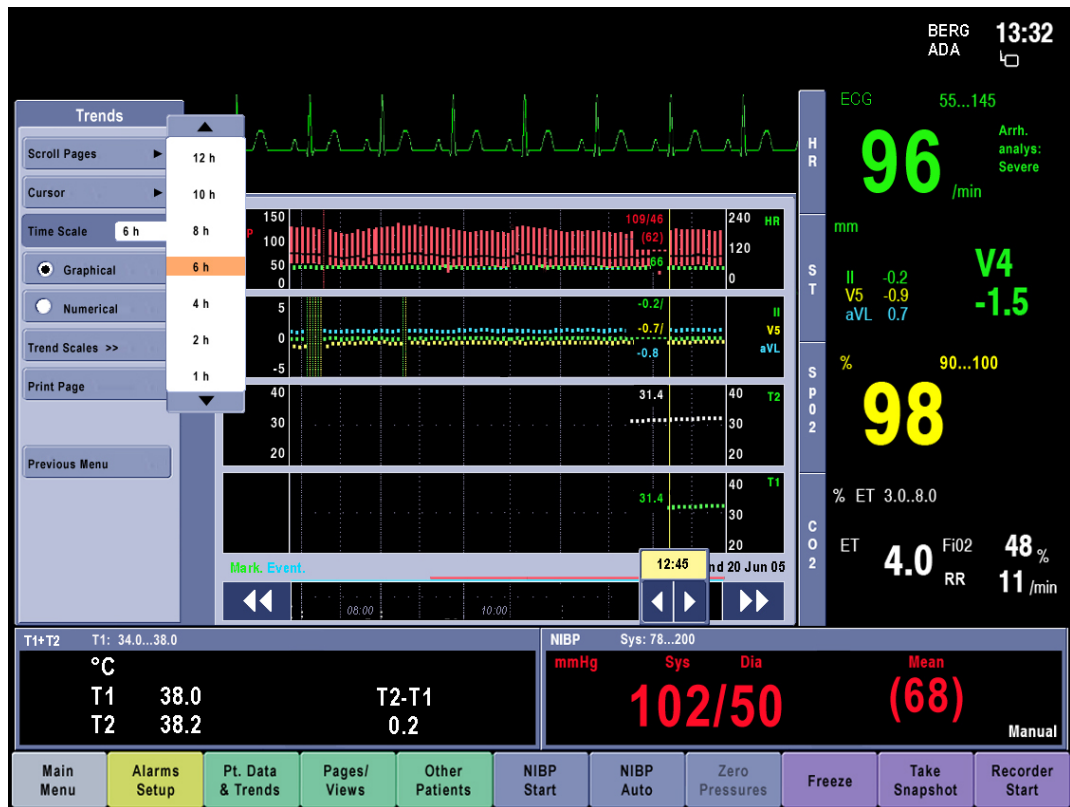


Figure 23 Graphical trends with the time scale selection list open.

Numerical trends

The new look of the *Numerical trends*, seen in Figure 24, was very popular - only one person did not like it. One other said that instead of the white background color something more beige could be used to make the view look less bright after the black background of normal screen. The time advancing from left to right was logical and the users said that they would quickly get used to the new direction of reading trends. The font was larger than in current Datex-Ohmeda monitors, which made the trends easier to read.

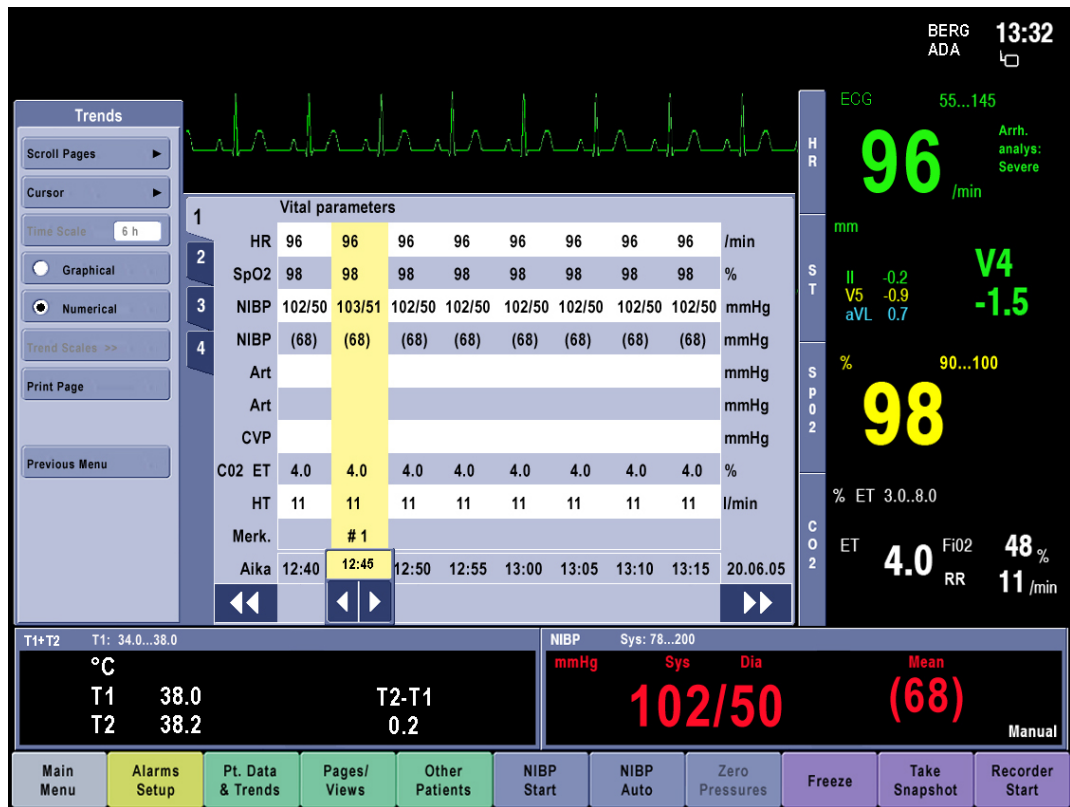


Figure 24 The Numerical trends.

The cursor and page tabs were easy to use because they are the same as in the graphical trends. In the numerical trends users seemed to find the double arrows useful and not as confusing as they were in the graphical trends. Six users said that it is enough to display half an hour of data in one screen while one said that more data should be shown at once. One user said that it would be useful to be able to change the resolution of the trends. Currently the resolution is always 5 minutes.

Snapshot

Only one user out of seven said that she uses the *Snapshot* feature at work. The other six do not use it, at least not regularly. Still users had relatively little trouble finding the *Snapshot* page in the *Events* menu. The users were used to *Snapshot* being part of *Trends* but after some thought it seemed OK in the *Events* menu as well. They said they would soon get used to it.

If *Snapshot* no longer is under *Trends* the trend box should be removed from the view. The scrolling arrows were associated with the trend box and users initially had trouble changing between the two snapshots. Labels like *Previous* and *Next* could be added next to the arrows and they should be closer to the saved ECG waveform.

The *Snapshot* feature was searched for in *Alarms Setup* because snapshots are taken when alarms occur, in the ECG menu because snapshot shows ECG waves, in *Pages/Views* because it is a “Snapshot view” and in *Take Snapshot* because the label of the button has the word snapshot on it. All of these places seem logical in that one context but when one thinks about the situation more widely the *Snapshot* cannot be tied to only ECG or alarms. Still it would be good to have access from *Alarm history* to the snapshot taken at the time of the alarm.

Put together, *Snapshot* should remain in the *Events* menu but the trend box option should be removed from the view since it is no longer in the *Trends* menu. The Snapshot scrolling arrows should be moved closer to the waveforms so that they are easier to notice but they should still look similar to the scrolling arrows in *Trends* and of course OCRG. Labels like *Previous* and *Next* could be added next to the arrows. There should be link to the corresponding snapshot from an alarm in *Alarm history*.

Alarm limits

The quick access to alarm limits through the limits displayed in the digit field was a success. All users said that it was a good feature and they would surely use it after they learned it. No one thought of it independently. They did think the touchable area was rather small but it could not be larger than the digits and the digits need to be small because they are not so important. In this prototype the area for alarm limit access was a rectangular area that also covered the small label ECG in the HR digit field and the label % in the SpO2 digit field. This was not good because if one touches those labels, one does not want to adjust alarm limits but do

something else and that something else can more likely be found in the parameter menu.

If there is more than one page-full of parameters in the *Alarms Setup*, there should be another tab in the menu with the rest of the parameters on it. For control wheel use there need be a next page item in the menu the same way as in *Trends*. This way pages would work the same way as in *Trends* and one parameter slot would no longer be wasted on the Next Page button.

The alarm limit should scroll fast when the arrow button is pressed down for a longer time. Some users assumed that this would happen and there was no situation in which this would have caused problems. One user also asked for an option to drag the limit quickly all the way up. This might be useful in some quick paced situations in the operating room but there is a possible risk to patient safety in making the alarm limits too easy to change. Also the line to be dragged is rather small and it is hard to indicate that it can indeed be dragged. The control wheel still remains as a fast way to change alarm limits.

ECG lead change

Four users preferred the wide ECG menu while two users liked the narrow menu better. One user said he would create a hybrid, a narrow menu but the selection list opens to the right side of the menu so that the width of the menu area changes.

All menus should be wide so that selection lists can open next to all the menu items and not cover up the current applied values. In menus such as *Trends* and *ST view* the selection lists should open on top of the view on the right and not on top of the menu items. Whenever possible the list should be so long that all values can be displayed at once. The wide ECG menu with an open lead selection list is shown in Figure 25 below.

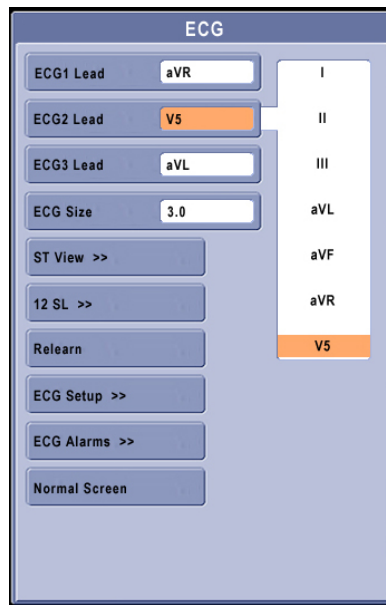


Figure 25 Wide ECG menu with a lead selection list open. The orange color marks the current applied value.

NIBP measurement

The functioning logic of the two different NIBP buttons seemed fairly clear to the test users. They were used to the Datex-Ohmeda way of NIBP functions and the prototype tried to simulate this behaviour. Some confusion was caused by the incompleteness of the prototype – sometimes the NIBP status jumped to a wrong state when a new menu was opened, the number indicating cuff inflation did not change and there was no sound from the NIBP module pumping air.

All users tried to touch exactly on the green progress bar in the NIBP digit field when asked to change the automatic measurement cycle time. They seemed satisfied with getting the normal NIBP menu open and changing the time setting in the menu. Users were asked if something special should happen by touching the progress bar or if the whole NIBP field should be one area leading to the NIBP menu. One opinion was that it is better to have just one large area that is easy to hit as long as all relevant settings are in the first menu so that no menu navigation is required. The other opinion was that since the alarm limits are a link to a specific

menu, so should be the progress bar. Consistency across all functions was said to be important.

Most users did not notice the text Start/Stop change in the NIBP button but they said it was a good feature when it was pointed out. One user noticed that the time of the previous measurement was not shown in the digit field. She said that it is important to know when the last measurement was made. Measurement time is a better way to do this than a statement “x minutes ago”. The measurement time should of course be displayed in the NIBP digit field always when values are displayed. This may be ok in current products but was not in the prototype.

One user suggested some type of colour coding (red/green) for the NIBP Start/Stop button because it can be hard to notice the different texts when they both start with an S.

Based on these tests it is better for the NIBP digit field to be one touch area so that the auto measurement progress bar is not a separate link. Consistency across all functions is very important and if there are other digit fields that must to be split up this decision can be reconsidered.

Size of touch buttons

All users said that the button row at the bottom of the screen was large enough. The height of the buttons was 1,5 cm and width 2,5 cm.

The keys in the on-screen keyboard in *Patient data* menu were large enough for six users. One user said they could still be bigger although he seemed to manage to type the name just fine. The size of the keys was 1,3*1,3 cm.

Menu item buttons were too small in height according to three users. Their height was about 1 cm. Small buttons one above the other were surprisingly problematic for one user with long fingernails. She often missed the button she intended to touch and the fingernails caused multiple touches in fast succession. This could be

observed because the computer made a beep sound every time the touch screen registered a touch. The same user also tried the screen with gloves on which further emphasized the problems with the fingernails.

Trend page tabs were too small according to two users. The size of a visible tab was approximately 0,8*1 cm but the active area was a bit larger. One user said he was worried about accidentally touching one of the menu items instead of a tab when they are so close to each other. This never happened to anyone in the tests. Another comment was that although the tabs are small, there is no reason to waste more screen space on them.

Alarm limit adjustment arrows were too small according to five users. Their size was 0,8*1 cm. This problem was less severe because the area around the arrow was inactive so missing the target did not result in anything.

Selection list items (1 cm high) and scroll arrows (0,6 cm high) were too small according to five users.

The alarm limits that functioned as a link to the alarm limit adjustment menu were large enough according to three users while only one commented that they are too small. The height of the digits was less than 0,5 cm while the active area was a little bigger. Such a small area was most likely seen as adequate because the users do not want the less relevant alarm limits to be displayed in a larger font.

Everything except the button row should be bigger. GE Common User Interface guidelines recommend 1,27 cm as the minimum size of touch screen elements and that seems quite right considering the results of this test. The keyboard keys being 1,3*1,3 cm were big enough to almost all users. Menu items, selections list items, list scrolling arrows, alarm limit adjustment arrows etc should be enlarged to at least 1,27*1,27 cm and the new design should be evaluated.

Also the fonts need to be larger to be visible in all lighting conditions, from all viewing angles and for users with poorer eyesight.

Control wheel use

The test users found little use for the control wheel when a touch screen was available. The control wheel could be used to scroll trends or alarm limits quickly, in remote controllers, if the touch screen is broken, if you have very dirty hands or if someone is too old-fashioned to learn something new. No unanimous answer was found to the question on control wheel functionality when normal screen is on. Someone wanted the focus to go through all touchable fields, buttons, digit fields and alarm limits. Someone wanted the focus to go through only the button row because jumping all over the screen would be confusing.

Control wheel use needs to be studied further with a functional prototype. It is almost impossible to image what it will be like without trying it. We should have one version where a focus goes through all touchable areas on screen and one version where a focus goes through only the button row. These two versions should be evaluated and compared to find the best solution.

Button row

The users seemed pleased that the button row did not change in different situations but all menus were available all the time. The colour coding was a good thing but the exact tones of the colours need more thought. The possibility to customize the button row for each hospital or department was seen as a good idea.

There were 11 buttons all together which is quite a few buttons. All users were able to name one or more button that they do not need or use and would rather remove from the screen. There was no common understanding on this however. The comments were: *Main Menu* is redundant since all menus can be reached in other ways, the meaning of *Pages/Views* is not clear and it is never used, *Freeze*, *Snapshot* and *Recorder* are not all needed on screen at the same time, *Freeze* is

never used since a *Snapshot* can be taken, only one NIBP start button would be enough, *Other Patients* is not needed in operating rooms or when there is no network in use

Only one user named a button that was missing from the row: the *Monitor Setup* button. We should consider adding this.

One insightful comment was that the *Silence Alarms* key is situated in a hard to reach place in the middle of other keys in the bezel. Alarm silencing is such a common task that the key should be easy to hit and preferably separated from other keys that you could hit inadvertently. The location of this key should be reconsidered.

The button row should be configurable so that unnecessary buttons are not shown. There can be large personal preference differences among co-workers and it needs to be considered carefully who gets to decide whether or not buttons are removed for that site.

Prompt texts

There were no prompt texts at the bottom of menus in this demo. None of the test users noticed that the texts were missing. They said that they do not pay attention to or read the texts in the monitors they have at work. Someone mentioned the need for some assistance for new users or for features that are used seldom but many said that there is no need for prompt texts. One user suggested some sort of help button that shows context related information. Another commented that the extra space at the bottom of menus could be better utilized making the menu items larger. A new help system should be designed to replace the prompt texts. There might be a Help item in every menu or a Help button on screen or in the bezel all the time. The help should be context aware so that it shows information related to the situation that the user is in.

5 Conclusions

This chapter summarizes the results of this study. The information about hospital environments, clinicians as users, touch screen usability and patient monitors manufactured by both GE and competitors was used to compile a prototype of the new touch interface. Here is the introduction of the final user interface that is the result of three rounds of iterative design and usability testing followed by a summary of different input devices used in patient monitors.

5.1 *The final UI*

Improvement ideas that came up in the third test round were implemented in the user interface that is the final result of this thesis work. The button row in the bottom of the screen is configurable so that only buttons that are needed are shown. The measurement time was also added to the NIBP digit field.

Figure 26 illustrates the ECG menu, an example of parameter menus. All menu items and selection list items were made larger and a new menu item *Help* was added to provide access to a context related page in the help menus. The ECG menu is one of the few menus with so many items that to make room for *Help*, *Normal Screen* had to be placed to a second column. *Normal Screen* was chosen as the single item to be placed in another column because it is needed every time the menu needs to be closed. Being separate from other items it is easy to notice and easy to touch accurately.

Selection lists always open to the right side of menu items. In some menus there is an empty area like in the ECG menu while in others such as *Trends* there is some information that inevitably will be covered up by the list. The selection list is always as long as possible so that no scrolling is needed in most cases.

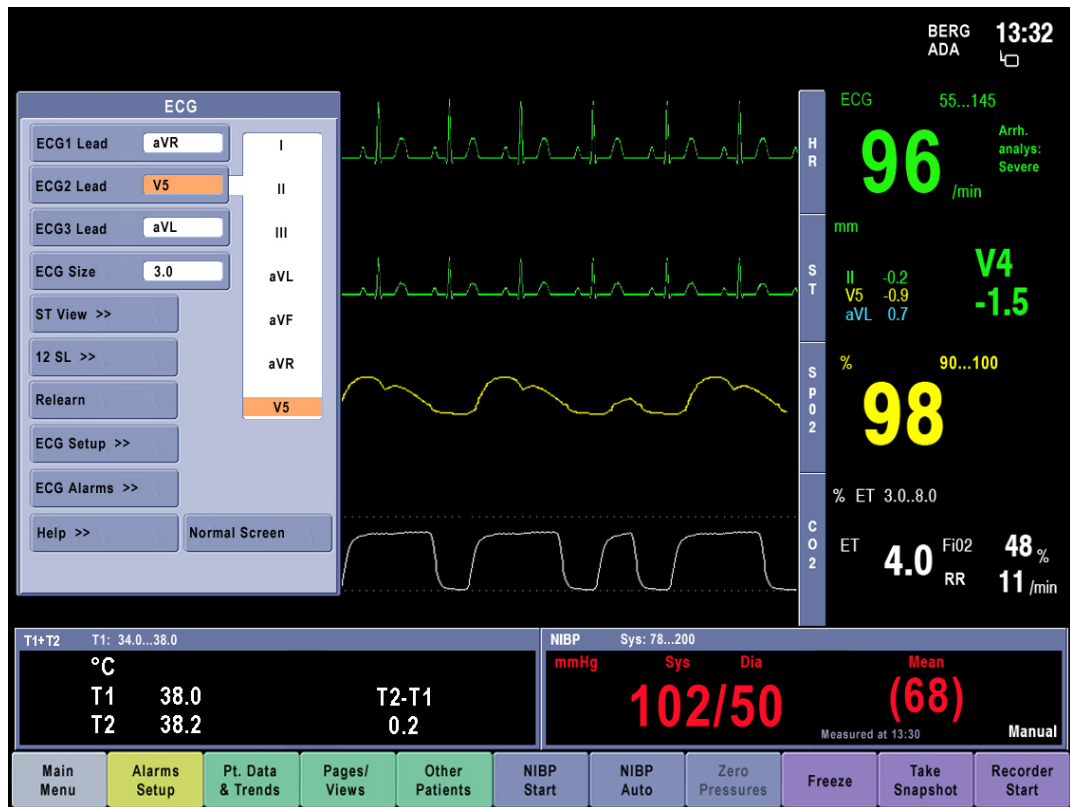


Figure 26 The final ECG menu with larger fonts and menu items. Also a Help menu access was added.

The setup menu of each parameter can be opened by touching either the corresponding digit or waveform field. If there is a need to access the menu of a parameter that is not shown on screen, this can be done through *Main Menu-Parameters*. If alarm limits are displayed in a digit field, they are a link to alarm limit adjustment. Apart from that digit fields are not divided into further smaller touchable areas.

The final *Patient data* menu is displayed in Figure 27. OK and Confirm buttons were removed and Enter, Cancel and Previous menu added. Instructions were added to the date field. The text “dd.mm.yyyy.” will disappear when the field comes to focus. *Help* menu access was added here as well as in every other menu. All possible patient data fields are shown here but in practice the menu will be localized for each site so that unwanted fields are not shown.

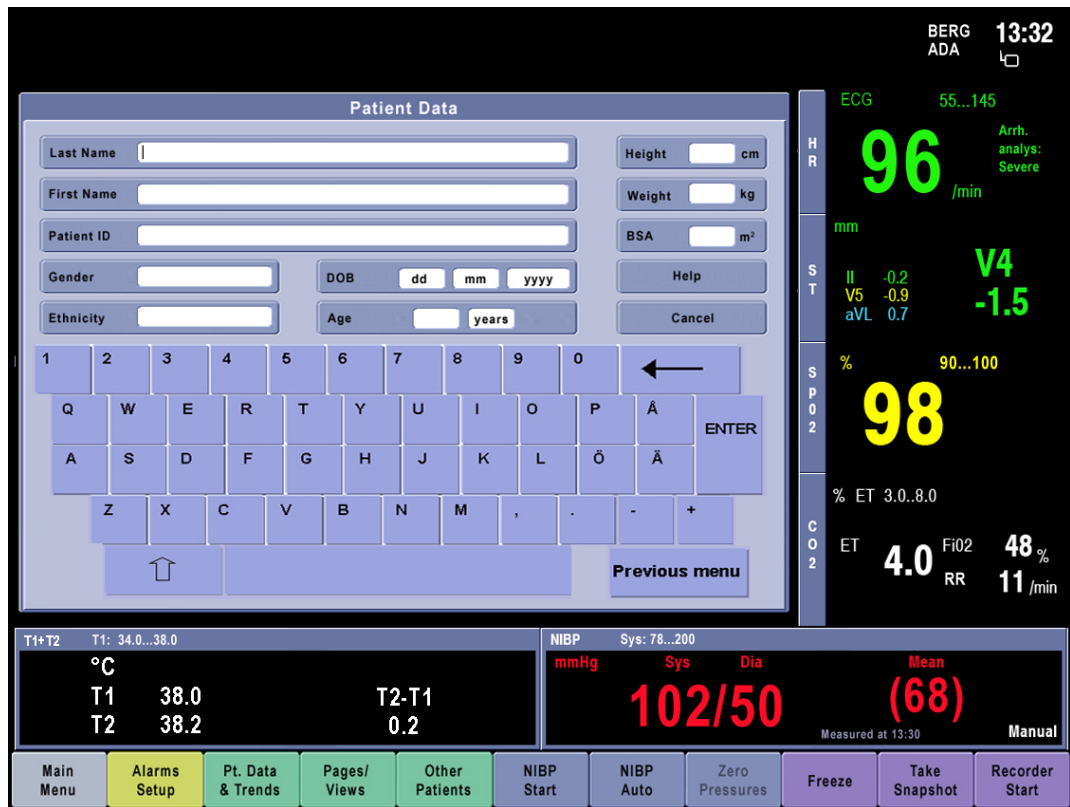


Figure 27 The final *Patient Data* menu with new Help, Cancel, Enter and Previous menu buttons.

Figure 28 shows the final *Numerical trends*. Page name abbreviations were added on the trend page tabs in a small font because there is so little room. This is not a problem since the name here is only an additional clue and it causes no serious problems if someone cannot see it. Numerical trend resolution selection was added to the menu so that values can be seen at 1, 5, 10 or 15-minute resolution.

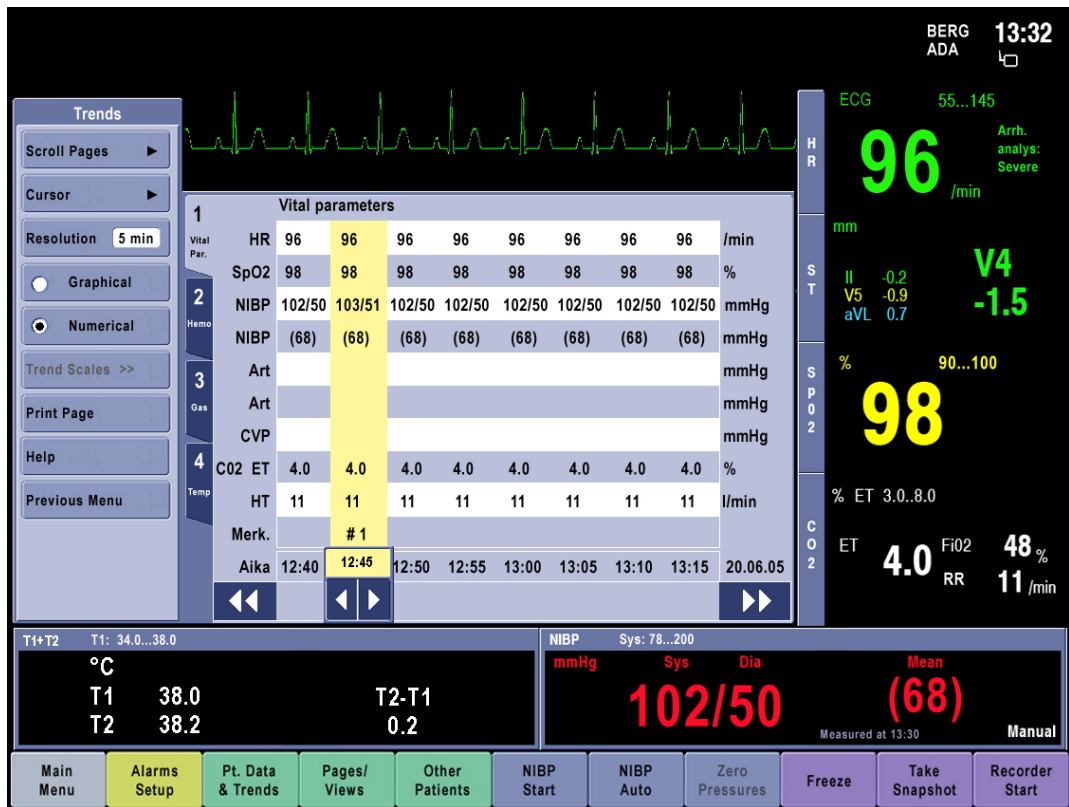


Figure 28 The final *Numerical Trends* menu with trend resolution selection, tab names and Help access.

Figure 29 illustrates the final *Events - Snapshot* menu. The trend box was removed and another saved waveform was added to its place. Previous/Next labels were added on top of the scrolling arrows.

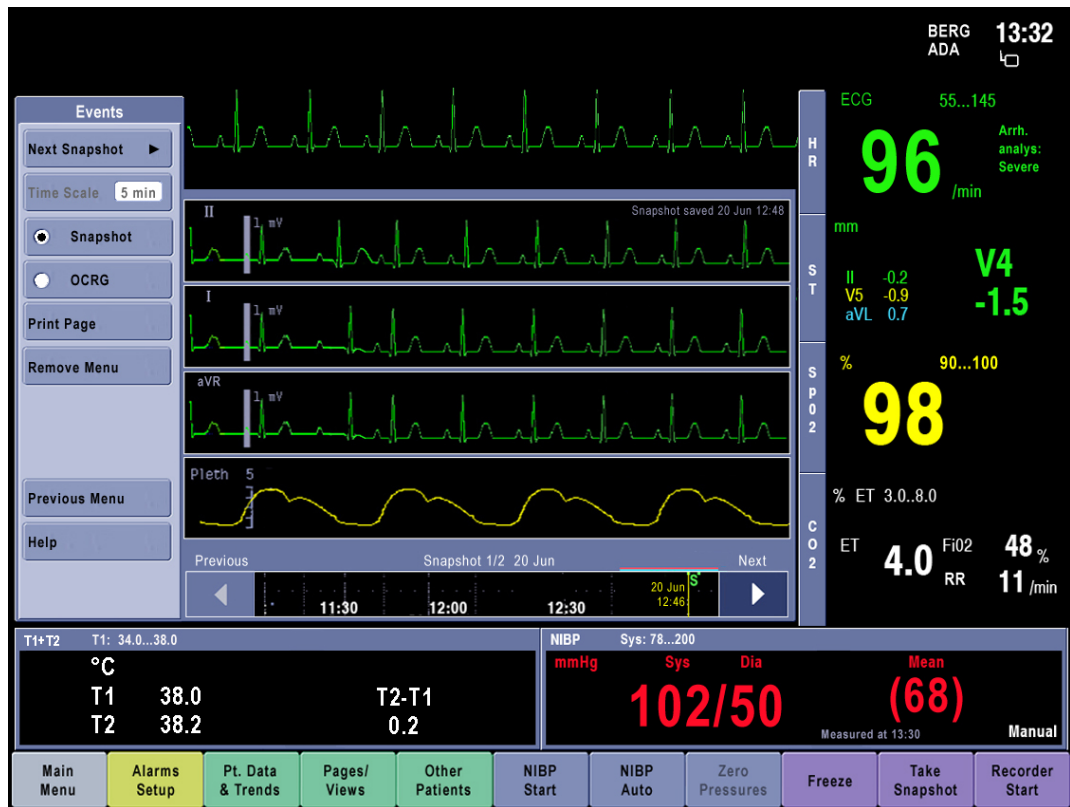


Figure 29 The final *Snapshot* menu with trend box removed and Previous/Next arrows labeled.

Finally, some changes were made to the *Alarms Setup* menu. A second page for additional parameters was added as a tab and *Next page* item in menu for control wheel use. Alarm limit adjustment arrows were made a little larger and limits will indeed scroll fast when the arrow is kept pressed down.

5.2 Input devices in patient monitors

Different input devices are needed for different tasks and environments. A simple and direct pointing device, such as a touch screen, often suffices in patient monitors. Mouse and keyboard can be useful if more extensive data entry is needed, desk space is available and sterility is not a strict requirement. Having

several alternative input devices also gives a modern image of the manufacturer and is an important asset in competition for market share.

Typical input devices in patient monitors are measurement cables and modules, control wheel and physical keys, touch screen, keyboard and mouse and for alphanumeric data entry centralized input. In the future input could be done with a projected keyboard, touch sensitive mouse or trackball, personal mobile devices, voice control or using context information.

The touch screen is a present day technology that is not yet used in GE patient monitors. The most important principles to keep in mind when designing a touch interface include, in addition to the general UI design guidelines, the following points. All touch elements need to be large enough to accommodate use by fingers and they should give a visual indication when they have been touched. Dragging should be avoided because it is hard to slide a down pressed finger on the screen. Tilting the screen to an about 30-degree angle reduces arm fatigue as does placing the screen at an appropriate height. Placing touch elements at the bottom of the screen prevents the users hand from obscuring the screen as well as reduces fatigue.

Touch screens are best suited for use where little alphanumeric input is needed, users cannot receive much training, frequency of use is low and tasks are short and there is not much desk space. All of these conditions are met in the use and environment of patient monitors so a touch screen is a very effective input device in this case. It is no wonder that all manufacturers either have introduced or are about to introduce touch screens in their patient monitors.

6 Discussion

Here I would like to discuss some of the interesting observations that I have made during this project and the things that I have learned. The improvement ideas of the test users were sometimes very insightful. Typically users are unable to say what they want before they see some suggestions but some of our test users had given a lot of thought to these devices that they need to use every day. In general it seems easier to elicit requirements from users of professional applications than from the general public.

It was interesting to notice how much the definition of “adequate size” can change in different situations. The general touch screen guideline of 2*2 cm was too large for this application where a size of 1,3*1,3 cm seemed more correct. Still the 0,5 cm high alarm limits were large enough because they are a feature that should not be made larger on screen. The correct size depends on the context.

The lessons that I have learned while working on this thesis include many experiences about working with end users and performing usability tests. Not everything has to and cannot be strictly planned. Test tasks, interview questions, introduction speech etc. need to be modified for different users and situations. Sometimes replacing planned questions with ones better suited for the situation is the best way to go. It is impossible to guess what will happen in the tests when you are planning them. E.g. if a great insightful question comes to mind because one user says something it can be a good idea to ask the rest of the users the same question too.

There is no need to feel awkward with short silences. It is better to give the users time to think and talk at their own pace and to ask questions and give alternatives only after that. It is important to look at the users and follow their eyes to see where they are looking. That gives you an idea where you should place elements on screen. Good questions to ask are: What word or term are you looking for?

What should it look like? Where should it be? This time it turned out to be a good tactic to just leave some functions out of the prototype and let users look for them. Looking at their eyes and asking questions helped in finding out what they thought before they saw any designs. Finnish people are good usability test users because they are honest and not over-polite. There are no such problems that might be associated with the American interaction style that everything is great and amazing and true opinions are hidden behind these superlatives.

Having the first two test rounds in hospitals in the users' own working environment was a good idea because this way we were able to recruit more "normal" nurses that were not especially interested in technology. Some of our test users were very uncomfortable with technology and we had to admit that some people just do not know what to do unless they get some training. No matter how usable and intuitive our user interface is, providing training material, manuals and help is still important. Users in the third test round had to come to the office to do the tests in their free time which most likely limited the user group to people who are more active and technically oriented than average.

The original purpose of the practical part of this study was to "transform" the old control wheel interface into a touch interface, which was successfully done. Successfully in this case meaning that after the three usability test rounds there were no significant usability issues left in the design. Additionally, the look and feel of menus was freshened up and a few menu paths modified from the current design.

The most significant area for further improvement in the final UI is the artistic side. The graphical design was done as quickly as possible just to get an idea of what it could look like. There may also be some menus that have some exceptional features that cannot be implemented without more detailed design. Another important issue that was not covered by this thesis is the sensitivity and reaction time of the touch screen. The touch screen technology for the new product has not

been selected yet. It would be interesting to try different types of screens to see if there are differences in their performance. A screen that does not register all touches or is too slow to respond could be a major usability issue.

This project has been a success in the sense that the final UI of this project will be used as a basis for further development. The original goal was to implement the UI to a new product very soon but recent developments in the company have led to a situation where more development and remodeling of the UI are needed. The final result of this project is not the last and complete final interface after all.

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Appendix A: Background information form used in usability tests

Osallistuminen käytettävyystesteihin. Tietoa testeihin osallistumisesta ja testeissä kerätyn materiaalin käytöstä.

Testin tarkoitus	Haluaisimme kuulla mielipiteesi potilasvalvontalaitteesta jota GE Healthcare Finland Oy on kehittämässä täydentämään nykyistä laitevalikoimaa.
Kerättävät tiedot	Sinua pyydetään puhumaan äänen ja kertomaan vapaasti mielipiteesi käsillä olevasta tuotteesta. Haluaisimme kuulla odotuksistasi, mieltymyksistäsi ja mielipiteistäsi koskien uutta valvontalaitetta. Mikäli annat suostumuksesi, haluaisimme nauhoittaa testin. Lisäksi teemme muistiinpanoja testin aikana.
Videotallenne	Tarkoituksemme on tallentaa käytettävyydesti videonauhalle. Testin analysoinnin yhteydessä mahdollisesti siteeraamme sinun lausuntojasi kuitenkin paljastamatta henkilöllisyyttäsi. Materiaalin tullaan käyttämään vain salassapitosopimuksen määrittelemän hankkeen sisällä.
Tauot	Testin aikana on suunniteltu tauko, mutta voit pyytää meitä pitämään tauon milloin tahansa testin kuluessa.
Salassapitovelvollisuus	Pyydämme sinua allekirjoittamaan erillisen sopimuksen salassapitovelvollisuudesta.
Testin keskeyttäminen	Voit keskeyttää testin missä vaiheessa tahansa testin kuluessa tarvitsematta perustella keskeyttämisestäsi syitä.

Taustatiedot. Valitse sopivin vaihtoehto.

Sairaala, jossa pääasiallisesti työskentelet

Millä osastoilla työskentelet? _____

Mikä on tämänhetkinen tehtäväsi? _____

Kuinka monta vuotta olet työskennellyt tässä toimessa ?

Minkä valmistajan potilasmonitorit osastollanne on käytössä?

Mitä tyypillisesti monitoroidaan?

ECG 3-kytk. 5- kytk. 12- kytk.	SpO2	NIBP	Invasiivia verenpaineita Art Art & CVP Art, CVP & PA	NMT Relak- saatiota	Kaasuja
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Spirometria- mittauksia Minuutti/kerta- tilavuus, ilmatiepaine, virtaukset	Sydämen minuutti- volyymi Kiilapaine	Lämpö- tilaa 1 kpl 2 kpl 3 kpl	EEG AEP SSEP	BIS Entro- pia
---	---	--	--------------------	----------------------

Millaisiin paikkoihin monitorit on sijoitettu osastollanne? Esim. hyllyllä, seinäkiinnikkeissä, kuinka korkealla? Käytättekö monitoria suoraan vai kaukosäätimellä vai molemmilla?

Appendix B: Test tasks and interview questions used in the first usability test

Näytetään Normal Screen.

Kysymys 0: Mitä näet tässä näytöllä?

Mitä kiinnität huomiota ensimmäiseksi?

Näytetään Normal screen, jossa röpelöä ECG käyrässä.

Tehtävä 1: EKG käyrä näyttää vähän oudolta ja tahdot tulostaa sen. Mistä luulet, että se onnistuu?

- Tarkoitus painaa Recorder start/stop näppäintä.

Tehtävä 2: Haluat katsoa trendeistä yleisen silmäyksen, mikä potilaan tila on viime aikoina ollut. Mistähän tämä voisi löytyä?

- Tarkoitus olisi selata läpi graafisen trendin sivut, muttei vielä muuttaa mitään asetuksia.

Näytetään Graafiset trendit

Kysymys 2: Miten kuvittelisit selaavasi trendisivuja?

Mitä mieltä olet trendisivujen selaamisesta tällä tavalla? Hyvää / huonoa?

Olisiko joku nuoli-systeemi parempi kuin välilehdet?

Onko välilehdet tuttu käsite?

T 3: Leikitään, että tämän hetkinen SpO2 arvo on erikoisen matala, alle 90. Haluat tarkistaa onko se ollut jo kauan matalalla vai juuri laskenut vai hetkellinen virhelukema. Mistä lähtisit tätä tutkimaan?

Lisävihjeenä tarvittaessa: Mitä luulet, että tämä Time scale 6h tarkoittaa?

Saisikohan näytölle jotenkin vähän tarkempia arvoja lyhyemmältä ajalta?

- Tarkoitus olisi mennä oikealle graafisen trendin sivulle, vaihtaa time scaleksi 20min ja liikuttaa kursoria arvojen katsomiseksi.

K 3a: Miten valintojen vahvistamisen pitäisi toimia?

Onko se tarpeen? Millaiseen tapaan olet tottunut? (Post-it lappu Vahvista - painikkeeksi)

Mitä pidit Time scale menussa olleesta vahvistus tavasta? (piti painaa parametrin nimeä uudelleen)

K 3b: Mitä pidät trendien kursorin toiminnasta, hyvää / huonoa?

Näytetään tyhjä kuva ja post-it nuolet

Miten itse sijoittaisit nuolet / vai käyttäisitkö jotain muuta?

T 4: Haluat nähdä numeroina, mitä tuloksia viimeisistä NIBP mittauksista on tullut ja samalla päätät vilkaista läpi muutkin numeeriset trendit.

- Tarkoituksena käydä läpi numeerisen trendin sivut ja liikuttaa kursoria.

K 4a: Onko sivujen selaaminen tällä tavalla luontevaa? Vai olisiko nuolien tai jonkun muun tavan käyttäminen parempi?

K 4b: Mitä mieltä olet kursorin liikutus nuolista? Näkeekö niistä heti, mihin ne liittyy?

Näytetään tyhjä kuva ja post-it nuolet

Miten itse sijoittaisit nuolet / vai käyttäisitkö jotain muuta?

Näytetään nuolet alareunassa kuva.

Mitä pidät tästä? Kumpi on parempi, tämä vai ensin näytetty?

T 5: Viimeisestä NIBP mittauksesta oli kulunut jo sen verran aikaa, että tahdot tehdä uuden.

- Tarkoitus painaa NIBP on/off näppäintä.

Näytöllä kuva, jossa HR 0.

T 6: Trendeissä näkyi yksi kohta, jossa HR arvo kävi alhaalla. Haluat tietää, mitä silloin kävi. Mistä lähtisit etsimään tätä tietoa?

Lisäksi tarvittaessa: Mitä luulet, että tämä Snapshot kohta on? Kokeilepa sitä.

Oletko ennen käyttänyt tällaista toimintoa?

- Tarkoitus katsoa Snapshotti.

K 6a: Mitä luulet, että tuosta Remove menu –kohdasta tapahtuu?

Kokeilepa sitä. (Näytetään kuva.)

Onko tällainen näkymä / toiminto hyödyllinen? Käyttäisitkö sitä? Missä tilanteessa?

K 6b: Miten toimisit, jos tahtoisit tässä vaiheessa saada kaikki menut kiinni ja ihan perusnäytön esiin?

Normal screen esillä -> tulee hälytys.

T 7: Haluat hiljentää hälytysäänän.

- Tarkoitus painaa Silence alarms.

T 8: Haluat tarkistaa, minkä parametrien hälytykset ovat päällä ja mitkä ovat niiden hälytysrajat. Mistä luulet, että löytäisit tämän?

- Tarkoitus vain avata Alarms Setup menu ja katsoa siitä.

K 8: Mistä paikoista luulet, että tässä menussa voi painaa? Mitä niistä tapahtuu?

T 9: NIBP hälytysrajat eivät mielestäsi ole sopivat. Päätät muuttaa ylärajaa 200 - >180.

- Tarkoitus painaa NIBP:in kohdalta ja avata menu ja säätää.
(Epäilen kuitenkin että valitsee ensin Adjust limits.)

K 9a: Jos tekee heti oikein: Oliko heti selvää, mistä piti painaa?
Jos valitsee ensin Adjust limits: Mitä ajattelit tapahtuvan, kun painat siitä?

Säädön jälkeen näytetään kuva, jossa yksittäiset säätönuolet.

K 9b: Kummasta pidät enemmän, tästä yksittäisistä nuolista vai tuosta tuplanuolista?

K 9c: Mitä odotat tapahtuvan, jos sinulla on rajan säätö kesken ja painatkin vahingossa ECG numerokenttää?

Jääkö vanha menu auki, vai aukeaako uusi, vai jotain muuta?

Näytetään ECG menu kuva. Olisiko loogista, jos siitä aukeaisi tämmöinen menu?

Mikä hälytysraja jää voimaan?

Ennen säädön aloittamista ollut 200 vai se mihin asti olit säätänyt, esim. 186?

T 10: Potilas nukkuu ja tila on vakaa, joten tahdot rauhan takaamiseksi varmistaa, että monitori pysyy hiljaa eikä hälyttele mitään ääneen. Mistä lähtisit tätä etsimään?

- Tarkoitus valita Silence All.

K 10: Mihin kaikkiin ääniin luulet, että tämä valinta nyt vaikutti?

Ja nyt kun potilas nukkuu ja äännet on pois päältä, niin voidaan jutella vielä muutamasta asiasta.

Haastattelu

K 11: Olivatko kosketettavat alueet / painikkeet sopivan kokoisia?

Osuuko sormella vai pelottaako, että menee ohi?

Peittykö näytöltä käyrät liikaa?

Mahtuuko kaikki menun kohdat hyvin vai ovatko ne liian ahtaasti?

Kuinka pienet painikkeet on vielä kelvolliset?

Minkä kokoiset olisi optimaaliset?

K 12: Luetko yleensä / luitko nyt menuissa olevia ohjetekstejä? (prompti)

Onko ne hyödyllisiä?

Kuinka tärkeitä ne on?

K 13: Millaisia kokemuksia sinulla on kosketusnäytöistä yleensä?

Mikä niissä on hyvää ja mikä huonoa?

K 14: Oletko käyttänyt työssäsi monitoria, jossa on sekä kosketusnäyttö että ohjauspyörä (Comwheel)?

Kumpaa käytät mieluummin?

Jos käytät molempia, mitä toimintoja teet kosketusnäytöllä ja mitä pyörällä?

K 15: Mistä kaikkialta näytöltä oletat, että voi painaa?

Minkä menun oletat avautuvan mistäkin? (näytetään paikkoja, käyräkenttä, numerokentät, labelit, kello, hälytyslippu, hiljennysmerkki, potilaan nimi, moodi, CO2 kentän O2 kohta, hälytysrajat, NIBP kentän manual teksti jne)

K 16: Tähän monitorin runkoon on tulossa myös painike, jolla saa kosketusnäytön pois päältä, niin ettei se enää reagoi kosketuksiin. Keksitkö jonkin tilanteen, jossa tälle toiminnolle olisi käyttöä?

Appendix C: Test tasks and interview questions used in the second usability test

Näytetään Normaalinäyttö.

Kysymys 0: Mitä näet tässä näytöllä?
Mihin kiinnität huomiota ensimmäiseksi?

Tehtävä 1: Tahtoisit saada tästä tämän EKG käyrän talteen myöhempää tarkastelua varten. Miten lähtisit sitä tekemään?

- Tarkoitus painaa Piirturi start/stop -näppäintä tai Käyränäyte-näppäintä.

Kysymys 1: Haluatko koskaan saada näytöllä näkyvän käyrän talteen tällä tavalla? Teetkö silloin aina tällä tavalla?
Haluaisitko koskaan tulostaa käyrää paperille / tallettaa monitorin muistiin? Mistä luulet, että se tehtäisiin?

Tehtävä 2: Olet mitannut potilaan pituuden ja painon ja tahdot syöttää nämä tiedot monitorin muistiin. Minne luulet, että ne voisi syöttää?

- Tarkoitus painaa Potilastiedot ja trendit ja sieltä Sisäänkirjaus

Kysymys 2a: Oliko tämä mielestäsi loogisessa paikassa?
Oliko siinä tehtävä liian monta menuvalintaa ennen kuin pääsit syöttämään tietoja (vai onko hyvä, että harvoin / vain kerran casen aikana tarvittavat tiedot ei ole ekana osumassa silmään koko ajan)?
Löytyikö sieltä kaikki tarvittavat potilastiedot?
Oliko siellä jotain ylimääräistä, mitä et ymmärtänyt?
Oliko käytetyt termit mielestäsi oikeita?

K2b: Mitenkäs tässä edellisessä Sisäänkirjaus -kohdassa, syötättekö te yleensä potilaan nimen monitorille?
Onko muita tilanteita, jolloin tarvittaisiin näppäimistöä?
Meillä on tässä kaksi vaihtoehtoista hahmotelmaa näppäimistöä. Kumpi on mielestäsi parempi? Mihin kohtaan näytöllä sijoittaisit sen? Puuttuuko siitä jokin näppäin, joka olisi tärkeä?

T 3: Haluat katsoa trendeistä yleisen silmäyksen, mikä potilaan tila on viime aikoina ollut. Mistähän tämä voisi löytyä?

- Tarkoitus avata graafiset trendit.

K 3a: Miten kuvittelisit selaavasi trendisivuja?
Mitä mieltä olet trendisivujen selaamisesta tällä tavalla? Hyvää / huonoa?
Olisiko joku nuoli-systeemi parempi kuin välilehdet?
Onko välilehdet tuttu käsite?

K 3b: Nyt kun tämä sivu on avattu tähän ja alkaa pyörittää tätä pyörää ennen kuin on painanut mistään, niin mitä mielestäsi pitäisi tapahtua? Missä pyörä liikkuu?

T 4: Nyt tässä trendissä näkyy kuuden tunnin ajalta tietoja, mutta haluaisit nähdä tarkemmin. Miten luulet, että saisit vaihdettua siihen tiedot vaikkapa vain 20 minuutin ajalta?

K 4: Miten valintojen vahvistamisen pitäisi toimia?

Onko OK ettei tarvitse vahvistaa ollenkaan, vaan arvo vaihtuu heti kuten tässä?

T 5: Jos tahtoisit nähdä tarkan numeroarvon juuri tuosta kohtaa [osoittaa kohtaa trendissä] miten saisit sen selville?

- Tarkoitus siirtää kursori osoitettuun kohtaan.

K 5: Mitä pidät trendien kursorin toiminnasta, hyvää / huonoa? (kursorin liikutus comwheelilla, kosketus-nuolilla, koskemalla kohtaa näytöllä ja liu'uttamalla)

T 6: Haluat nähdä mitä tuloksia viimeisistä NIBP mittauksista on tullut ja samalla päätät vilkaista läpi muutkin numeeriset trendit.

- Tarkoituksena käydä läpi numeerisen trendin sivut ja ehkä liikuttaa kursoria.

K 6a: Onko sivu-välilehdet mielestäsi paremmat täällä yläreunassa vai vasemmassa reunassa kuten graafisissa trendeissä?

K 6b: Mitä mieltä olet kursorin liikutus nuolista? Näkeekö niistä heti, mihin ne liittyy?

Miten itse sijoittaisit nuolet / vai käyttäisitkö jotain muuta?

Käyttäisitkö ohjauspyörää tähän? Miten sen käyttäminen tapahtuisi?

K 6c: Mitä mieltä olet taulukossa olevista apuviivoista? Onko ne hyvät näin vaakasuorassa, vai olisiko parempi olla viivat pystysuorassa, vai molemmat eli täysi ruudukko?

T 7: Viimeisestä NIBP mittauksesta oli kulunut jo sen verran aikaa, että tahdot tehdä uuden.

- Tarkoitus painaa NIBP start/stop näppäintä.

T 8: Silloin alussa talletettiin se EKG käyrä monitorin muistiin. Mistäköhän sen voisi nyt katsoa?

- Tarkoitus katsoa Käyränäyte.

K 8a: Onko tämä näkymä selkeä? Kerrotko mitä siinä on?

Jos näitä talletettuja käyriä olisi enemmän kuin yksi niin mistä mielestäsi voisi vaihtaa näkyvissä olevaa käyrää?

K 8b: Miten toimisit, jos tahtoisit tässä vaiheessa saada kaikki menut kiinni ja ihan perusnäytön esiin?

Normaalinäyttö esillä -> tulee hälytys.

T 9: Haluat hiljentää hälytysäänen. Miten se voisi onnistua?

- Tarkoitus painaa Vaimenna hälytykset näppäintä.

K 9: Mitä mielestäsi pitäisi käydä, jos painaisit tuosta hälytyslipusta?

T 10: NIBP hälytysrajat eivät mielestäsi ole sopivat. Päätät muuttaa ylärajaa 200 - >180.

- Tarkoitus painaa Hälytysasetukset tai NIBP numerokenttää ja avata menut ja säätää.

K 10: Olisiko tässä hälytysrajan säätämisessä mielestäsi jotakin epäselvää/ vaikeaa/ parannettavaa?

Jos ohjauspyörää alkaa kääntää nyt kun NIBP rajan säätö menu on avattu, niin mihin se vaikuttaa? Liikkuuko fokus vasemman laidan menussa vai muuttuuko jompikumpi hälytysraja?

T 11: Nyt kun hälytysrajat on kohdallaan, tahtoisit laittaa automaattisen NIBP mittauksen päälle 10 minuutin välein. Mistä tätä hakisit?

- Tarkoitus painaa NIBP numerokentästä, josta aukeaa NIBP-asetukset ja sieltä Muuta mittausväli kohdasta valita 10 min ja sitten Käynnistä autom.

K 11a: Meillä on tässä kaksi vaihtoehtoista ulkonäköä tälle menulle [näytetään menu viivalla ja pikkulaatikolla]. Tarkoitus on käyttää jotain merkintätapaa, jolla merkitään kaikki arvot, joita voi muuttaa, niin ettei ne näytä vain esillä olevilta tiedoilta. Kumpi näistä on sinusta selkeämpi? Miksi?

[näytetään myös P1-asetukset menu]

K 11b: Kerrotko mitä nämä kaikki eri kodat tässä menussa sinun mielestäsi voisivat tehdä? Puuttuuko tästä joku tarpeellinen kohta tai asetukset?

Haastattelu

K 12: Olivatko kosketettavat alueet mielestäsi sopivan kokoisia, liian suuria tai liian pieniä?

K 13: Millaisia kokemuksia sinulla on kosketusnäytöistä yleensä? Mikä niissä on hyvää ja mikä huonoa?

K 14: Mistä kaikkialta näytöltä oletat, että voi painaa?

Minkä menun oletat avautuvan mistäkin? (näytetään paikkoja, käyräkenttä, numerokentät, labelit, kello, hälytyslippu, hiljennysmerkki, potilaan nimi, moodi, CO2 kentän O2 kohta, hälytysrajat, NIBP kentän manual teksti jne)

K 15: Oletko käyttänyt työssäsi monitoria, jossa on sekä kosketusnäyttö että ohjauspyörä (Comwheel)?

Kumpaa käytät mieluummin?

Jos käytät molempia, mitä toimintoja teet kosketusnäytöllä ja mitä pyörällä?

K 16: Kun mikään menu ei ole auki ja näkyvissä on pelkkä normaalinäyttö, mitä pitäisi tapahtua ohjauspyörää pyörittämällä?

Valkoinen kehys käy läpi näytöllä olevia numerokenttiä, joista voi sitten pyörää painamalla mennä asetus-menuun?

Käykö se läpi myös alareunan painikkeet?

Missä järjestyksessä se liikkuu ja mistä se aloittaa?

K 17: Onko alareunan nappularivissä kaikki tarpeelliset pikanappulat? Mitä puuttuu, mitä on ylimääräistä?

Nappulat on ryhmitelty eri värejä käyttämällä. Onko tämä ryhmittely mielestäsi hyvä, onko siitä apua, muuttaisitko jotain?

Appendix D: Test tasks and interview questions used in the third usability test

Eli katsotaan vaikka ihan ekana tätä normaalinäyttöä ja sinä voisit kertoa minulle, mistä kaikkialta luulet, että tästä tapahtuu jotain ja mitä tapahtuu. Kun kosketusnäyttö on kyseessä niin sinänsä ei ole mitään rajoituksia, mistä kaikkialta voisi tapahtua jotain. Voit myös kokeilla ja koskea. Mikä ensivaikutelma?

Katsotaan seuraavaksi potilaan tietojen syöttämistä ja leikitään, ettei tässä vielä ole annettu potilaan nimeä. Voit siis mennä sinne, missä tämän tiedon mielestäsi kuuluisi olla ja syöttää nimen Berg, Ada.

Kommentteja sijainnista menussa? Menun ulkonäöstä? Käyrien peittämisestä? Miten voisi parantaa?

Onko täällä kaikki tarvittavat potilastiedot – puuttuuko vai onko jotain liikaa? Miten luulet, että tämän potilastietojen syöttämisen voisi tehdä ohjauspyörällä?

Otetaanpa sitten trendit esille, ensin ihan graafiset. Löydätkö ne jostain?

Miten luulet, että tässä kosketusnäytöllä kursori toimii?

Entäs sivujen vaihtaminen? Entä miten kursori ja sivujen vaihtaminen toimisi pyörällä?

Ja sitten vaihdetaan numeerisiin trendeihin. Onko tämä vaihtaminen selkeää radio buttoneilla? Mitä pidät uudesta lookista?

Tässäkin voi kokeilla kursoria ja sivujen vaihtamista. Parannusehdotuksia?

Mennään takaisin graafisten trendien 1. sivulle.

Osaatko sanoa, kuinka pitkältä ajalta tässä nyt näkyy trendidataa?

Mistä saisit vaihdettua niin, että samalla näytöllä olisi dataa vaikkapa kokonaiselta vuorokaudelta? Meillä on tästä kaksi eri vaihtoehtoa, joissa valintalista aukeaa vähän eri paikkaan. Kummasta pidät enemmän ja miksi?

Huomasitko, että trendeissä ei enää ollut snapshottia (käyränäyte) kuten ennen?

Mistä luulet, että se löytyisi? Onko tämä uusi paikka OK?

Mistä tiedät onko snapshotteja vain tämä yksi vai useampia?

(Jos kysyy: OxyCardioRespiroGram kuvaa hengityksen, hapetuksen ja sydämen sykkeen yhdellä näytöllä, käytetään vastasyntyneitten hoidossa.)

Voisitko vaihtaa EKG hälytysrajan? Tarkemmin sanottuna laskea ylärajan 140:een. Se on valitettavasti ainut mihin tämä värkki taipuu. Kommentteja sijainnista, toiminnasta? Osaatko arvata mistä muualta pääsee tähän samaan menuun?

Onko hyvä, että numerokentissä näkyvistä hälytysrajoista pääsee suoraan säätämään rajaa?

Seuraavaksi, voisitko vaihtaa EKG kytkentää? Taas on mahdollista tehdä vain yhdellä tavalla eli laittaa EKG 2 kytkennäksi aVF.
Mitä pidät tästä toiminnasta? Ulkonäöstä?

Tässä on myös toinen vaihtoehto, jossa ideana on saada menu kapeammaksi ja enemmän käyriä näkyviin. Toisaalta tässä nyt tämä valintalista peittää näkyvistä tiedon, mitkä on valittuna 1 ja 3 leadiksi. Kummasta vaihtoehdosta pidät enemmän?

Paluu normaalinäyttöön.

Voisitko aloittaa automaattisen NIBP mittauksen?

Voisitko vaihtaa sen viiden minuutin sijasta tapahtumaan 15 minuutin välein? [tarkkaillaan painaako yleisesti NIBP kenttää vai vihreää 5min mittaria vai jotain muuta]

Oliko tässä mitään yllättävää? Kommentteja?

Tekstin vaihtuminen nappulassa – huomaako sen, onko OK?

Haastattelu

Millaisia kokemuksia sinulla on kosketusnäytöistä yleensä? Oletko käyttänyt niitä työssäsi? Mikä niissä on hyvää ja mikä huonoa?

Voisitko kuvitella käyttäväsi tällaista monitoria työssäsi kunhan tämä valmistuu?
Miten kosketusnäyttöön siirtyminen vaikuttaa sinun työhösi?

Luuletko, että ohjauspyörälle on edelleen käyttöä, vaikka monitorissa on kosketusnäyttö? (Ohjauspyörää tarvitaan edelleen, koska kaukosäätimissä on oltava joku millä laitetta käytetään ja lisäksi kaikki eivät halua maksaa kosketusnäytöstä vaan ostavat 'tavallisen' näytön ja me halutaan käyttää samaa käyttöliittymää molemmissa.)

Näppäinrivi – onko muutoksia niissä nappuloissa, joita itse yleensä käytät? Onko OK, muutokset parempaan/huonompaan, parannusehdotuksia?

Onko tässä näppäimet ja muut kosketettavat alueet sopivan kokoisia? Potilasdatan syötössä, trendeissä, menuissa?

Huomasitko, että tässä demossa puuttui menujen alareunoista ne ohjetekstit, jotka nykyisissä Datexin monitoreissa on? Onko ne tärkeitä? Pitäisikö ne saada jotenkin tähän mukaan? Ideoita?