DESIGN OF A PDA USER INTERFACE WHICH TAKES ACCOUNT OF ERGONOMIC ASPECTS

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Abstract: There is a close relationship between current progress in technology and medicine. New developments and technologies are helping to obtain more detailed information about patients' health thus allowing new approaches in treatment. But medical applications are characterized by increasing functional integration. As a result, patients are faced with an ever wider array of medical equipment. Technological progress is also forcing doctors and nurses to cope with the higher demand for interaction with the new complex technologies.

Technology is making ever deeper inroads into all patient-centred activities. This ever wider use of technical equipment is imposing new demands on technical safety and the quality of use. The usability of medical equipment is ensured by corresponding requirements and parallel risk management. Predictable wrong operation leading to unacceptable risk can be prevented. This brings ease of operation into focus and several framework conditions have been defined to compensate for ergonomic deficiencies.

Today, home-care and telemedicine are becoming increasingly more important. An ergonomic user interface that enables simple, intuitive and fault-tolerant input has been implemented for typical mobile devices (tablet PCs, PDAs, mobile phones). The rules and principles of universal design as well as current normative developments have also been taken into consideration.

Introduction

Ergonomics is the science of establishing regularities in human work. The central point is improvement of the interface between user (= human being) and inanimate object (= machine). An analysis and perfection of human activity and performance is in progress whilst including subjective and objective factors and processes, all with the aim of increasing human well-being and the perfection of systems. To perfect the ergonomic quality of a product it is necessary to integrate the typical users already at the development stage, and to continually allow these results to exert an influence [1,2].

Ergonomics covers all aspects of human action which uses technical support. Some ergonomic aspects derive from the areas of use of a product, while others have their origin in the physical parameters of the user. Ergonomics thus tries to include the varying needs of the performing person under psychological and mental aspects such as perception, learning ability, etc when designing an application and has become a quality feature of products. In medical technology, ergonomics, operability and suitability for use are very strongly linked as regards the user patient. Only clear, intuitive communication between user and device during varying working conditions will contribute to guaranteeing a considerable gain in safety when operating medical products [3,4]. The methods and discoveries of ergonomics can assist the design of medical products to be adapted to the user and his working processes, so that demands for safe operation can be fulfilled.

This article is essentially concerned with the independent interaction of an inexperienced user such as a patient, with a portable computer system having simple in- and output functionality [5]. PDAs and modern mobile phones are examples of such portable devices. Entering by keyboard has been largely ignored in favour of touch screen technology. When designing software for such user systems, a number of aspects should be taken into account in order to guarantee intuitive and satisfactory ease of use (e.g. Look and Feel).

Materials and methods

In formal guidelines and norms the development process regarding ease of use is described in order to observe the safety of medical electronic systems [6,7,8,9]. These are instructions for the design of systems for implementing and executing software ergonomics processes. In order to protect users and patients from inadequate medical products, various technical norms and regulations have been introduced over recent decades or existing ones improved [10,11]. In this way the area of ease of use has become more and more the focus of attention and various frame conditions have been defined to counteract ergonomic deficiencies.

In Europe the manufacture, sales and use and operation of medical products is governed by European guidelines 93/42/EEC "Medical Products" and DIN EN ISO 14971 [12]. In addition to various norms, the supplementary norm DIN EN 60601-1-6 "Medical Electrical Devices, Parts 1 - 6: General Principles established for the Supplementary Norms concerning Safety: Ease of Use (First Edition)" finally defined the requirements for the development process. Due to the

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corresponding requirements and accompanying risk management, ease of use for medical products has been guaranteed. It was possible to exclude predictable wrong use which might lead to unacceptable risks during operation.

It is incumbent upon all operators and users of medical products to report incidents occurring in connection with the medical products, including errors by the user which have been caused by deficiencies in the ergonomic design. In Germany the Federal Institute of Medicines and Medical Products (BfArM) has undertaken centrally the recording, analysis and evaluation of incidents. Criteria for medical software are included in IEC 62302 and IEC TR 61258 governing the compilation of training material.

Some important terms, definitions and norms:

- EC Guideline 90/270/EEC for the presentation of information on screen and its manipulation.
- ISO 14971:2000 The use according to the regulations of a product, procedure or service according to the specifications, instructions and details supplied by the manufacturer.
- ISO/IEC Guide 51:1999, Definition of the risk of the probability of occurrence of injury and the extent of the severity. And also the definition of safety as freedom from unjustifiable risks. This also includes Definition 3.14 on the common-sense predictability of misuse in ways not foreseen by the manufacturer or in the accompanying documentation, but which is easily predictable for human behaviour.
- ISO 14971:2000 Residual risk which remains after the use of protective measures.
- ISO 9241-11:1988, Definition 3 on effectiveness as accuracy and completeness by means of which the user can achieve defined goals.
- ISO 8402:1994, Definition 2.17 2.23 Verification based on an investigation and the provision of evidence that the established requirements can be fulfilled.
- DIN-Norm 66234 concerning the general basic principles of dialogue design. These include the dividing up of screen content into input and output areas, screen construction and messages as to system status.
- EN 60601-1-4. Medical Electrical Devices. In: Parts 1-4: General Established Principles for Safety - Supplementary Norm: Programmable Electrical Medical Systems, 1999
- DIN ISO/IEC 12119. Information Technology in Software Products. Quality Requirements and Test Regulations, 1995
- DIN IEC 62B(CO)106. Evaluation and Routine Monitoring in Medical Illustrative Sections. Draft 1994
- DIN EN ISO 13485. Quality Assurance Systems Medical Products. Special Requirements for the application of EN ISO 9001, 2001,
- DIN EN ISO 14915 Software Ergonomics for Multimedia User Interfaces, Design Principles and Frame Conditions 2000);
- ISO/IEC 11581 Information Technology User Interfaces and Symbols - Icons and Functions, 2000.

A restricted user description is necessary already at the invention stage for a new product. This will include *inter alia*, the sex, education, experience, ability and skills, resilience, health limitations, learning ability, private interests, IT experience, expectations, cultural circles and access to technological means. Similarly limitations on reading ability and language knowledge need to be included. Demands on the user in each of his work situations should be carefully adapted to his experience, e.g. whilst taking into account cognitive psychology, etc.

From the user description and product functionality a number of generally applicable user requirements emerge:

- Task suitability, i.e. only necessary and appropriate functionality is available
- Controllability by the user
- Minimisation and distinguishability of the number of interactions
- Preserving conformity of expectations and consistency
- Making things visible: both the state of the system and alternative actions must be clearly discernable at all times
- Reader friendliness by means of clearly discernable shapes and symbols
- Always providing the user with feedback. He should always know what he has done and what he can do
- User's freedom of decision
- Individualisability or adaptability to every user and working context
- Error tolerance in the system
- Self-description capacity and comprehensibility through integrated help and feedback
- Uncomplicated learning of system use
- User training, user instructions, must be available
- Maximum efficiency of system use
- Access must be guaranteed, for the product to be attainable by the user.

The use of knowledge of human behaviour, capabilities, limitations or other qualities is necessary in the design of medical electrical systems in order to assure efficient, effective use. This is also referred to by the term "human factors engineering". Usage is only well designed if the user can concentrate on his tasks and does need to spend much of his time finding out how to carry out certain stages of the work with the system. The principles of universal design should be observed here, i.e. the widest possible group of users with the most varied conditions and capabilities are in a position to operate the device. It is well known that users scan through contents on the monitor, but seldom read through them thoroughly.

The most important viewpoints are summarised here, which are of decisive importance for the ergonomics of dialogue-based systems.

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The purpose of navigation is: purposeful orientation: where was I, where am I now, and where can I still go. In navigation, apart from the tree-type, there is no unitary navigation design. It must be logically designed and equipped with help. Most users are ready to learn through exploration as far as their learning ability and level of knowledge permit. The response-time behaviour of dialogues should be optimised. Unclear statements should be avoided in order to achieve a short learning time.

Natural and artificial limits, mental, logical, semantic and cultural compulsory functions should be used, thus giving the user the feeling that it is the only correct possible action. Restrictions should reduce the number of possible alternatives at any stage. Compulsory functions and physical limits can render making errors in critical situations more difficult.

"Making errors" on the part of the user should be regarded as a sequence of actions which represent an "approximation" to the desired result. Any error which can be made will be made. The causes of errors should be understood, and consequently, things should be designed so that these causes are reduced. To support the user, the revelation of errors and their cure, should be made easier, and cancelling undesired results should be made easy to understand. Correction and revision of actions should be made possible, and actions which cannot be cancelled should be made more difficult.

When reproducing texts, attention should also be paid to the greatest possible contrast, also at oblique angles of vision, through the choice of font and colour (DIN 66234). The font size should be so chosen that the text is still visible from a distance of 30 cm to a person suffering from a 20% reduction in vision. Easier legibility can be achieved through sans serif print e.g. the newer DIN1451 fonts. These have proved to be advantageous on low-resolution screens of mobile devices.

Picture language is a way of communicating nonverbally which can be converted in real time. Images and symbols are more easily understood by people than textual descriptions and mostly easier to notice. It is possible to communicate much more complex information at a glance by means of symbols [13].

They should always have a simple structure, strong contrast and just a few, expressive colours, whereby, depending on the cultural circle, a particular meaning can be attached to individual colours. This relationship between symbol and what it expresses is known as mapping. A sign which is similar to a picture is called an icon. Sigmatics investigates the relationship between signs and their denotation. Syntactics in turn sets up rules for how the signs are composed of a basic sign, a reference sign and an additional sign. (road signs). The combined meaning of the sign finally results from the combinatorial analysis of the meanings of individual signs (semantics) The user must further be able to recognise which working possibilities are represented, which seems all the easier if the symbolism is linked to well-known traditions. Fortunately, more or less uniform symbols have been implemented for continually returning operations on all-embracing platforms, and have been standardised. For medical symbols there is a compulsory collection: IEC 60878 [14].

The development of the alphabet too is based on symbols and languages such as Braille, BliSS symbols, PCS, COMPIC or Löb symbols. With the introduction of new symbols a text explanation should be included which is appropriate for the target group. Under conditions of acoustic interference, graphics which are suited to the situation are more easily stored in memory than a written form. The language-independent use of iconic representation always requires a learning process to achieve more certain mastery. Nonetheless it conceals the danger of false interpretation, and also misunderstandings resulting from cultural differences.

Colours and their combination invoke emotions and demand a reaction from the observer. Human colour perception is dependent on many individual factors such as culture, sex, personal experience, up-bringing, fashion, the season, age and much more, and hence trigger a multiplicity of reactions and associations. It should further be borne in mind that men have a more limited field of vision than women. In addition, from 3 to 9% suffer from weakness in the green colour area. Germans frequently associate the following properties with individual colours:

Red: love, danger, energy, heat
Blue: trust, cool objectivity, the technical, the functional, knowledge, wisdom, breadth
Green: spring, hope, naturalness, health
Yellow: sour, sun, merry, optimism joy
Orange: gaudy, warning
Grey: boredom, monotony, emptiness, studied insensitivity, modesty, the everyday
Black; mourning, hard, elegance, power, evil

Least loved is brown, with blue and green the most loved.

No deficiency of design should, however, be remedied through the use of colour.

Neighbouring regions of the screen and the background influence each other due to peripheral perception. Consequently an object, symbol or text has an effect through the space surrounding it. The generation of order is striven for. Neutral background graphics with low contrast should be meaningfully used.

The design (e.g. uniformity) makes the reception of information easier. Objects of similar or identical form and also objects situated next to each other form logically coherent information blocks. These objects then behave in unitary fashion in the event of common changes.

Keys are sensitive areas on the monitor. It is well-known that too small keys or distances between them frequently lead to wrong operation (minimums size). Short intervals from 50 to 300 ms in action increase input reliability.

The use of photographs for dialogue control is questionable. They can even distract attention. They should not be used purely for embellishment purposes.

The adaptation of a software user interface to another culture requires a conversion of language, measurements, coloured spaces and icons. As examples, attention should be paid when adapting the data form or the progress of the text to converting full-stops and commas in figures, and changing the date format or the writing direction.

The usability of a user interface is ascertained and assessed through user's reactions. These reactions are dependent on the properties of the system, of the capabilities of the user and his characteristics as regards tasks and activity. With the aid of tried-and-tested methods and psychological experiments (interviews, questionnaires, observation, checklists, visits, controlled experiences, product tests, field observations, etc) so as to achieve genuine results, the user's performance is ascertained when carrying out a routine task or when learning how to operate the device.

Economic evaluation: Finally, an analysis follows of the cost of qualified development work and documentation in the form of a cost-to-benefit account of the user interface from the point of view of the manufacturer.

Results

Telemedical applications for post in-patient treatment need a universal, user-friendly dialogue design. The Service Centre for Telematic Traumatology (TELTRA) has been developing systems for televisiting over recent years, in close collaboration with the BG Clinic at Bergmannsheil, on a variety of device platforms (PaceBlade, Vodafone PDA, Nokia N90).

All implementation was preceded by a patient-orientated draft plan. Each dialogue design was first tested with a function prototype in HTML and Java Script. The interfaces of all three device types are based simply on bitmaps. All texts, buttons, displays and aids are implemented as a temporal sequence of graphic elements, so that a language adaptation requires merely the exchange of graphic files without recoding.

Each page has a visible brief title for orientation. Details such as time, connection or battery status are only superimposed top right when necessary. The navigation elements and screen areas such as Back, Continue, Help are superimposed on the bottom screen margin in fixed positions and are only visible when these are currently fulfilling a function. For navigation, blue arrows with corresponding white text are used. Calling up Help is permanently linked to the symbol "?" and the colour green. The escape key is coloured in red. Reading any functions such as informing the doctor, entering the pain or temperature, or taking a picture are carried out individually whilst using the same colour chart.

Figure 1: Pain page, PaceBlade

The intensity of the pain value entered by the patient on a scale of 0 to 10 is visualised in an acute-angled triangle familiar from the brightness or volume settings on a television. The filling of the triangle takes place in the colours of the rainbow (cold colour blue = hardly any pain and warm colour red = severe pain). On the temperature input page a stylised thermometer shows the corresponding analogue value on the scale in addition to the numerical value. Frequent user errors are prevented as far as possible when entering and through the hierarchical, tree-type menu. An overview page at the end of the televisiting session allows checking and revision before sending. The help position is kept short and explains only the basic function of the keys. The individual questions are listed for the patient on request. The patient's messages are only carried out linguistically, so that the meaning of a key is totally irrelevant. The symbols on the screen areas for recording language correspond to those of a cassette recorder (record button = red point, stop button = black square). The patient is always introduced to the device before the first time of using.

When designing the user interface of a PDA the emphasis is on user-friendliness, since the display area is relatively small (320 x 240 pixels). The interface elements should further be controllable with a finger instead of the normal pen. The patient is therefore given in- and output elements which are easy to recognise. The screen areas take up as large an area as possible on the display. The arrangement of the figures corresponds to telephone keys as normally found, and not to those of a pocket calculator. Wide user ability is guaranteed through the size of the in- and outputs, and the navigation interface, so that people with limited vision of up to around 20% will know how to use the device. The menu design is kept simple so that time-intensive teaching of the user is not necessary.

The division of the screen content into input and output, the screen layout and also messages concerning system status follow DIN Norm 66234.

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The interface layout is maintained in the various submenus, so that the user can recognise the areas input, output and navigation at all times. In this way a high tolerance of error is achieved.

A high degree of user-friendliness should be provided through the intuitive control of the interfaces [15,16]. To this end, the high recognition value of particular colours, shapes and patterns is used whilst using strong contrasts. Both the structure of the menus and data input allow the user as little scope as possible in order to limit sources of error through incorrect use.

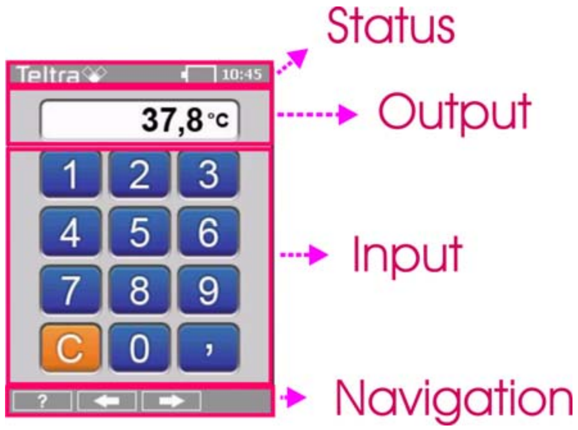

Figure 2: Division of the PDA dialogue design

Figure 3: PDA temperatur dialogue dialog

To allow the user to correct his own input errors, direct feedback is carried out. The user gets an immediately reaction to his input, here in the form of a display. The input can be seen directly by the user, tested, and if necessary corrected. When inputting data, in order to allow as much system independence as possible and also to simplify handling, the occupation of function keys and the use of pens has been avoided.

The status line on the upper margin of the screen provides information all the time about the location of the user within the menu.

The user enters the pure values of his medical data. The device will be given to him as a fixed component of the interface. This increases tolerance of error and simplifies usage.

Figure 4: Pain page on PDA

Figure 5: Pain page on mobile phone

Due to the very small display, implementation on Symbian mobiles also uses both the navigation keys or alternatively the navigation joystick. Figures can also be entered using the keys 0-9. Keys specifically reserved for the device such as for audio recording or triggering the camera are also moreover retained. Unfortunately this requires the aid setting to be reduced to a minimum.

In order to test the entire usage for user-friendliness, it was offered to a test group. The interfaces were converted with reference to their user-friendly operation to satisfy the users. The modular programme structure allows for expansion.

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Discussion

The large PacePlade device met with a high degree of approval as regards legibility, operation, stability, etc. The PDA is, with its small but precisely sufficient display size, an ideal compromise between cost and size. However, compromises have had to be made in the design and especially in the arrangement of symbols. Clearer marking of the symbols is not always possible. Today's mobiles present a challenge despite larger displays. The menus have been reduced largely to known symbols, and acoustic signals have a supporting role.

From the point of view of the programmer, the MS windows-based PDA is totally unsuitable, since important interfaces in the operating system are not disclosed or switchable. PC-based systems such as PaceBlade or Symbian OS-based mobiles on the other hand allow the development in C++ of more reliable applications with access to the hardware (camera, audio, touch screen).

Conclusions

Ivan Sutherland programmed his "Sketchpad", as early as 1963 with a number of features such as objects, icons, or a copying function. The efficiency of today's µ-processors and touch screens allow more user-friendly, intuitively controllable patient interfaces to be designed whilst taking account of ergonomic recommendations.

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