The Design and Research of Human-computer Interactive Interface on the Medical Infusion Pump

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Abstract: Medical infusion pump is a commonly used clinical nursing equipment, which is of great value in the field of medicine. On one side, this paper collected and analysed user requirements by conducting user research on nurses and patients; on the other hand, it analysed the software and hardware interface, combined with the present market used the medical infusion pump, proposed the design principle of human-computer interaction of medical infusion pump, and the improved design is carried out under this guidance finally for having a better usability and user experience.

1. Introduction

Medical infusion pump is a commonly used clinical nursing equipment. It is suitable for clinical treatment of almost all departments such as anesthesia, analgesia and antibiotic treatment. It has gradually become a universal popular treatment instrument [1]. However, the medical infusion pump has long been at the forefront of the statistics of active medical device adverse events, and the design problem of the human-computer interaction interface is particularly prominent. According to Norman's "Design Psychology", the product is not easy to use, not easy to use, not the user's problem, but the product design problem [2]. In order to improve the usability of human-computer interaction interface of medical infusion pump, this thesis proposes the human-computer interaction interface design principle suitable for medical infusion pump by researching the human-computer interaction interface of the infusion pump and its users. Make an improved design.

2. Characteristics of human-computer interaction interface of medical infusion pump

As an important clinical nursing equipment, the medical infusion pump should not only take care of the needs of nurses and patients in the design of human-computer interaction interface, but also ensure the integrity of the software and hardware interfaces and the coordination of interaction. The design of the interactive interface is a dynamic process, which is the design process [3] of meeting people's needs. After several years of development, the design of the human-computer interaction interface has
completed the transition from interface design to behavior design to experience design, reflecting the design thinking from relying on machine mode to following human cognitive behavior, and then pursuing people's emotional experience and the evolution of value realization.

2.1. User's duality and dual human-computer interaction interface

![Diagram](image)

**Figure 1.** Medical device dual - machine interface

The user of the medical infusion pump is a nurse, and the target object is a patient. The interface formed by this special human-computer interaction relationship is a dual human-computer interaction interface [4]. As shown in Fig.1, the human-computer interaction interface of the medical infusion pump can be divided into a nurse-infusion pump interface and a patient-infusion pump interface. The nurse-infusion pump interface generally includes a hardware interface and a software interface for the nurse to set the infusion parameters, patrol operation status, and obtain the alarm information. It is the main object of the human-computer interaction interface design; the patient-infusion pump interface mainly enables the patient to obtain a certain amount. The infusion information is an auxiliary object of the human-computer interaction interface design.

2.2. The integrity of the software interface and hardware interface

The human-computer interaction interface of the medical infusion pump is divided into a hardware interface and a software interface, as shown in Fig.2, which is a human-computer interaction interface of the Medcaptain infusion pump. The hardware interface mainly refers to the control panel part that contains the buttons. The software interface mainly refers to the display panel part that carries infusion information and interaction. In the design of the human-computer interaction interface of the medical infusion pump, the integrity of the software and hardware interface attributes and the coordination of the interaction must be considered.
3. Investigation and analysis of medical infusion pump

3.1. Hardware interface research and analysis

The hardware interface of the infusion pump mainly refers to the control panel part composed of a plurality of buttons with different functions. The button is the key node of the function flow, which can be the physical physical button or the touch screen virtual button. Under the premise of considering the hardware limitation, the key of the designer's effort is to properly allocate the button function and quantity to ensure the smoothness and hierarchical of the button layout.

As shown in Table 1, through the functional analysis of multiple brand infusion pump buttons, the implementation of the infusion process generally requires the following 12 functional support.

| Number | Function    | Number | Function |
|--------|-------------|--------|----------|
| 1      | Delete/Empty| 7      | Mute     |
| 2      | Return/Cancel| 8      | Power    |
| 3      | Enter       | 9      | Off      |
| 4      | Start       | 10     | Menu     |
| 5      | Pause/End   | 11     | WASD     |
| 6      | Vent/Bolus  | 12     | Numeric  |

Through comparative analysis, the design of the hardware interface of the infusion pump on the market is quite confusing. Overall there are the following problems: (1) There is no function and quantity for assigning virtual buttons and physical buttons to the hardware size; (2) Keys and functional semantics Mismatched collocation, semantic-related functions are assigned to different keystrokes or semantically unrelated functions are assigned to the same button; (3) key common functions are not assigned separate physical buttons; (4) some functions use key combinations Lack of consideration for button usability; (5) button layout does not consider the fluency and hierarchy of features.

3.2. Software Research and Analysis

Firstly, three representative medical infusion pumps, Mindray, Qixi and Medcaptain, are selected in the market, which are mainly analyzed in terms of functional composition, operation flow and interface design of the software interface. The results show that the following problems exist: (1)
Some basic functions and humanized functions are lacking. Although there are some common functions such as partial infusion mode adjustment, infusion completion configuration, system parameter setting, KVO rate setting, calibration setting, etc., there is still a lack of more intelligent infusion mode to adapt to multiple scenarios, password permission settings and personality configuration; (2) interface layout is confusing and similar operation process is not consistent, increasing nurse memory pressure, especially for novice users are not friendly; (3) important information cannot do it visually.

3.3. User research and analysis
Based on subdividing users, this study conducted questionnaire surveys and user interviews for novice users, skilled users and patients using infusion pumps in the nurse group. The survey results are organized as follows:

3.3.1. For the needs of nurses, the human-computer interaction interface of the infusion pump needs to have the following characteristics:
(1) Full-featured, with a variety of infusion modes, the overall satisfaction of clinical infusion needs. (2) The layout of the buttons should be reasonable and basically conform to the operating habits of the nurses. (3) The layout and information of the interface are hierarchical and have a high information recognition. (4) The operation process is concise and consistent, which allows users to get started quickly and improve operation efficiency. (5) The function trigger mode is set properly, avoid setting common functions as combination keys or setting different functions to similar trigger modes. (6) The feedback system is perfect, feedback is timely and feedback information is easily obtained. (7) The alarm prompt information is clear and easy to understand, so that the nurse can promptly eliminate the fault. (8) High fault tolerance and certain error correction capability to prevent users from entering the wrong situation.

3.3.2. According to the needs of patients, the human-computer interaction interface of the infusion pump needs to have the following characteristics:
(1) Infusion information is easy to understand, it is convenient for the patient to understand the operating status and infusion of the infusion pump. (2) The overall design is humanized, stable, concise, and affable, which is easy to weaken patients' anxiety.

4. Design principle of human-computer interaction interface for medical infusion pump
Through the above analysis of the software and hardware interface of the medical infusion pump and user research on the dual users of nurses and patients, combined with the product positioning and functional performance of the infusion pump, the design principle of human-computer interaction interface suitable for medical infusion pumps is proposed. details as follows.

4.1. Hardware interface design principles
1. The principle of layout fluency. The button layout of the infusion pump should be divided into functional areas according to the importance of the function of the button and the operating frequency. At the same time, according to the correlation between functions and operations, the key layout should be in accordance with the operation sequence.
2. The principle of visual hierarchy. The visual design of the infusion pump button should consider
the importance and particularity of its function, and build a visual hierarchy based on the functional level, thus providing good visual guidance to the user.

4.2. Software interface design principles

1. Consistency principle. Internal consistency, all parts of the infusion pump software interface should be consistent in terms of interaction process, layout form, information representation, color design, etc.; external consistency, design of infusion pump software interface should be based on user experience and operation habits consistent, it is convenient for users to quickly understand and master the interface operation.

2. Prompt guiding principle. The operation and parameter limits of the infusion pump are complex and diverse, and reasonable prompting and guidance can assist the nurse to complete the operation smoothly and efficiently.

3. The principle of minimum information load. The nurse's cognitive and attention resources are limited. Based on ensuring effective and timely information transmission, the information presentation form should be rationally designed to enable users to obtain information simply and intuitively and reduce cognitive load [5].

4. Feedback principle. Timely feedback on the nurse's operational behavior and timely alarm of the abnormal operation of the infusion pump to avoid or reduce infusion errors.

5. The principle of fault tolerance. The infusion pump software interface should have the ability to prevent user errors and assume user error, to avoid errors or reduce the risk of operating errors.

6. Limitation principle. The infusion pump software interface should be able to limit the user's incorrect operation, such as setting an in-range infusion parameter.

7. Dual user principle. The human-computer interaction interface design of the infusion pump should be based on the needs of the nurses. Under the premise of meeting the needs of the nurses, the patient needs should be as much as possible, and the interface should be optimized according to the needs of the patients.

5. Improved design of human-computer interaction interface for medical infusion pump

In this paper, based on the human-computer interaction interface design principle of the above medical infusion pump, the improved design of the human-computer interaction interface of Huaying Medical Infusion Pump is as follows:

5.1. Hardware interface design of medical infusion pump

The new Huaying medical infusion is a horizontal infusion pump. Firstly, according to the importance of the button function and the frequency of use, the layout area is divided. In the middle of the screen and in the infusion, pump is the convenient operation area of the finger, and the convenience on the right side is relatively weak. Parameter setting and determination, return should be in the convenient area of operation, and the remaining buttons can be assigned to the right. Therefore, the control panel function area is divided from left to right: side keypad, digital operation area, function key area, as shown in Fig.3.
After determining the layout of the control panel buttons, this study is based on user survey and human-computer interaction interface analysis, the twelve key function semantics required for the normal operation of the infusion pump (start, stop, confirm, delete, return, BOLUS, mute, boot, shutdown, menu, azimuth adjustment, digital input) analysis, as follows: the input and modification of the infusion parameters are user's pain points, so the digital input directly uses the number keys, decimal point keys, delete keys; the fast forward function needs greater, should be a Key independently to avoid the use of key combinations. According to the brand design tradition and advantages, four screen-side function keys should be retained: up, down, OK, and back; start, stop, mute, menu semantics are assigned to independent keys, boot and shutdown semantic allocation on a button. Specifically shown in Fig.4.

5.2. Software interface design of medical infusion pump

5.2.1. Consistent design of layout form.

According to the visual laws and information characteristics, based on the global consideration of different functional requirements, the interface is clearly divided into regions, and different functional interfaces follow a consistent layout form, but this consistency is relative, only in overall consistency. Based on the different interfaces, flexible adjustments can really improve the usability of the interface.

As shown in Fig.5, the overall setting interface is from top to bottom, respectively, the title area, the setting item area, and the prompting area. Based on the overall consistency, some parameter setting areas are set for the case where detailed prompting and guiding are required. Merged into the hint guide area; for the case where many parameter alternative items are required, the layout of the parameter setting area is divided into two columns.
5.2.2. Consistent design of the interaction process

In the process of interactive process design, the principle of consistency is adopted, and the main functions are all simple linear processes. Users can quickly understand the whole process of core functions by relying on real-world experience, and are friendly to novice users. At the same time, in specific processes, adding certain shortcuts can improve operational efficiency.

Take the startup process as an example. The process involves the boot process, the menu process, and the running process. The user may touch these three parts in one operation. If the design is unreasonable, it will affect the smoothness of the operation. As shown in Fig.7, the three processes are designed as linear processes, and the user can advance or retreat step by step. At the same time, the
mode side keys and menu keys can be used to directly enter specific interfaces, providing shortcuts to improve the efficiency of skilled users.

![Diagram of boot operation process design](image)

**Figure 7.** Boot operation process design

### 5.2.3. Information Visualization Design

The medical infusion pump has a large amount of information on certain functions. If you only rely on the nurse's memories, it will bring a large memory burden to the nurse and it is easy to make mistakes. Visualizing the complex information in the design will help users to obtain information intuitively and quickly, reducing cognitive load. This article only shows the alarm information visualization interface and calibration preparation visualization interface, as shown in Fig.8 and Fig.9.

![Prototype design of block processing interface](image)

**Figure 8.** The prototype design of block processing interface

![Prototype design of calibration interface](image)

**Figure 9.** The prototype design of calibration interface
5.2.4. **Dual User Interface Design**

According to the survey results, the patient also has the information attention requirement for the running interface. Therefore, for the running interface, the design is divided into the nurse interface and the patient interface. In practical applications, the patient interface can be selected to be turned on or off.

Nurse's running interface: According to the survey results, the nurses have different concerns about the different information of the running interface, so different information is presented in different positions on the running interface, as shown in Fig.10.

![Figure 10](image)

**Figure 10.** The prototype design of operation interface for nurse

Patient's running interface: According to the survey results, the patients mainly pay attention to the remaining time and running state. The patient interface mainly highlights the remaining time during the design, and the visualized dropper form is used for the running state; the infusion rate, preset amount and pressure for the nurses will also be presented for the direct attention of the nurse, and the nurse can also exit the patient interface by pressing any side button. Specifically, as shown in Fig.11.

![Figure 11](image)

**Figure 11.** The prototype design of operation interface for patient

6. **Summary**

Design is a creative human activity, and the process of design is the process of human beings constantly creating civilization [6]. The human-computer interaction user interface bears the interaction between management and users, such as displaying data to the user, obtaining data from the user, interpreting events caused by user operations, and helping the user to view the progress of the task [7], it plays an important role in the product itself and human-computer interaction. Medical infusion pumps are commonly used as medical equipment for clinical care, and the design of human-computer interaction interfaces should receive more attention. This thesis aims to improve the ease of use of human-computer interaction interface of medical infusion pump. Through the research
and analysis of human-computer interaction interface theory and the characteristics of medical infusion pump interface, the design principle of human-computer interaction interface of medical infusion pump is proposed. Under the guidance of design principles, the interface between hardware and software is improved.

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