3. Scope of Ergonomics Design and Usability for an Intensive Care Unit (ICU): An Indian Perspective

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Abstract
In this paper, we have tried to identify the scope of ergonomics design and usability for an Intensive Care Unit (ICU) through the study of seven different hospitals in India. The feedback received from physicians about the usability of ventilator systems is also discussed. Our study highlights the need to evolve standards focusing on ergonomics design and usability of an ICU. It is also felt that the user interface design of medical equipment and hospital signage systems must support culture specific and localized adaptations for better comprehension.

Keywords
Intensive Care Unit (ICU), Medical Equipment, Ventilator System, Human Factors, Ergonomics Design, Usability

Introduction
In this paper, we are presenting the findings of our usability study of Intensive Care Units (ICUs) in Indian hospitals. Our study touches upon its various aspects such as location, layout, signage system, doors, windows, patient information boards, switchboards, power plugs, various medical facilities and equipment. Through this study, we have realized that there is vast scope for enhancement of ergonomics design and usability of an ICU and each aspect needs an individual focus. However, presenting an overview of these aspects will be helpful for appreciating the complexities and challenges faced by the physicians, ICU staff and patients. An example of this complexity was noted in relation to the usability of ventilator system, which is one of the most important pieces of medical equipment used in an ICU.

We came across many ICU standards that primarily focus on ensuring quality of service through process monitoring. Some of them make a passing mention of ergonomics design but do not provide any specific guidelines to enhance the usability of an ICU [13].

Critical role of an intensive care unit (ICU)
In the first instance we need to appreciate the purpose and objectives of an ICU. Mostly the ICUs are meant to offer emergency services to patients. ICUs are specialty-nursing units designed, equipped and staffed with skilled personnel for treating very critical patients or those requiring specialized care and equipment [7]. An ICU has a cognitively complex environment [14] like the cockpit of an aircraft or the operating room of a nuclear power plant where one is required to:

- monitor various systems and equipment;
- integrate and understand complex information;
- attend critically ill patients;
- judge the dynamically evolving situation; and
- take quick and accurate decisions.

Time critical
Densely populated cities in India, narrow lanes, traffic congestion and parking problems create hurdles for critically ill or accidentally injured patients en route to a hospital. In the process, such patients lose precious time at this life critical moment. Once the critical patient is brought to the hospital, without any further loss of time, it should be possible to give immediate attention and proper treatment. In this critical moment, the usability of an ICU becomes important for efficient and accurate treatment.

Life critical
Poor usability increases the risks associated with medical equipment [9]. It also results in undue expenditure in terms of unproductive time needed to be spent on learning how to operate the equipment and unsafe handling possibly resulting in accidents [10]. Furthermore, device-induced errors can also injure or kill a patient [8].
Emotionally stressful
ICUs have a very emotional and critical environment as they deal with life and death situations. The patients and their relatives can become emotional. Their reactions may be very sharp. Also, behaviour of physicians and ICU staff can be directly affected by the operating environment and physical characteristics of medical equipment [3].

Need for user friendly ICUs
Patients and their families need user-friendly environments that have a more natural look and feel [2]. They also expect improved décor, more privacy, reduced environmental stressors, natural surroundings and greater control over tasks and information.

On the whole, we can understand how important ICUs are and how critical ergonomics design and usability are for its users. Our study is very relevant, particularly in the Indian context, and it is also applicable to any other developing country scenario.

Method

Selection of hospitals

Our study is based on seven different ICUs belonging to different hospitals from cities and small towns from two different states in India. This has given us a proper representation of conditions in well-equipped and modestly equipped hospitals. For recording purposes the names of the hospitals are given below:

- Bharati Hospital, Sahyadri Hospital, Ratna Memorial Hospital and Siddhi Hospital from Pune city in Maharashtra State, India;
- Giriraj Hospital and Jogalekar Hospital from smaller towns namely Baramati and Shirwal in Maharashtra State, India; and
- People’s Group Hospital from Bhopal City in Madhya Pradesh State, India.

Data gathering

- Structured interviews of many physicians and ICU staff were carried out. It was a very hectic and tricky challenge to get access to medical practitioners.
- A questionnaire was designed as per the guidelines given by Chauncey Wilson [4] to gather feedback.
- Field studies, observations of facilities and usage of equipment were photographed and documented.

Types of Users

Various users of an ICU have been are categorized as:

Primary users
Physicians, specialist physicians, resident doctors and sisters who actually use the equipment.

Secondary users
Intern doctors, ward boys, patients and biomedical technicians who also assist the primary users in maintenance of medical equipment.

According to Jennifer Martin et al [9], even when patients don’t operate the medical equipment, they are subjected to the diagnosis and treatments produced using the equipments. Therefore even the patients are also considered as important users of medical equipments.

Tertiary users
Administrators, relatives of patients, visitors who come in proximity to medical equipment.

The planning team for an ICU design should include representatives of all the users—especially patients and their families as they are experiencing some of the most traumatic moments of their lives [2].

Discussion

Location of an intensive care unit (ICU) in the hospital premise

Table 1. Floor wise location of ICUs in different hospitals

<table>
<thead>
<tr>
<th>Floor</th>
<th>No. of ICUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>2</td>
</tr>
<tr>
<td>First</td>
<td>2</td>
</tr>
<tr>
<td>Second</td>
<td>1</td>
</tr>
<tr>
<td>Third</td>
<td>2</td>
</tr>
</tbody>
</table>

As shown in Table 1, we have observed that the ICUs are located on different floors in different hospitals. This compels the patients to use elevators and as a result increases the dependency on power supply, maintenance and smooth functioning of the elevator. ICUs are not immediately approachable when you enter the hospital. In many places an exclusive entrance and parking facility is not provided.
Ideally, the ICUs have to be on the ground floor and not far from the casualty department and a general ward [7]. As recommended by Miranda et al [5] the supporting services such as an operating theatre, the department of radiology, the laboratories, and the blood bank should be nearby. On the contrary, we found that the ICUs are surrounded by random facilities and services. There does not seem to be any standard practice or design. Because of the unavailability of a standard location and easy pathway to reach the ICU, the patients and their relatives have to search for it, which results in delays and disturbance to other patients.

Figure 1. Signage for an ICU

Signage System

A good signage system is an imperative for directing the patients and visitors through the hospital. A proper signage system is also essential inside the ICU. It can help the users to navigate independently through various departments, without requiring any assistance or disturbing the patients. But many hospitals in India do not use signage systems. Where some signs and symbols are used they look different in different hospitals. One such signage board is shown in Figure 1. Standard guidelines for hospital signage are essential wherein the depiction of sign, colors, shapes, sizes and placement of signs should be consistent. Culture specific localization of hospital signage needs to be considered for effective communication with patients and visitors belonging to a geographic region.

Layout and Composition of Facilities in the ICU

The typical ICU includes various facilities such as a procedure room, visitors’ room, counseling room, changing rooms for nurses and physicians, a security room, dead body room, conference room, reception, communication centre, pantry, store, places for clean and dirty linen, patient toilet, staff toilet, and gadget parking area [12]. In the ICUs visited by us, we found that the above-mentioned functions and facilities were all arranged differently. In many cases, some of the facilities were not provided at all.

During our interviews with the experienced physicians, they agreed unequivocally that the above-mentioned functions and facilities are interrelated and interdependent and hence should be considered at the time of architectural planning. Many facilities are created in any available space, in the built environment of the hospital. Design of the architectural layout along with all the facilities related to it, have a strong impact on overall usability and effectiveness of an ICU.

Figure 2. Patient Information Boards

Design of Patient Information Boards

Effective communication with patients, relatives and visitors is vital in healthcare settings where miscommunication may lead to misdiagnosis and improper or delayed medical treatment [1].

As shown in Figure 2, patient information boards are used to provide information about resident patients. This information helps the family members and newly visiting medical staff to find where their patient is located.
Figure 2 shows that the bed numbers have been hand-written on cards that are partly or fully covered by the cardholder. A typical information board has many such card-holders arranged in a grid format. Patient information on the board can be updated in random order. As a result, the family members of the patients have to take a walkthrough of an entire ICU to locate their patient. It would be ideal to have the cardholders arranged as per the layout of the ICU. It would help the family members get a proper orientation and eventually locate their patient without disturbing other critically ill patients.

Figure 3. ICU Doors with written instructions on whether to push or pull them open

Door Design and Window Positions

Figure 3. shows the doors of one ICU. Figure 3A shows the outside view of doors and Figure 3B shows the inside view of the same doors. Figure 3A shows an instruction in a blue color strip that says ‘Push the Door’. Figure 3B shows another instruction that says ‘Pull the door’.

The following usability problems with the doors are noted below.

- The instructions are written in Marathi, the regional language used in the Maharashtra State of India. This means that they may not be readable by the physicians, staff members and visitors who cannot understand Marathi language. These people will be left with no option but to explore pushing, pulling and may be even sliding the door and thus waste valuable time.

- The design of door itself should provide cues for one to know whether it should be pushed or pulled [11]. Design can transcend languages and be used to communicate effectively with the users.

- Such doors make it difficult, especially when the patient is taken in or out on a stretcher, as the radius of door opening is large. Thinking logically, sliding doors would be easier than doors which require to be pushed or pulled.

Figure 4. Windows causing bright reflections in the monitors

It is essential for every ICU to have windows as the source of natural light. It is extremely important for the patients as about 50% of them who have stayed for more than eight days in ICU, develop ICU psychosis [7]. It is a condition whereby a patient loses track of time.
At the same time, the relative positions of windows and monitors of medical equipment should be such that monitors won’t lose readability because of reflections. Information displayed on the monitor must be easily readable for the physicians. Figure 4 shows bright reflections in the monitor which is on a shelf opposite wide glass windows.

**Design of Power Switches, Plugs and Cables**

We often found that some power plugs were marked with indications of where they belonged, or with which equipment they needed to be used. This was because the cables and plugs do not carry any pre-defined colour-code or symbols for their usage. This resulted in a potential mix-up of power cables. As a result the users had to stick labels—or scribble some information using marker pens—on the power plugs and cables. Power plugs and cables should be designed with unique color-coding, shapes and sizes for better identification [11]. The same approach is also applicable to switchboards … as otherwise one has to operate them by trial and error.

**Usability of Medical Equipment**

An ICU has many medical types of equipment such as a ventilator system, defibrillator, multi-parameter monitoring system, central monitoring station, electrocardiogram (ECG) and analyzer. These are the most critical and commonly required medical equipment, which provide extensive information to help with medication.

In this wide variety of medical equipment, we focused mainly on the usability of ventilator systems, as many physicians specifically advised us to do so. They accorded the highest priority to the usability of this equipment. A ventilator system gives respiratory support to critically ill patients [10]. The usability issues commonly observed during this survey are summarized below.

**Switches Don’t Last, Labels and Symbols Fade Away**

The ventilators are costly and are intended to be used for a long period in order to recover the initial expenditure. But the users’ experience did not support this assumption. The switches, knobs and control panels did not last very long as a result of their frequent use. The labels and symbols printed on the buttons also tended to fade away [6].

**Legibility and contrast**

Very often the physicians have to glance at the monitor of a ventilator system from a distance. The monitor shines and reflects the light. As a result the readability of information displayed on the monitor is compromised. In the case of physicians having poor eyesight, it makes it harder to read the information. Therefore, the legibility of information and its contrast in the display monitor need to be enhanced.

**Clutter of features**

Ventilator systems are provided with many functionalities and features, which remain unused. This complicates the routine usage and results in cognitive overload for the users.

**Culture specific symbols**

Users felt that interface labels, symbols and abbreviations were designed for western users. They need to be localized and tuned to suite different cultures.

**Lack of templates and intelligence**

Templates for frequently used settings, intelligent and predictive system behavior would enable quick usage during the moments of emergencies and in the absence of specialist physicians [6].

**Right-handed design**

Many ventilator systems are designed only for right-handed users. This is reflected in the layout of the control panels. The left-handed users are disadvantaged and not very efficient or effective with right-handed design of control panels. As shown in Figure 5, the circular button and the touch-buttons are positioned on right side of the display screen [15]. The circular button may be difficult for left-handers to rotate.

Figure 5. Right-handed design of ventilator system
Mobility and portability

Users felt that ventilator systems [15] need to be more compact, along with a robust design that supports mobility and portability. Dismantling of a ventilator stand can be very time-consuming.

User manuals in foreign languages

During the interview, many sisters, intern doctors and ward-boys reported that the user manuals were difficult to locate when needed or manuals were not accessible because they were in the custody of some authority. User manuals were not readable for them when the information was presented in a foreign language such as English, French, or Dutch [9]. User manuals need to be provided in Indian languages like Hindi or other regional languages. The ventilators could also benefit from provision of online-help [10].

As shown in Graph 1, an increasing demand for training as well as the provision of better user manuals revealed the users’ helplessness in understanding the controls and interface design. It indicated an alarming need to focus on overall usability of medical equipment in an intensive care unit.

Conclusion

- Figure 6 illustrates the various aspects affecting the usability of an ICU, as separate layers of location and layout, signage system, internal facilities, medical equipment, control panels and software. Each aspect must be evaluated and designed to satisfy different human factors and user requirements. Our study has revealed many ergonomics and usability problems pertaining to these issues.

- The aspects of the ICU covered in this paper belong to diverse specialized disciplines namely architecture, visual communication, interior and furniture design, industrial / product design and user interface design. Ergonomics design and usability have to be accomplished through proper orchestration and integration of multi-disciplinary inputs.

![Graph 1. User feedback](image)

Figure 6. Scope of ergonomics design and usability for an Intensive Care Unit (ICU)

- It is imperative to evolve an encompassing design strategy to achieve ease, efficiency, goal fulfillment and overall effectiveness for the users of an ICU including physicians, patients, sisters, and ward-boys.

- Standards focusing on ergonomics and usability guidelines for an ICU need to be generated. Those standards should cater to the requirements of richly resourced ICUs in the developed countries as well as the modestly equipped ICUs in the developing countries. Healthcare should not be compromised in any part of the world.

- In addition to the considerations for various human factors, the user interface design of medical equipment and signage systems must support culture specific and localized adaptations for better comprehension.
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