Chapter 2.8
Ergonomic User Interface Design in Computerized Medical Equipment

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ABSTRACT

Current statistics suggest that preventable medical error is a common cause of patient morbidity and mortality, being responsible for between 44,000 and 98,000 deaths annually, and resulting in injuries that cost between $17 billion and $29 billion annually. An important approach to tackling this problem is to apply system design principles from human factors engineering (ergonomics). By doing so, systems and equipment become easier for people to work with, ultimately reducing the frequency of errors. In particular, in the case of medical equipment, the design of the user interface can impact enormously on its successful use. In this chapter we consider some of the elements of good and bad medical equipment design, using examples drawn from the literature and elsewhere. The concept of ecological interface design is also discussed, and some practical design guidelines are provided.

INTRODUCTION

American statistics suggest that preventable medical error is the eighth leading cause of death, being responsible for between 44,000 and 98,000 deaths annually, and resulting in injuries that cost between $17 billion and $29 billion annually (Kohn, Corrigan, & Donaldson, 1999). Experts have often stated that an important approach to improving patient safety is to apply system design principles from human-factors engineering (ergonomics; Kohn et al.; Leape, 1994). Human-factors engineering is a relatively young scientific discipline that focuses on those factors that affect the performance of individuals using systems or equipment (Kroemer, 2001). The product may be as simple as a spoon or an office chair, or as complex as an aircraft carrier, but in all cases the goal is to design products to conform to human nature rather than merely expect people to adapt to technology. By doing so, systems and equipment become easier for people to work with, ultimately reducing the frequency of errors.

In the case of medical equipment, the design can impact enormously on its successful use. In particular, errors in operating such equipment are often caused, at least in part, by the design of the user interface. Of course, such errors can not only hamper patient care, but in some cases can even lead to injury or death. It is obviously important that medical equipment be designed with special consideration given the impact of design on safe operation. Thus, the user interface for medical equipment should be straightforward and intuitive: If its operation is excessively complex or counterintuitive, safety can be compromised. Human-factors techniques have been applied to other industries, such as nuclear power and aviation, and have been very successful in reducing error and improving safety in these contexts. Note also that in addition to increasing safety, an added benefit of using good ergonomic design practices is the likelihood that training costs will be reduced.

BAD DESIGN EXAMPLES

Examples of perplexing, arcane, and hazardous designs produced in violation of ergonomic principles are not hard to find. For instance, Michael J. Darnell's Web site www.baddesigns.com offers a collection of frequently humorous examples. But when bad designs in medical equipment lead to injury or death, the situation can be far from amusing. This is sometimes the case for computerized medical equipment.

In one case reported on the U.S. Food and Drug Administration Web site (http://www.fda.gov), a patient was overdosed after a nurse read the number 7 as a 1 in the drug-infusion pump display. Because the flow-rate display was recessed, the top of the 7 was blocked from view at many viewing angles.

In another case report from the same source, a physician treating a patient with oxygen set the flow-control knob between 1 and 2 liters per minute, not realizing that the scale numbers represented discrete, rather than continuous, settings. Unbeknownst to the physician, there was no oxygen flow between the settings, even though the knob rotated smoothly, implying that intermediate settings were available. The patient, an infant, became hypoxic before the error was discovered. One solution could have been a rotary control that snaps into discrete settings.

In yet another case, a patient on a ventilator died following the accidental detachment of the ventilator tubing from the humidifier. Unfortunately, an alarm did not sound because the pressure-limit alarm setting had been set so low that it was essentially nonfunctional.

Finally, Figure 1 illustrates a less hazardous example drawn from personal experience.

A series of reports from the laboratory of Dr. Kim Vicente of the University of Toronto have looked at user-interface issues for patient-controlled analgesia (PCA) equipment (Lin, Isla, Doniz, Harkness, Vicente, & Doyle, 1998; Lin, Vicente, & Doyle, 2001; Vicente, Kada-Bekhaled, Hillel, Cassano, & Orser, 2003). PCA is a computer-based medical technology used to treat severe pain via the self-administration of analgesic agents such as morphine. Potential benefits include superior pain control, automatic documentation, and improved utilization of nursing resources.

Unfortunately, however, one of these units (Abbott Lifecare 4100 PCA Plus II) has been linked to a number of overdose deaths. This machine is easily set up incorrectly by caregivers, who must manually enter the PCA parameters, and a number of patients have received drug overdoses as a result of user errors when using this product: the insertion of a 5 mg/mL morphine cartridge when the machine is expecting a 1 mg/mL concentration, or the acceptance of the default (initial) drug concentration when the correct action is to scroll up to the correct value, among other errors. In the latter case, when nurses program the drug concentration, the Lifecare 4100 display shows a

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