The Nature of Human Errors: An Emerging Interdisciplinary Perspective

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Introduction

In light of a growing awareness of the role of human errors in widely publicized incidents such as airline accidents and complications of medical procedures, now is the right time for cognitive science to make a contribution to the study and prevention of human errors. As shown in Figure 1, human errors account for more than half of accidents in most industries. In air traffic control, the rate is over 90%. Human errors occur primarily due to inadequate information processing. As an interdisciplinary field for the study of information processing in humans and machines, cognitive science can make a significant contribution to human error studies.

In this symposium, the four presentations will address human errors from four different perspectives.

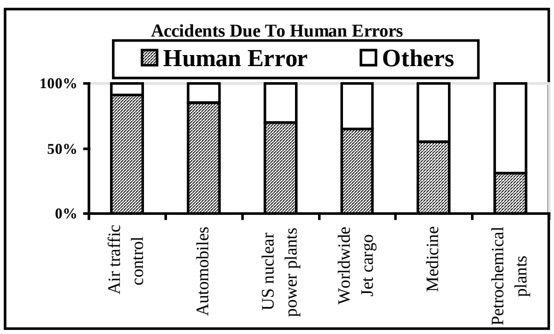

Figure 1. Accidents due to human errors

Human Errors: Cognitive Theory & Interface Design

Jiajie Zhang

There are two major types of human errors (Reason, 1990): planning and execution errors. Slips are errors of execution in which the correct action does not proceed as intended. Mistakes are errors of planning in which the original intended action is not correct. This presentation will focus on four types of slips (Norman, 1981). Caption slips result from automatic activation of a well-learned routine that overrides the current intended activity (e.g., driving home directly instead of picking up a prescription on the home way). Description slips are due to incomplete or ambiguous specification of intention that is similar to a familiar intention (e.g., inserting a Zip disk to a floppy drive). Associative activation slips are due to activation of similar but incorrect schemas (e.g., picking up the desktop phone when the cell phone rings). Loss-of-activation slips are due to loss of the activation of current intention (e.g., forgetting an idea for this symposium proposal after answering an interruptive phone call). The first part of this presentation will describe a cognitive theory of slips (based on Norman's schema theory) that attempts to explain why slips occur and predict when they occur.

The second part will be about the design of systems that minimize human errors. The cognitive theory of slips points out the causes and predicts what types of slips will happen under what circumstances. With such a theoretical guideline, we can design systems that have properties that can make certain types of slips impossible to occur or minimize the factors that can cause errors (e.g., a good user interface that minimizes mental workload).

Conceptual and Procedural Errors in Medical Decision Making

Vimla L. Patel

Cognitive studies of errors in medical decision making have traditionally focused on biases and faulty heuristics that lead health professionals to fail to attend to, or properly consider, relevant data. The error is sometimes attributed to physicians' lack of competency in probabilistic reasoning. In our view, decision making is an inherently complex cognitive and social process and errors can have multiple etiologies. It is convenient to partition sources of error into three categories: 1) individual/cognitive, 2) social/communicative and 3) systemic/institutional. Errors can arise due to actions (or neglect) of a single individual. Decision making critically depends on the availability of current information, a level of understanding, and the use of appropriate decision strategies.

The most serious cognitive errors are those that arise for reasons other than simple neglect or oversight (e.g., unintended slips). Possible causes include procedural errors and faulty conceptual knowledge. In addition, several studies have documented errors due to dissociations between subjects' conceptual understanding and their application of knowledge in solving patient problems. For example, a subject may understand that certain levels of serum cholesterol coupled with other symptoms necessitate pharmaceutical intervention, but may fail to incorporate this knowledge into an action plan. Similarly, an individual may know how to carry out an effective procedure, but lack the prerequisite conceptual knowledge required to determine its suitability or to cope with problems that arise when it is being performed. This can lead to errors of overgeneralization or contribute to use of an overly narrow perspective (violation of constraints).

High velocity decision-making environments, such as intensive care settings, are vulnerable to multiple sources of social and communicative errors. These errors can emerge from disruptions in the flow of information such as the failure of coordination and communication between an overnight and daytime nurse who must achieve mutual understanding about the state of a patient for whom they both care. Systemic and institutional errors are caused by problems that are not due to any individual or team of individuals, but rather are caused by some fault in a system. This category may include problems with technological systems, the physical design of the workspace, or the use of institutionally sanctioned, but faulty protocols.

This presentation will consider a range of medical decision making errors, drawing on both laboratory and naturalistic studies, and will attempt to relate these errors of reasoning to issues of education and training.

Information Technology's Role in the Prevention of Human Errors in Clinical Medicine

Edward H. Shortliffe

A recent report from the Institute of Medicine (IOM, December 1999) indicates that 44,000 to 98,000 patients die from medical errors every year in US hospitals. The study suggests that more people die from medical errors in hospitalization than from motor vehicle accidents, breast cancer, or AIDS (see Figure 2). When deaths from ambulatory settings are considered, the estimate can go much higher.

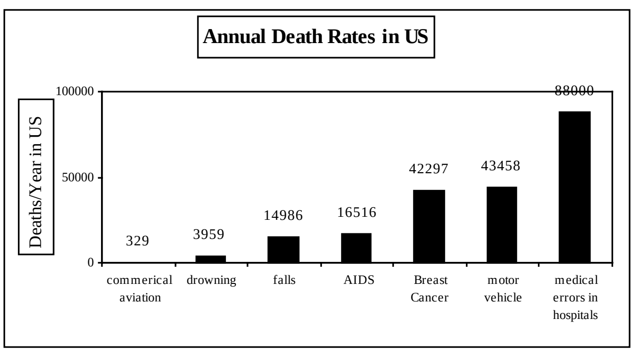

Figure 2. Annual death rates in US

Several industries (e.g., aviation and nuclear power plants) have been very successful in preventing human errors, perhaps because their accidents, when they do occur, make bigger headlines than medical incidents due to their catastrophic nature. For example, 329 people die a year from commercial aviation in US. In contrast, the death rate due to medical errors in the US is equivalent to one jumbo-jet crash every day. The IOM report has increased the public's awareness of the frequency and significance of medical errors, and the Clinton Administration has authorized the creation of a Center for Patient Safety with initial funding of $35 million a year, setting a goal of reducing medical errors by 50% in five years.

This presentation argues that there is much that the health-care industry can do to prevent the kinds of errors described in the IOM report. Many of the problems are related to inadequacies in process rather than to incompetence in health workers, and information technology can play a particularly important role in dealing with such errors. Examples include the computer-based verification of dosing information at the time that a drug regimen is ordered, or improved access to (and legibility of) pertinent clinical information that may prevent decision-making errors before they occur. Challenges in implementing and integrating such facilities into clinical environments will be discussed, along with examples of systems currently in use to address these kinds of human errors in clinical settings. The role of computer-based clinical decision-support systems will be emphasized.

Human Error Modeling in Aviation

Mike Freed and Roger Remington

In commercial aviation, as in many other demanding tasks, human error is among the most significant sources of cost and risk. One important consequence is a necessary conservatism about introducing new aviation technologies. In particular, new procedures and devices that affect the type, pace, or amount of work of an operator may inadvertently facilitate error. Designers typically assess the human performance impact of new technology by building system prototypes, training users, and then running "human in the loop" studies in which operators are observed carrying out tasks in a variety of scenarios. This tends to be very costly, limiting the amount of testing that can be done and, indirectly, the flexibility of the system to accommodate innovation and adjustment.

One solution is to develop better methods for evaluating at an early stage in design (before a physical prototype), when altering the design is inexpensive. For some domains, methods such as guideline based critiquing and cognitive walkthrough can be used to detect human factors problems in a design at this early stage. For more complex domains, computer simulation is needed to handle the vast amount of situational detail that must be considered as possibly contributing to operator error.

We will describe APEX, a tool for simulating human operators in complex, dynamic environments (so far including TRACON air traffic control and Boeing 757 flight deck). The human performance model used in APEX adapts an AI technology called reactive planning to enable capable behavior in such demanding environments. This technology turns out to be especially suited for simulating human proneness to certain forms of systematic procedural error, especially what Reason calls "frequency gambling errors." Ultimately APEX is intended to help designers sift through thousands of possible scenarios to identify possibilities for error that might otherwise have been overlooked. To this end, we have used examples of operator error from "human in the loop" simulation studies and from reported incidents in the Aviation Safety Reporting System database to drive development of the model. We are also beginning to study procedural errors empirically in order to test the effect of certain possible causal factors.