Into the abyss: Seven principles for identifying the causes of and preventing human error in complex systems

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"To err is human" and "accidents happen" are clichés that describe an aspect of our lives that everyone encounters. A literal interpretation of such phrases suggests that mistakes are a part of human nature, have always been, and always will appear in our daily activities, including those within health-care systems. Implicit in such thinking is a nagging doubt about whether such deeply rooted characteristics of people can ever be completely brought under control. One would like to believe that our efforts at preventing people from unintentionally harming themselves or others have not reached a plateau and that there is room for improvement.

"Zero defects" is often espoused as the goal, but this goal is more of an ideal than a reality. Some workplaces fare better than others, with commercial aviation and nuclear power having relatively good (but not perfect) safety records. Generally, in workplaces where the major interfaces are between people and equipment it is easier to gain control over safety problems. In health care, the interfaces involve not only people with equipment but people with people engaging in rather extensive and often critical and nonroutine interactions. The possibility for some aspect of "human nature" to cause a deviation from the intended course of action increases dramatically with the number of people who interface with each other and with the equipment, products, and procedures of the workplace.

Trying to resolve issues of error in the health care system under the latter circumstances can be perceived as a deep and foreboding abyss. One is never quite sure where to tread, what to do, or how far to venture in trying to resolve a succession of problems. In the spirit of suggesting directions for navigating this abyss, I offer seven principles intended to provide a frame of reference for what directions such efforts might take. The principles are sensitive to how human nature interacts with the complexities of systems and to the fact that both must be taken into account if we hope to make a dent in our current problems.

Principle 1: Optimism encourages and nurtures change

One quality of effective problem solvers stands out—their tendency to remain optimistic in the face of difficult circumstances and to believe that a solution is possible.[1] Most people seem to possess reserves of optimism that are potentially available for engaging the issues they face.[2-4]

For the adaptive side of optimism to emerge, two things must occur. The problems must be properly presented to people (to facilitate solutions), and the participants must not be allowed to drift into a sense of helplessness. Believing that solutions are possible is helpful in overcoming lingering doubts that nothing good will come from efforts to resolve them.

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Both the planners and the end users need to take steps to maintain a sense of optimism about finding solutions to the issues involved in re-engineering the medication-use system. The former group needs to remain positive to effectively engage issues. Research shows that optimists are willing to challenge the problems they face, to persist until a solution is found, and to involve others in resolving issues.[5] End users need to remain optimistic in order to believe that new directions have a chance of succeeding.

To persist in their efforts, planners and end users need reminders of other difficult problems that were successfully resolved in the face of doubt and cynicism. Efforts to place a man on the moon, the atomic bomb project, mapping the human genome, building the Chunnel and the Panama Canal, and other large-scale projects all had their detractors. Yet, these efforts are now seen as creative outcomes that occurred when people pulled together for a common cause. Indeed, there may be lessons in these efforts that can be applied to our task.

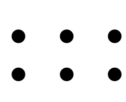
Some of those caught in the initial enthusiasm for planning and implementing new ideas will remember other efforts that failed. For them to maintain a positive attitude involves more than tapping any reserves of optimism they possess. Seligman[5,6] noted that the challenge is to reaffirm or perhaps learn anew a more positive outlook. His work shows that people develop a more effective sense of optimism if they are willing to restructure their perceptions of a problem. This involves people treating the problem as a temporary condition that appears in a particular frame of time, perceiving the situation as modifiable, and believing that they possess the ability and skills to influence what will happen and that their skills will make a difference. I suggest that it is also important to act on new perceptions, no matter how fleeting they may be. Our perceptions guide our actions, but it is also the case that our actions reinforce new and existing perceptions.

In effect, stimulating a sense of a better future should be a part of the problem that is to be solved in a re-engineered medication-use system. And this must be a part of the mental makeup of the planners as well as the end users. One consideration overrides everything I have said: Those responsible for planning and implementation must work together. Cooperation and collaboration are critical to this enterprise.[7] Changes that are dictated from above—no matter how good or well-intentioned—typically lead those on the receiving end to resist.

It is clear from the literature that when trying to re-engineer anything, one needs to (1) focus on underlying issues and not symptoms, (2) use definitions of problems that do not contain solutions embedded within them, (3) generate at least two alternative solutions from which to choose, and (4) make decisions about solutions on the basis of clear and relevant criteria rather than the desires of any one individual or group.[1] Taking the time to develop a consensus regarding the criteria that solutions should meet is just as important as finding alternative courses of action.

Principle 2: Old solutions seldom fix new problems

Albert Einstein said, "We should not try to solve problems with the same ideas that created them in the first place." Breaking existing frames of thinking and going beyond them is necessary but not always easy. Consider the problem below as a metaphor for the difficulties involved and how you approach situations that demand new ideas. What you see are nine dots. Try to connect them by using three straight lines without lifting your pencil.



While a solution is provided in the appendix, it is only one of several that are possible. One can connect the dots with four straight lines as well as one line.

In all the solutions, it is necessary to go outside the boundary formed by the nine dots. Otherwise, a solution is impossible. On the other hand, the nine dots are still a part of the solution. Sometimes, in going outside existing boundaries, we must keep the best of what we already have. Or, we might reorganize, merge, or modify existing elements in order for them to become more effective within a new structure. Such is the nature of change in complex human systems like health care. Complex systems never change everything. They remember their history and include critical elements from their past in any new and reshaped forms of their former selves.[8,9] Similar things can be said about re-engineering the medication-use system. While we do not necessarily want to "throw the baby out with the bath water," we want to venture beyond existing modes of thinking.

Principle 3: A systems perspective is not enough

A system generally represents interrelated units that work together in the pursuit of one or more shared goals. Anything that occurs within the system is, to varying degrees, intertwined with other elements. Thus, conventional analyses suggest that when an error occurs no single antecedent is to blame. Rather, a combination of circumstances converged to produce the problem. In this scenario of finding the root cause, the person who failed to do what was intended or needed was victimized by a combination of factors within the system. In an attempt to "fix the problem and not the blame," that individual now becomes as much a victim as the person who was on the receiving end of the mishap.

I like systems explanations for adverse events, but there are others who prefer to hold individuals responsible for their actions. I recognize that "systems-think" is not for everyone. And if I can distance myself for a moment from an inherent tendency to think holistically about problems, I believe I understand why. People possess a "default mode" for explaining events that is learned through experience and that resists change.[10] The most popular default position is to blame others for any observed shortcomings. Psychologists call this the "fundamental attribution error." This tendency to look outside ourselves is so strong that we may even blame the victim for any misfortune suffered. Such tendencies help to wrap the uncertainty about the causes of events into tidy packages where at least a minimal but socially acceptable explanation is possible. When our own shortcomings are exposed, the story line changes. We look for other people and things to blame for our actions.[11]

I recently asked a physician friend what he thought the major contributor to medication error in health care was. Without any deliberation he said, "We looked at that problem in our hospital a few years ago. As far as I can tell, the problem would be solved if the nurses had more training." A pharmacist I know had another point of view: "If the physicians would only write legibly and keep up-to-date on how and what to prescribe, there wouldn't be as many misfills." And pharmacists interviewed about their misfills initially blamed patients attempting insurance scams, an anonymous someone other than themselves who made the mistake, and bad luck.[12]

Value conflicts inherent in a systems point of view. Attribution biases cannot be eliminated from our thinking processes. They are programmed into the culturally determined mental scripts we use to interpret events.[13] People with a Euro-American outlook are caught in strong cultural norms that people are responsible for their actions and deserve to be held accountable. They also face cultural norms that are not oriented toward holistic explanations for events.[14] In Eastern cultures, a sense of collective responsibility is often part of the template for thinking about blame, responsibility, and accountability.

While the presence of such values has been well documented, ways to change them have not received as much attention. Recent research suggests that, if a shift in cultural values regarding responsibility for actions is going to occur, changes in the subjective outlook of people are necessary.[15,16] In effect, how large groups of people define their self-concept would have to change before the acceptance of any systems or holistic explanations for adverse events became the norm. Those of us living in individualistic cultures would have to see the personal benefits of collective thinking. Attitudes and beliefs within our self-image would have to include ideas about our connection to others, the interdependency of events in the world, and the need to attend to multiple causes for adverse events. Modifying someone's self-concept is not easy, although there is evidence suggesting that small changes are possible.[17] Changing self-concept on a broader scale among the players in a complex health care system is another story.

How to maintain a systems perspective for blame while at the same time focusing on individual responsibility and accountability will be an issue in a re-engineered medication-use system. Rather than fight cultural expectations for individual accountability and responsibility, it might be better to use these expectations to enhance safety. In successful examples of how to enhance safety outside health care, two things stand out: (1) technology, training, and equipment that prevent mishaps are important and (2) programs that emphasize incentives for individual action within a collective enterprise are particularly effective.[18-21]

Characteristics of effective injury-reduction programs. In a meta-analysis of programs designed to reduce work injuries outside health care, Guastello[22] reported that behavior-based programs produced an average reduction in injuries of 59.6%. Those programs involving ergonomics to adjust work conditions and equipment reduced injuries 51.6%, while programs using engineering changes, such as robotics, reduced injuries 29%. Approaches to injury prevention that employed quality circles or group problem-solving were associated with a 20% reduction in mishaps. Other strategies were even less effective and yielded an average reduction in injury of 16%. Included here were safety audits, poster campaigns emphasizing safe work habits, inspections and other government interventions to enhance safety, setting standards for equipment, and job-related stress-management programs. The least effective measures were personnel-selection programs, which reduced injuries 3.7%.

The most effective behavior-based programs had the following elements:

- Buy-in by all levels of management to ensure that individuals at all levels took the initiative seriously.
- Establishing baseline levels of individual performance in targeted behaviors.
- Setting goals for individual and group improvement in targeted behaviors.
- Providing incentives for achieving individual as well as group goals.
- Charting individual and group accomplishments toward achieving those goals.
- Providing individuals with timely feedback and rewarding specific behaviors that contribute to safe work practices.

Individual action and accountability play a major role in the success of such safety schemes. Behavioral programs not only teach people to be safe but persuade them to do safe things. Thus we must think about medication errors and possible solutions at the level of individuals and at the same time maintain a systems perspective.

Principle 4: The qualities of individuals within a system are important

I am not suggesting that we emphasize the characteristics of people for purposes of pinning blame on someone. Rather, including a strong individual component in efforts to reduce error adds a credible and culturally expected component to the process. Furthermore, the qualities of people associated with error and those needed to perform well sometimes get lost in the shuffle when "systems-think" dominates.

Individual characteristics and the failure of technology. Solutions that emphasize technology, facility design, professional practice standards, training, procedures, rules, regulations, and a variety of other system-level interventions are effective, but there are limits to what they can accomplish because they inevitably encounter characteristics of people that may curtail their effectiveness. It is not unusual, for example, for individuals to become complacent and less vigilant when technology is involved. In *Set Phasers on Stun*, Casey[23] reported on how people may assume that technology and work equipment function as advertised, never questioning the assumption until it is too late. The book's title is derived from an incident in which a computer malfunction led a patient undergoing radiation therapy to receive two successive blasts of 25,000 rads—more than 125 times the prescribed dose. Before his death, the patient, a Star-Trek fan, remarked with dark humor that the technician probably forgot to set his phaser on stun. In reality, the technician did not think anything was amiss, since the system's controls appeared to be working normally and a supervisor verified that this was the case. The unit had appeared to be very reliable in the past and had in effect earned the trust of those using it.

In some community settings, pharmacists use bar-code scanners to check a Universal Product Code on a product against a bar code on the label generated by a computer during data entry. Sometimes an incorrect drug name is entered and is not caught. Essentially because the two codes match, people assume that everything is fine. In a sense, we are victimized by the normal reliability and promises of technology, and we may at times come to regret our trust in it.

In a re-engineered medication-use system, people would be taught that technology can fail and would be shown what to do when it does. The problem is that people either (1) never learn what to do when technology is not working well or (2) forget old skills that might help. So what do we do when technology fails? How should we react when it is not there at the moment we need it? What should we do when it appears to be working correctly but something is amiss?

We probably ought to do what is done in other industries. First, hold "fire drills." Periodically, take people through a dry run in which the technology they depend on develops problems. Have them practice other ways of handling their jobs and responding to the crisis. Fire drills already are used to simulate disasters in a variety of industries, including health care. We should make the failure of technology an equivalent disaster and have units within a system practice what to do.

Second, require simulation training of people in technology-dependent jobs. Airline pilots periodically have to spend time in a flight simulator, where they experience simulated problems that they have not actually encountered but for which they need to be prepared. It is easier to think on one's feet during a crisis if there is a base of experience to draw from. That base can be established by using simulations of problems. Such simulation training might be held in regional centers designed especially for that purpose.

Ignoring personal qualities in human error. There are other ways in which the characteristics of people associated with errors have been placed in the background. Schemes for reporting and categorizing human error in health care typically do not include the characteristics of the person who made the error. For example, medication errors have been categorized as mechanical (e.g., wrong dose, wrong strength) or judgment (e.g., lack of drug-use review, improper or no patient counseling)[24] or on the basis of their severity, as in the medication error index adopted by the National Coordinating Council for Medication Error Reporting and Prevention (NCC-MERP). One might ask, Are people with certain qualities more likely to make errors in judgment than mechanical errors? Also, are some individuals more at risk than others for committing mistakes within each of the NCCMERP index categories? We do not know, but these are important questions.

The reporting of research findings on medication errors reinforces this point of view. It is not uncommon to find analyses in which sets of prescriptions filled correctly and incorrectly are associated with a variety of situational factors. Understandably, such studies take a systems perspective, and thus the analysis is compatible with such assumptions, but for every prescription set misfilled under low levels of illumination, with distractions present, in a busy pharmacy, and at the end of the day, there was a human being present. The same can be said about any medication error, regardless of where it happened.

Knowing the psychosocial characteristics of people and how they contribute to inaccurate performance may suggest additional options for managing the problem. This might provide guidelines on who to hire, where to place people to minimize errors, and what additional training is needed. However, none of this can be accomplished unless important characteristics of people are taken seriously and active attempts are made to deal with them.[25] The excuse that "we can't get warm bodies, let alone those with certain characteristics" is a hollow retort. To re-engineer a system by not using a more scientific selection process for people in the most sensitive error-risk environments will only, in the long run, impede our efforts.

A model for individual performance in health systems. Developing a list of personal qualities that predict accurate and inaccurate performance is helpful but not enough. The reality is that there are many psychosocial variables that are correlated with human performance, including human error. To determine what human qualities to focus on, we need a conceptual scheme for directing our efforts. This is not unlike what scientists do to explain the path of a subatomic particle or a planet in the solar system, the dissipation of energy in a system, or the flow of automobile traffic. In each case, models exist for explaining such events and contain variables of interest. Such models also limit the factors that affect the phenomenon under study. In effect, a model helps us to identify the precious few among the multitude of factors that might be involved.

As a starting point in such an endeavor, and to illustrate one way this can be done, let me describe a cognitive systems model I developed. It is used to guide and direct work in community pharmacy and work with people on stress-management issues in the workplace.[12,26,27] When applied to human error, the basic assumption of the model is that the root cause of mishaps is a failure in information processing.

The model identifies and builds upon the operation of three parts of our cognitive system. There is a sensory register similar to an input device on a computer (e.g., a keyboard, CD-ROM drive, or floppy disk), a long-term memory or storage area similar to the hard disk on a computer, and an operating system that is labeled working memory. The three parts are interdependent and normally work rather well together. They can be visualized as three circles, each overlapping the other two. If one part fails to perform when needed or does not have what it needs to function, the chances of an error increase.

Listed in Table 1 are the key functions of each part of the cognitive system, the typical failures in those functions, and the characteristics of people that affect each aspect of the cognitive system.

Sensory register. In the model, degraded sensory inputs and sensory "noise" affect the quality of the "signals" the processing system encounters. Look-alike, sound-alike, and spell-alike errors in a pharmacy are examples of mishaps that might be reduced by providing better visual and auditory discriminations. Dispensing errors might also be related to environmental noise in the form of ambient sounds, interruptions, and distractions.[28]

Lambert[29] used a computer program to measure the overlap in two- and three-letter sounds between two or more product names. Those names with overlapping sounds produce discrimination problems and are confused. His program provides a way to quantify the potential confusion between items with similar names. Using his program to test names of drugs before they are released should help reduce name-discrimination problems.

Requiring personnel in pharmacies and other areas where auditory and visual deficits could cause errors to have mandatory checkups might help as well. For example, among 750 pharmacists who took a basic visual and hearing screening as part of a continuing-education program series I was conducting, 3% had undiagnosed visual and auditory deficits. To the best of my knowledge, there are no corporation or board of pharmacy requirements for pharmacy personnel to have such checkups. Most community pharmacies I have

Table 1.
Functions of Parts of Cognitive System, Causes of Errors, and Personal Characteristics

Component of Cognitive System	Important Functions	Causes of Errors	Personal Characteristics That Affect Component
Sensory register	Acts as gateway to the system, produces image of sensory stimulation, holds images for working memory to scan	Degraded sensory image, presence of sensory noise, lack of needed sensory input	Sensory deficits (e.g., auditory, visual, and tactile problems), problems in focusing attention on critical stimuli
Working memory	Scans sensory register for input, codes input for short-term and long-term memory, assists in conscious thought and deliberation, makes estimates and predictions, establishes criteria for decisions, directs attention narrowly and broadly, controls repetitive actions by using automatic mental scripts, helps with discriminations among structural features of stimuli, recognizes patterns and deviations from norms in perceptual field, detects errors and unsafe conditions	Demands exceeding cognitive resources; attention and pattern-recognition deficits; lack of appropriate input from other parts of the system; distractions and interruptions preventing retrieval of information or the ability of the system to check its operations; confusion due to similarity, frequency, and recency of input to stimuli present; taking shortcuts, using cognitive biases, or misapplying information; increases in rate of transfer of information among parts of the system	Anxiety, impulsivity, field dependence and field independence; levels of personal, work, and environmental stress; fatigue, illusion proneness, moods, task interest, and motivation; mental and physical hardiness and resources for coping with stress; attention span, processing speed, and cognitive capacity; personal style
Long-term memory	Consolidates and permanently stores memories; maintains packets of factual knowledge, semantic knowledge, and rules; stores sensorimotor scripts, perceptual schemas, and knowledge of procedures; establishes networks and patterns for interconnecting the information within it	Interference among structurally and semantically similar data; failures to retrieve information; inappropriate retrieval of schemas, information, and procedures; poor connections of information in memory; inability to reconstruct what is needed; absence from system of necessary information; poor connections of information in memory	Education, training, and experience; level of stress and emotions at time of learning or recall; intelligence, aptitude for task, and motivation to recall

observed do not have volume controls on their telephones, nor do they have copy strips and other aids on their computers for positioning prescriptions for data entry at good visual angles. Finally, the lighting in pharmacies often needs to be improved. Increasing illumination levels in work spaces reduces error.[30,31]

In the National Association of Chain Drug Stores (NACDS) Educational Foundation study I am currently completing, we provided participants with copy strips to aid data entry and with enlarged product labels and National Drug Code numbers (attached by removable wraps and sleeves to stock bottles).[32] Such things reduced tendencies for error and the amount of time it took to complete an order.

In the NACDS Educational Foundation-sponsored study, community pharmacists corrected themselves 12.1% of the time, and 3.5% of the prescriptions waiting to be picked up by patients had mistakes in them (i.e., wrong prescription in bag, incorrect directions, wrong amount, wrong strength, or wrong drug). These data were compatible with data reported in studies in which auditors checked prescriptions during dispensing activity. An average error rate of 3–5% of prescriptions filled is typical in studies of hospital outpatient, independent, and chain pharmacies.[24,32-34] The rate of process errors (mistakes made and corrected while working) was reported as 8.3% in an outpatient setting,[35] but no corresponding data outside of our current work exist for community pharmacies. We found a 4:1 ratio between process errors and mistakes that get past normal verification processes. Reducing process errors would seem to be a good idea. Changing conditions that impair health care workers' ability to discriminate among sensory inputs should help to reduce the need to self-correct while working.

Working memory. In our recent work, we used two interventions designed to influence the working-memory system.[32] One was to ask people to pay extra attention to specific products that posed problems. There were about 25 of these; the goal was to provide a strategic focus of attention for people's efforts at error reduction. Essentially, we wanted to reduce the cognitive load on the attentional resources of the working-memory system. In addition, we wanted to enhance the awareness of tendencies people had to make errors. Thus, during 6–10 hours of their workweek, participants monitored their process errors by noting in booklets how often they corrected themselves for targeted and nontargeted products. Relative to the number of self-corrections for nontargeted products, there were 68.6% fewer self-corrections associated with targeted products.

Increasing individual self-awareness is only one part of the issue, since other factors are involved. In our work with community pharmacists, personal qualities such as impulsivity, task frustration, fatigue, perceptual ability (e.g., field independence [easily discriminates among the individual elements of a perceptual field] versus field dependence [has difficulty discriminating among the individual elements]), concern for doing well, a lack of physical hardiness, and personal effort expended are related to self-corrections or errors that get past normal processes of verification.[27] Indeed, there are times when personal qualities are more important predictors of mishaps than are task-related stressors such as work pace, number of orders filled, and number of hours worked.

In a recent study, Grasha and Schell[36] found that task-induced anxiety (as measured by the State–Trait Anxiety Inventory) was an important predictor of error in a simulated pharmacy task. It appeared to be the mechanism through which other factors influenced errors. A multiple-regression analysis revealed that stress in a significant-other relationship, cognitive ability, task frustration, and work pace were important predictors of task-induced anxiety. Such things had no direct relation to error, but they appeared to affect performance through the anxiety they created.

Task anxiety occurs whenever the threat of losing existing control over one's work is present. Depression results from not having control over important elements in the workplace. In our pharmacy fieldwork, we assess specific task-induced tension by using the National Aeronautic and Space Administration's Task Load Index[37] and general job stress by using the job stress subscale of the Holistic Stress Inventory.[38] The latter examines issues involving coworker relationships, job stability, promotions, compensation, and other aspects of the overall workplace.

Among community pharmacists in our grant project, anxiety was a stronger predictor of task-related tension associated with filling prescriptions ($r = 0.53$, $p < 0.001$) than were the workload indicators of number of prescriptions filled ($r = 0.18$, $p < 0.05$) and number of hours worked ($r = 0.19$, $p < 0.05$). Depression was a stronger predictor of overall job stress ($r = 0.48$, $p < 0.001$) than number of prescriptions filled ($r = 0.14$, $p > 0.05$) and number of hours worked ($r = 0.12$, $p > 0.05$). The point is that task-related anxiety and overall job depression should be examined with an eye toward taking actions that can help people cope. Such things affect not only job satisfaction but also performance.

Long-term memory. A direct route to dealing with the needs of the long-term-memory system is to provide appropriate training to ensure that the long-term-memory system has the knowledge (information, rules, and action-based procedures) that the working-memory system needs.

The health care system has in place accreditation and educational requirements as well as on-the-job training opportunities for such things. However, human-resource and training divisions are typically underfunded and inadequately staffed and are among the first functions to suffer when budgets are tight. Because inadequate or untimely training is a contributor to error when information in long-term memory is needed but not available, training functions need to be elevated in importance.

We also need to identify people who are prone to making specific types of mistakes within specific work-related situations. This is not a plea to look for a general trait of "error proneness," since no one to date has been able to satisfactorily define or measure that construct. Instead, let us take what is known about performance in an area and categorize people who are relatively proficient, nonproficient, careful, or careless in performing a task or series of tasks. The goal is not to find new ways to label people or to point blame. Instead, we want to use the information obtained to enhance the functioning of a system through selecting the right people, enhancing their training, and becoming sensitive to the role of task-related personality characteristics in human error.

Let me illustrate how we have used these ideas to form a scheme for categorizing pharmacy personnel. In our work, we typically find no consistent relationship between speed and accuracy in our laboratory simulations or when analyzing the work of pharmacists.[27,39,40] This allows us to treat speed and accuracy as independent dimensions and to form a 2 × 2 matrix for classifying people (Figure 1). Thus, for any task, we can classify people as proficient, nonproficient, careless, or cautious. The categories illustrate that people are inaccurate or error prone on a task in different ways and that the mix of psychosocial and other factors within each cluster is not the same. This information can help with training, supervising, and assigning those at risk to particular types of jobs.

Principle 5: People internalize components of the systems in which they work and live

It is impossible to work in a complex system such as health care without bringing significant parts of that system into our mental life. And, since we hold membership in multiple systems, mental representations of the systems we inhabit outside work also come along. Thus, our understanding of people, events, and conflicts; our perceptions of self and others; our attitudes; our rules for how to behave and work; and our motivations and emotions are a part of our mental life. Such things occupy our thoughts at conscious and unconscious levels.

In effect, systems exist within us and influence us regardless of whether we are physically present within them. In a large multinational organization, 20% of the job stress of middle managers came from family and social-life concerns.[41] Pharmacists sometimes reported how thoughts of family conflicts, concerns for the welfare of their children, or worries about financial problems were associated with a misfill. In our simulated pharmacy, stressors from relationships with significant others and from sources such as school are associated with error.[36,39] In a *New York Times Magazine* article, Belkin[42] eloquently de-

Figure 1. Example of task-specific performance categories for a simulated pharmacy task. The psychosocial factors that represented statistically significant differences between the groups are shown. Slow work pace and fast work pace represent speed in performing the task that was above and below the median time. Low error rate and high error rate represent rates that were below and above the median for the task. Mean no. errors = mean number of data-entry, counting, and product-selection errors committed in processing 42 simulated prescriptions; field independent = has ability to discriminate easily among the elements of a perceptual field; field dependent = has difficulty discriminating among the elements of a perceptual field.

	Low Error Rate	High Error Rate
Fast Work Pace	**Proficient** (*n* = 17) No. errors = 2.23 Traits: • Lower task frustration • Lower stress in nontask roles • Field independent • More concerned with doing well	**Careless** (*n* = 20) No. errors = 7.25 Traits: • Perceives lower mental demand for task • Higher significant-other stress • Less formal education
Slow Work Pace	**Cautious** (*n* = 21) No. errors = 2.28 Traits: • Perceives high mental demand for task • Lower significant-other stress • More formal education	**Nonproficient** (*n* = 18) No. errors = 9.17 Traits: • Higher task frustration • Higher stress in nontask roles • Field dependent • Less concerned with doing well

scribed a medication error involving a child and the antecedents of the mishap. Only at the end, and almost in passing, the author noted that the nurse who questioned the order was trained in a country where women rarely confront men and physicians.

Several outcomes from a study of hospital-based health care teams illustrate how mental representations of what is happening to people within their jobs can affect their ability to report and intercept errors.[43] The tendency to report errors and to intercept errors was associated with the following perceptions: that the team climate was positive, that supervision was not authoritarian in style, and that people's mistakes would not be held against them.

The cognitive-systems model I have been working with takes into account our ability to symbolize the world inside as well as outside of ourselves. In effect, the model views the cognitive system as embedded in a larger system of influences (Figure 2). Each influence (acting alone or in combination) becomes a part of our mental life and may increase our levels of stress. Stress, in turn, adversely affects the information-processing system, potentially altering the rate at which information is processed and transferred from one part of the system to another. Also, because stress narrows our focus of attention, we may overlook important information. Our cognitive system compensates by taking shortcuts that are not always in our best interests.

To illustrate the latter point, you have 10 seconds to answer each of the following problems:

1. Adding quickly from left to right, what is the sum of the following digits? 1000 + 20 + 1000 + 30 + 1000 + 40 + 1000 + 10 = ___________.
2. You are standing on a bridge, and several ducks come swimming out from under it. Two are in front, two are behind, and two are in the middle. How many ducks are there?
3. You are flying in a helicopter over Los Angeles, California. You want to go to Reno, Nevada. What direction on a compass would you have to fly?

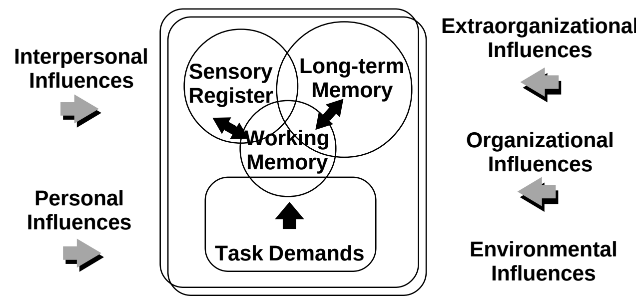
Most people report an answer of 5000 to the addition problem. The correct response is 4100. In their haste to add, they keep adding a thousand to the previous total and assume that what was appropriate before will continue to serve them well. There are two answers to the duck problem, six ducks and four ducks. Responding with four ducks would get you points for creativity in solving a problem. When rushed, we fall back on old habits and less creative modes of thinking. To fly to Reno, Nevada, you would have to head to the northwest. Reno is off to the "left" of Los Angeles, but our mental map of the coast of California makes it much straighter than it actually is. In effect, stress from multiple sources in the workplace opens us up to cognitive shortcuts and biases.

To meet the demands of new situations, problems, orders, and prescriptions and to complete tasks under pressure, our cognitive system does several things. It selects thoughts and actions that were similar to what was done before, the most frequent things we thought or did, and responses or ideas that resemble others that we recently experienced.[1,12] Normally, such strategies might help us out, but they also set the stage for a variety of slips, lapses, and unintentional actions.

Both the routine and relatively nonroutine parts of our jobs follow familiar paths. In each case we plan, set goals, make decisions to act on a variety of intentions, and then follow through with one or more coordinated sequences of thoughts and actions. With routine and familiar tasks, such things happen without much conscious thought. With less routine tasks, both conscious and unconscious (or automatic) processing play a role. Stress-related errors in the execution of coordinated sequences of thoughts and actions may occur in two ways. One is the misapplication of familiar rules and knowledge under stress, which affects our planning, goal-setting, and decision-making capabilities on the job. Second, stress creates ruminations and intruding thoughts that distract us and may cause us to miss critical checkpoints that we use to monitor the accuracy of our progress in meeting our goals.

Simply put, people are at risk for making errors when the things they internalize increase stress or prevent

Figure 2. Cognitive system and sources of influence on it. Examples of each source of influence and the source of the tension it produces include task-related influences (number of hours worked), environmental influences (lighting, noise, temperature), personal influences (personality characteristics, physiological arousal and functioning, attitudes, values, beliefs), interpersonal influences (conflicts with others on and off the job, social-life concerns, communication problems), organizational influences (norms, rules, procedures, work climate), and extraorganizational influences (cultural issues, legislative and professional organization rules and regulations, third-party paperwork).



them from taking appropriate actions. Anyone working in health care needs to understand this. Permission to engage in behaviors to offset such things and the encouragement and training to do so should be a part of any re-engineered medication-use system. People at risk, for example, need to learn how to tell coworkers, "I'm having a bad day today and I need you to help me out or to check what I'm doing." And they have to be able to do so without feeling that they will be punished for doing so. Similarly, how to behave assertively to counter cultural injunctions, such as "one does not challenge authorities," should be a part of the training people receive. One cannot simply be told to do such things, since telling is not as effective as doing and experiencing new actions. The experiences we learn best from are those that tap into a variety of sensory systems. Effective training will use role-playing, case studies, demonstrations, and situational coaching to teach such points.

Principle 6: Factors producing errors operate at manifest and latent levels

At the manifest level, the factors contributing to error and producing safety issues are easily identified by a rational and linear analysis of a situation. That is, they are there for all to see, although their presence sometimes is fully appreciated only after a mishap occurs. Nevertheless, unsafe conditions, bad equipment, and unsafe procedures are relatively easy to identify, and safety audits typically identify them. If anything, we probably need to conduct such audits more frequently.

Latent factors lurk beneath the surface for a period and then strike seemingly without warning.[44] A variety of factors fit this description, including counterfeit parts, delayed or inadequate training, inexpensive but less reliable equipment and tools, and organizational policies and practices that put the bottom line ahead of safety.

I recently attended a meeting with a financial officer for a corporation where the issue of knife cuts to warehouse workers was raised. The safety engineer for the insurance company involved explained that a training program was available that could reduce the problem. The response from the company representative was that it was cheaper to pay when an injury occurred than it was to roll out a companywide training program. In the deadly methyl isocyanate gas cloud disaster in Bhopal, India, the Union Carbide pesticide plant had no automated environmental monitoring systems, no gas sensors, and no automatic alarms. Such devices were prominent in the United States, but, because of an unwillingness of management to spend additional money on the Bhopal plant, there was no warning, in the middle of the night, of the disaster that was unfolding.[23]

Similar attitudes are present in health care whenever less than desirable staffing levels and qualifications of personnel are tolerated, even though they pose an increased risk to patient safety. In a re-engineered medication-use system, the game of "let's take a chance that nothing will happen" will not be played. To do so is to leave a latent factor in the system that will, in time, strike. In a re-engineered system, audits for organizational and personal attitudes and values that are not conducive to safety would occur along with those seeking tangible evidence of unsafe conditions.

Principle 7: Errors in complex systems are both predictable and unpredictable

Human beings have an uncanny ability to infer patterns and meaning even in random events. This applies to a variety of judgments, including our explanations for our own misfortunes and those of others. Before admitting that we live in an unpredictable universe, people will evoke explanations based on the gods, poetic justice, unfortunate positions of the stars and planets, bad karma, and even characteristics of the victims unfortunate enough to be in the wrong place at the wrong time. Or we may analyze a chain of events by using such techniques as failure-mode analysis to trace the precipitating events involved in an error. The assumption is that, if the culprits identified had been corrected beforehand, the error would not have occurred.

Such analyses assume that events leading to error are linear, predictable, and replicable. However, some of the errors we experience represent unfortunate and random juxtapositions of events.[45] The more complex the system, the more likely it is that a random mix of events will combine to produce a mishap. The acceptance of error as a stochastic process helps us to see that the events producing a mishap are probabilistic and not deterministic. As a result, how well solutions work is also probabilistic, and variability is expected. Some solutions may not work within a small cohort of people in the same way that they might within the system at large. Consider for a moment the point made earlier about poor visual and auditory capabilities, inadequate lighting, interruptions, and distractions that are associated with human error in a pharmacy. The reality is that, among any group of 10 pharmacists, these factors may individually or collectively have a very small effect because of the subtle way they influence behavior—so much so that we might be tempted to dismiss them. However, within a larger frame of reference, factors that produce small and subtle effects can have very large consequences. Thus, among several hundred thousand pharmacists and pharmacy technicians filling several billion prescriptions over 12 months, even something that affects errors by a fraction of 1% becomes rather large in its effects systemwide.

The latter points are reinforced by chaos theory, or nonlinear dynamics.[9] Chaos theory proposes that the factors that affect complex systems are dynamic, continuous, recursive, and nonlinear. This means that the factors are mixed together in different ways, the mixing is continuous over time, the factors recur in ways that may either hurt or help a system, and the combinations are not linear. A proportional change in one variable does not produce a proportional change in another. In a sense, the system is reborn from one time period to the next because of the subtle and not so subtle variations in how the system operates over time.

This "rebirth" over time means that factors important at time A may be even more important at time B. Thus, in the context of complex nonlinear systems, "little things can make a lot of noise." Even little things should be considered candidates for helping to reduce error because of their tendency to increase in magnitude and importance over time.

The flow in a system over time may appear to be random, but in reality an underlying pattern is developing. In physical systems, such patterns can be observed by plotting changes in several variables in a multidimensional space over time. Interesting patterns often emerge that represent the underlying pattern the system follows. In human systems, it is more difficult to plot such things, but the metaphors we use to describe the systems we inhabit accomplish similar goals. Here I use "metaphor" in its most general sense, as any construction that figuratively represents one entity in terms of another. That would include what some might see as a simile or analogy.

Metaphors help us to identify current patterns and to think about what future patterns might be like. In a recent workshop, I asked health care managers to describe metaphorically what it was like to manage people in the system. For some, the underlying pattern was a daily struggle. "It's like trying to push a brick across the street with your nose," one person remarked. Other patterns were more positive: "A health care manager is like a wilderness guide who helps those around her do things they have never done before."

In a formal study of a problem in health care training, I asked medical students, faculty, and administrators to use metaphors to describe the evaluation processes inherent in third- and fourth-year rotations.[38] Surprisingly, the three groups agreed on the underlying patterns. Students were seen as performing a high-wire act without a safety net or being dropped in the desert with an out-of-date map, a flashlight that did not work, and a vehicle that was low on gas. Such things signified the isolation of the students, as well as the lack of clear directions and expectations for their rotations. Where the groups differed was in their metaphors for what should be done. The students wanted to be evaluated just as they might when playing a position on a sports team. There the coach would guide and adjust their efforts to help them conform to a prearranged game plan. Faculty members and administrators thought that the metaphor of a quality control inspector was a pattern to work toward.

Metaphors that describe current conditions provide a context for the attitudes, values, and conditions that exist within a system, including conflicts that need attention. As Lakoff and Johnson[46] argued in their book *Metaphors We Live By*, figurative language not only captures what is but what something could become. Metaphor and analogy help us to think holistically about issues and to identify the patterns in the thoughts, actions, and behaviors of units within any system, including health care.[47,48] Susan Sontag, for example, believes that the primary guiding metaphor for treating illness during the past century has been a "battlefield metaphor." We go to war against disease. If that is the case, what implications are there for medication use and safety in this model? Is this the model we want to keep? What are the alternatives, and what do they suggest about the medication-use system and about making it more effective?

In my experience, the use of metaphor in planning is typically nonthreatening, fun, and quite helpful. In planning how to re-engineer our medication-use system, we should look for existing patterns in how the system operates and seek to identify desirable patterns for the future. Metaphor may provide a useful tool for such purposes.

Chaos theory suggests that there are limits to our ability to predict events in complex systems. While there are underlying patterns in what appear to be random or turbulent events, the movement of a system or the trajectory of factors within it cannot be predicted with a high degree of certainty. At best, we can describe what happened, but there is no guarantee that the same outcome can be expected in the future.

The identification and monitoring of factors contributing to human error must become an ongoing enterprise in complex systems. An interdisciplinary group with prominent members of the system serving on it needs to be a key component of any re-engineered health system. This will ensure that a variety of perspectives will be brought to bear on the task and that any recommendations will be taken seriously.

Conclusion

In his dissertation on the role of experiential learning in promoting the development of self from our mistakes, Fountain[49] noted that, contrary to popular belief, people do learn from their mistakes. The process involves reflecting on what was experienced, conceptualizing what happened, and putting the lessons learned into practice. Mishaps often change people for the better, Fountain wrote, although this takes time and although what was specifically changed is not always apparent to outside observers. In confronting our mistakes, the goal is to learn enough to individually and collectively make fewer of them. I do not believe that totally eliminating human errors is possible, but I also believe we can learn more from them than we are normally willing to admit.

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Appendix—One solution to the nine-dot problem