# Human Performance Limitations in Medicine: A Cognitive Focus

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Note: this paper was originally written in 2006. The same principles apply today.

## Abstract

Medicine has traditionally been one of the most cognitively demanding occupations. This paper discusses the limitations of human performance in the hospital environment. Human Factors models are presented and used as an anchor for a randomly selected case study involving a potentially lethal medication error. The case study Root Cause Analysis showed five distinct factors that were causal to the error. The Human Factors models, in conjunction with an overview of basic human cognition, provide the reader with the tools to help understand all five findings of the case study. It is intended that this paper will provide a foundation for improving medical safety by creating an awareness of the factors that influence errors in medical procedures.

*A 55-year-old man with acute myelogenous leukemia and several recent hospitalizations for fever and neutropenia presented to the emergency department (ED) with fever and hypotension. After assessment by the emergency physician, administration of intravenous crystalloid and empiric broad-spectrum antibiotics, the patient was assessed by his oncologist. Based on the patient's several recent admissions and the results of a blood culture drawn during the last admission, the oncologist added an order for Diflucan (fluconazole) 100 mg IV to cover a possible fungal infection.*

*Because intravenous fluconazole was not kept in the ED, the nurse phoned the pharmacy to send the medication as soon as possible. A 50 ml bottle of Diprivan (propofol, an intravenous sedative-hypnotic commonly used in anesthesia) that had been mistakenly labeled in the pharmacy as "Diflucan 100 mg/50 mL" was sent to the emergency department. Because the nurse also worked in the medical intensive care unit, she was quite familiar with both intravenous Diflucan and Diprivan. When a glass bottle containing an opaque liquid arrived instead of the plastic bag containing a clear solution that she expected, she thought that something might be amiss.*

*As she was about to telephone the pharmacy for clarification, a physician demanding her immediate assistance with another patient distracted her. Several minutes later, when she re-entered the room of the leukemia patient, she forgot what she had been planning to do before the interruption and simply hung the medication, connecting the bottle of Diprivan to the patient's subclavian line.*

*The patient's IV pump alarmed less than one minute later due to air in the line. Fortunately, in removing the air from the line, the nurse again noted the unusual appearance of the "Diflucan" and realized that she had been distracted before she could pursue the matter with the pharmacy. She stopped the infusion immediately and sent the bottle back to the pharmacy, which confirmed that Diprivan had mistakenly been dispensed in place of Diflucan.*

*The patient experienced no adverse effects—presumably he received none of the Diprivan, given the air in the line, the infusion time of less than a minute, and the absence of clinical effect (Diprivan is a rapidly-acting agent). Nonetheless, the ED and pharmacy flagged this as a potentially fatal medication error and pursued a joint, interdisciplinary root cause analysis, which identified the following contributing factors:*
*(i) Nearly 600 orders of medication labels are manually prepared and sorted daily; (ii) Labels are printed in "batch" by floor instead of by drug; (iii) The medications have "look-alike" brand names; (iv) A pharmacy technician trainee was working in IV medication preparation room at the time; and (v) The nurse had been "yelled at" the day before by another physician—she attributed her immediate and total diversion of attention in large part to her fear of a similar episode.*

(AHRQ, Morbidity & Mortality Rounds on the Web, 2004)

# Introduction

The case study you just read is highly representative of an ongoing problem in medicine; the limitations of human performance in a cognitively demanding operational environment. Although this case did not result in the death of the patient due to a medication error, hundreds and even thousands more do. In this particular case, the fallibilities of cognitive performance were identified in the Root Cause Analysis (RCA) report. Specifically, the event was decomposed into the following chain of causal factors; 1) the inability to keep track of multiple medication labels, 2) assignment of the (batched) labels by floor instead of by drug type, 3) similarity in brand names of drugs, 4) a pharmacy technician trainee that was not very experienced, and 5) a nurse that was "yelled at" by a physician the day before that caused her to lose attention for fear of a repeat episode.

This paper addresses the cognitive aspects of human performance in medicine. Most of the time the last person in a chain of errors is conveniently assigned the blame for the final outcome of a procedure gone wrong. In the case of medicine, this is usually the physician, surgeon, anesthesiologist, or any other caretaker that assumes the primary responsibility of a patient's safety while they are in their care. This does not account for the fact that there may be many other overt or latent "links in the chain" that may have influenced the final outcome, including organizational culture and regulatory policy. This is an area that will be addressed in a separate and more detailed treatise in the near future. For now, the focus will be on the cognitive factors that the caregiver must understand as they pertain to their "last line of defense" designation in the prevention of medical errors.

Human Factors (HF) addresses, among other things, the interaction between people and people, and people and their environment. Human Factors is a multidisciplinary field that is comprised of a variety of disciplines including psychology, physiology, anthropometry, biology, and various engineering sciences. With that in mind, HF will be the foundation of this discussion, as it provides a solid model for human performance and the peripheral cognitive features that are the basis of this paper.

Human Factors Models

Two important models are presented to help visualize the concepts of HF. The first model is called the SHEL model (Edwards, 1972, see Figure 1). The acronym SHEL stands for Software, Hardware, Environment, and Liveware. Hawkins (1984) further modified the SHEL model by adding an additional "L" (SHELL). For clarification, Liveware, in this context, refers to humans. The additional "L" appears to be somewhat redundant at first glance since it is simply a repetition of Liveware. However, the emphasis on the L-L interface was an important factor in the modification due to the fact that significantly more accidents were occurring as a result of deficiencies in humans working with other humans and less because of factors such as errant machines, computers, airplanes, medical devices, nuclear power plants, etc.

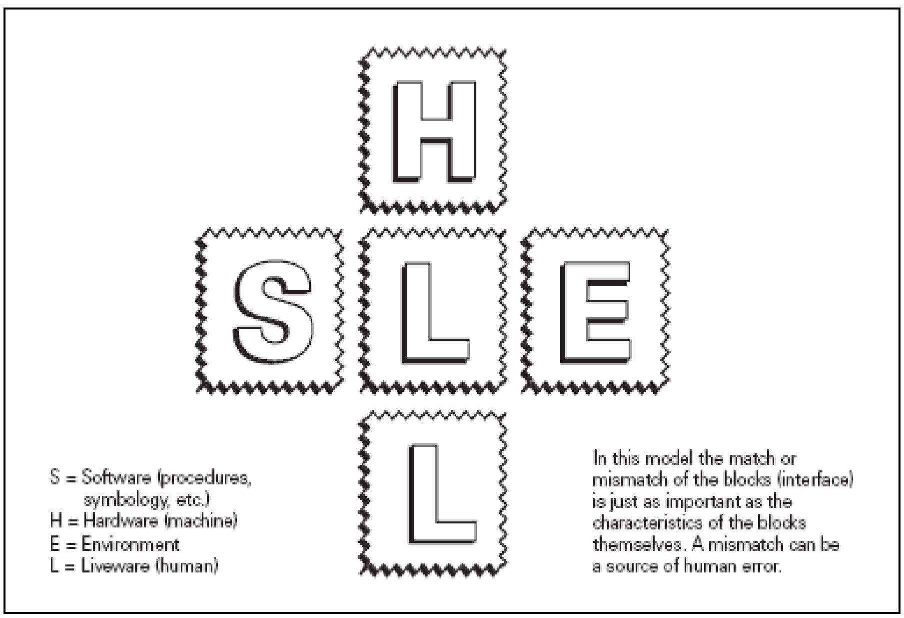


**Figure 1** The SHEL model as modified by Hawkins

The second model is called the Human Factors Interface Model (HFIM; named by the author). Similar to the SHELL model, HFIM shows the relationship between the human (who is at the center of the design) and the peripheral components that affect the human. Notice that there is an overlap of all the components that affect not only each other but also the human in the center of the model (Figure 2). For the purpose of this paper, an emphasis will be put on the right side of the model to specifically include cognitive human factors and human behavior.

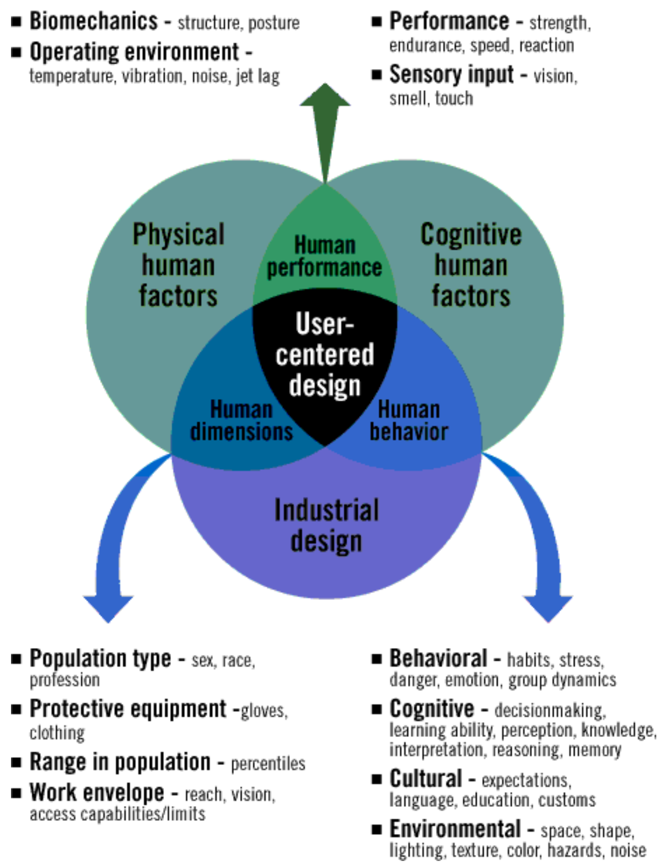


Figure 2. Human Factors Interface Model (HFIM)

With a picture of human factors beginning to take shape, we now shift to error classification. Errors can range from benign "slips of the tongue" to blatant violations leading to catastrophic outcomes, with a variety of types in between. Credit must be given to Professor James Reason (1990) for his contribution to an error typology that has been accepted and used widely in Human Factors systems and training programs throughout the world. Reason's error classification list includes the following:

- **Errors of Omission-** Not perform an act or behavior; simply just didn't do it.
    - **Examples:** when a delay in performing an indicated cesarean section results in a fetal death, when a nurse omits a dose of a medication that should be administered, or when a patient suicide is associated with a lapse in carrying out frequent patient checks in a psychiatric unit. Errors of omission may or may not lead to adverse outcomes. (JCAHO, 2005).
- **Errors of Commission-** Substituting an act or behavior.
    - **Examples:** when a drug is administered at the wrong time, in the wrong dosage, or using the wrong route; surgeries performed on the wrong side of the body; and transfusion errors involving blood cross-matched for another patient. (JCAHO, 2005).
- **Slips-** These are execution-based failures and are commonly termed *slips, lapses, trips, or fumbles.* They may be skill-based (repetitive tasks performed over and over) or rule-based (failing to properly follow established rules).
    - **Examples:** "Freudian slips" and "slip of the tongue." Signaling to turn left when it is intended to make a right turn. Physician addresses patient by the wrong name. ED doctor orders an X-Ray when she meant to order an MRI.
- **Mistakes-** These are higher-level failures. The actions may go entirely as planned but the plan itself is not adequate to achieve its intended outcome. Mistakes may be rule-based (the practitioner is properly following the rule but the rule itself is either incorrect or wrong for the task) or knowledge-based (the practitioner has no "pre-packaged" rules and must work out a solution from first principles). This reasoning is highly error-prone, as the use of availability heuristics, in this dynamic environment, tend to propagate improper decisions and actions.
    - **Examples:** A surgeon has performed a "textbook" amputation; unfortunately the amputation was on the wrong patient. During a routine laparoscopic procedure the surgeon encounters excessive bleeding due to a severed artery. Because of the

nature and location of the damage, as well as a lack of previous experience with this type of error, the surgeon may deviate from standard procedures and work from first principles, or heuristics, to control the bleeding. This "outside the box" thinking may exacerbate the problem and set the stage for additional errors.

- **Violations-** Violations are intentional deviations from safe operating procedures, recommended practices, rules, or standards. Violations can be further subcategorized as routine (repetitive and automatic) or situational (non-compliance committed simply in order to get the job done).
  - **Examples:** Driving 80 mph in a 55 mph speed zone is a good example of a "routine" violation. Skipping steps in a complex process in order to finish quickly because of time pressure is an example of a situational violation.

## Cognition

Cognition refers to mental processes of an individual. These processes can be broken down into three distinct phases: 1) sensing and perception, 2) processing and decision-making, and, 3) taking action. This is a three-step, sequential, Cognitive Processing Model as shown in Figure 3.

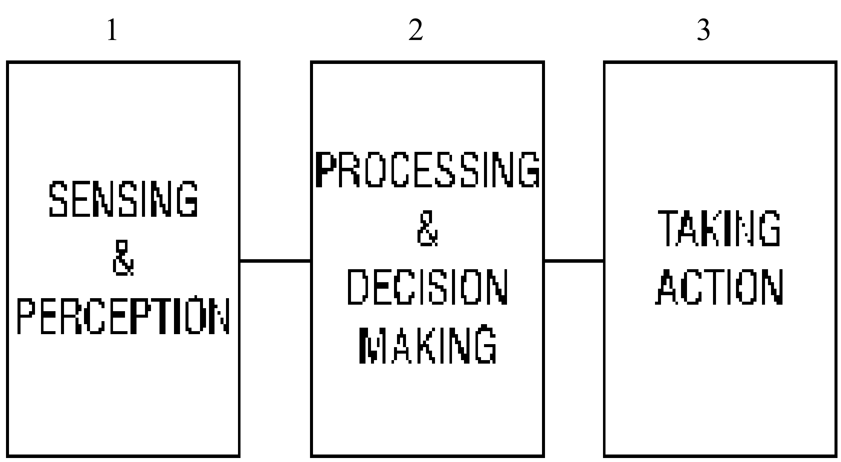


Figure 3. Cognitive Processing Model

Cognition is an integrated process that involves memory, attention, perception, action, problem-solving, and mental imagery. In fact, cognition can become quite complex when looking at the myriad of internal and external influences that might be apparent in each of the three phases. For example, in the *sensing and perception* phase, errors may occur due to inadequate lighting, noise, poor-quality manuals, and ambiguous or poorly written orders or prescriptions. *Processing and decisio*n errors might be due to fatigue, inadequate or lack of training, or time pressure. Errors in *taking action* may be caused by poor equipment design, lack of adequate procedures, distractions, or extreme workplace temperatures (such as the cold temperatures frequently encountered in the OR or ICU).

Medicine may very well be one of the most cognitively demanding careers a person can choose. Although much has been learned from the aviation domain in terms of complex cognition in a high-risk industry, the cockpit is a mere speck in comparison to the complexities of medical assessments and procedures. Unlike aviation, where for the most part there is at least some time for information processing, many life or death medical decisions need to be made in a split-second.

The quality of these decisions is based on, and influenced by, the Cognitive Processing Model. This process is analogous to a human computer. Massive amounts of stimuli are sensed by the human senses, such as sight, sound, and touch (inputs). Different perceptual thresholds are common among people and it is not uncommon for individuals to see the same thing differently or even not at all. This may not be due to a cognitive deficiency, but instead, based on such things as culture, age, gender, bias, or past experiences.

From there, the information is processed by higher-level brain functions to make sense of the inputted information. Memory is an extremely important part of the processing and decision-making phase. Memory is the core of most cognitive processes; without it a person would be extremely limited in function. Yet, human memory is highly fallible and subject to error (Baron, 2004). The two types of memory that people are most familiar with are short-term memory (STM) and long-term memory (LTM). STM is problematic in areas such as remembering verbal instructions or orders, particularly when there are numerous distractions (such as in the ER). You may remember that people "chunk" in order to remember information. Humans tend to process information most effectively when it involves approximately seven (plus or minus two) bits of information (Miller, 1956). Beyond this number, accurate short-term recollection becomes difficult.

LTM is also an extremely important part of the processing phase. Because many decisions are based on past experiences, LTM can be thought of as a storage area for global information. From this information, one is able to use schemata or templates to solve a current problem. Obviously, the more experience a person has, the more templates that will be available. The downside of LTM is that there may be problems in retrieving the data at the particular moment that it is required. The retrieval problem can be caused by a number of factors including pathological, environmental, the use of medication or prescription drugs, or simply a decline in memory retrieval as a function of normal aging. This does raise the controversial question of whether you, as a hospital patient or an airline passenger, would feel safer in the hands of an older surgeon or pilot, respectively. With age comes experience, but at what point is a doctor or a pilot not able to perform safely and effectively? An airline pilot, by regulation, must retire at age 65. There is no mandatory retirement age for a doctor.

Of course memory is not the only ingredient in the processing and decision-making phase. Many other factors, such as fatigue, stress, and traumatic life events, can have a profound effect on a person's decision-making ability.

The final phase of the Model is the action that is taken (or the output) after processing has occurred. Assuming a proper decision has been made, it is still possible that an error in execution can occur in this final phase. The surgeon not having the proper equipment for the task may hamper a well-intentioned act. One of the best examples can be found in laparoscopic surgery. Laparoscopic surgery is less invasive and the recovery time is much faster than traditional surgery. However, this procedure is not designed to be the most accommodating for the surgeon. Compared to an open procedure, the surgeon does not have direct visual contact with the surgical site. Instead, he or she must look at a video monitor to see what is taking place. Some of the problems with this setup are that the surgeon does not have the tactile feedback of open surgery due to the length of the shaft of the surgical instruments (Matern, 1998, 1999, 2001, cited in Bogner, 2004, p.79). Additionally, the limited movement of the video camera and instrument forces the surgeon into unnatural and uncomfortable body postures that can affect the outcome of the operation (p.79).

Laparoscopic surgery can be classified as a fairly risky procedure, due in part to the problems listed above. This example shows where the right plan can go wrong during the *taking action* or the execution phase.

Case Study Revisited

Much of what has been covered to this point has been a cursory look at human factors, human behavior, and cognition. It must be stressed that "cursory" is the operant word and volumes have been written for each subject. However, these fundamental tools should provide the reader with enough insight at this point to revisit the case study and understand human performance limitations as they apply to medicine. The case study will concentrate on the five causal factors listed in the Root Cause Analysis. The first three factors will be amalgamated into one category: medication errors. These errors were listed as follows:

1. **"Nearly 600 orders of medication labels are manually prepared and sorted daily"**
2. **"Labels are printed in 'batch' by floor instead of by drug"**
3. **"The medications have 'look-alike' brand names"**

Medication errors might just be the largest and most insidious problem in the hospital environment. According to U.S. Pharmacopeia (2002), data derived from a 2001 study indicate that medication errors are often due to distractions (47%), workload increases (24%), and staffing issues (36%) as contributing factors. The report also states that these percentages are fairly uniform among hospitals nationwide. That said, all of the necessary factors are in place to challenge the cognitive abilities of even the most highly skilled medical professionals. Some of the most pronounced problem areas include the following (these are in no particular order):

- Right medication wrong patient
- Wrong medication right patient
- Improper dosage or wrong administration time
- Difficulty in reading written prescriptions
- Similar sounding drug names
- Similar looking drugs (tablets, pills, fluids) and packaging (vial sizes, shapes, etc.)
- Computer input/output errors
- Storage location

With nearly 600 orders of medication labels manually prepared and sorted daily, the atmosphere was rife for potential error. This all stems from the fact that many drugs have similar sounding names, and during the labeling process the technician is likely to be multi-tasking, under time pressure, and subject to multiple interruptions (not to mention an environment that is consistently noisy by nature). The ideal remedy would be to allow the technician to concentrate on one project at a time, allow unlimited time to finish that project, not allow any interruptions, and provide a soundproofed room where this activity could take place. Since this "fantasy work environment" is unrealistic, there needs to be an understanding of the forces that affect the practical working environment.

People are able to multi-task fairly well when lower-level attention is required. In other words, we can do multiple things when there is a certain amount of automaticity built in (such as the proverbial walking and chewing gum). However, when multiple higher-level cognitive demands are required, humans are subjected to many processing/decision errors. The reason for this is that the saturation of stimuli is beyond the capability of effective human processing.

One of the most salient examples of this limitation can be found in a pair of activities that most people do on a daily basis; talking on a cell phone while driving an automobile. Separately, these activities are fairly innocuous. Together, they can rapidly become a cognitive overload with deadly implications.

As an example, a meta-analysis of the impact of cell phone conversations on driving showed how mental processing ability is compromised when these two activities are conducted concomitantly (Horrey & Wickens, 2004). Of the 16 studies (contributing a total of 37 analysis entries) it was found that there was a clear cost to driving performance when drivers were engaged in cell phone conversations. It was further found that these costs were due primarily to reaction time with smaller costs associated with road tracking performance. Interestingly, the results also showed that there was no significant difference between hand-held and hands-free phone conversations, suggesting that the conversation itself is the distracter and not the method by which it is conducted. The very worst scenario occurs when a person is driving in an unfamiliar area (or through a construction zone) while talking on a cell phone. In this scenario it is plainly obvious that humans are limited in high-level multi-tasking ability. Combine the driving task (non-automatic because of road unfamiliarity or construction) with an emotional cell phone conversation (cognitive distraction) and the potential danger becomes obvious.

Advances in medication technology can help to mitigate errors—to a point. Take for example, the automated drug-dispensing machine known as Pixis®. These systems combine storage with inventory control software where the request for a drug is entered into the system, resulting in the appropriate drawer being unlocked to obtain the drug (MedPAC, 2003). Under direct observation by the author, at a large hospital, a medical error was observed in real-time at one of their Pixis® machines. The machine itself worked flawlessly; instead, the human interaction with the machine caused the error. This case involved a nurse who correctly entered a patient's information into the computer and the Pixis® dutifully unlocked the correct drawer and dispensed the medication. A few minutes later the nurse came back to the station and proclaimed that she "almost administered the wrong drug" and was "glad she caught it when she did." She had entered the correct information and retrieved the drug from the proper drawer but unfortunately the incorrect drug was placed in the correct drawer. This error was exacerbated by the fact that the incorrect drug vial was similar in size, shape, and color to the correct vial. Apparently, the technician who last refilled the Pixis® erringly placed the wrong drug in that particular drawer. The lesson learned here: Modern technology is only as good as the humans who interface with it. The nurse was commended for mitigating a potentially serious medication error.

Another technological step that has been recently taken has been the implementation of bar coding for human drug products and biological products. Similar to the bar coding found on many consumer products, drugs and blood are required to have a bar code label containing critical information such as the drug's National Drug Code (NDC) number, at a minimum. For blood products the code must include, at a minimum, the facility identifier, the lot number relating to the donor, the product code, and the donor's ABO and Rh (USFDA, 2004). This is another step in the right direction from the technology front. It will eliminate much of the ambiguity in drug names and blood types. This method will certainly reduce the likelihood that similar sounding drugs, such as *Celebrex* and *Cerebrex*, will be confused (especially in their raw written form). Similarly, many of the problems with wrong-type blood transfusions will be decreased due to mislabeling. On the downside, the human aspect of error remains. If the physician erringly orders the wrong drug, the bar coding will not prevent a medication error. It will however, verify that the errant drug is exactly what was ordered. Again, even with technology, one must understand the limitations of the input/output process where the human is still accountable for a multitude of actions.

Ambiguous terminology has caused, and continues to cause, numerous medical errors. Specifically, written orders that must be deciphered by nurses and pharmacy technicians are subject to processing errors due mainly to the fact that abbreviations and shorthand, for example, can be open to subjective interpretation. So bad is the problem that the Joint Commission on Accreditation of Healthcare Organizations (JCAHO, 2004, cited in UVHS, n.d.) issued a "prohibited abbreviations" list. The list includes nine items that must be included on each accredited organization's "Do not use" list. An additional three items had to be included by April 1, 2004 and because of this requirement the list is now referred to as "the dirty dozen." (UVHS, n.d.). The following chart shows the abbreviations, their potential problems, and the preferred terms:

| | Abbreviation | Potential Problem | Preferred Term |
|---|---|---|---|
| 1. | U (for unit) | Mistaken as zero, four or cc | Write “unit” |
| 2. | IU (for international unit) | Mistaken as IV (intravenous) or 10 (ten) | Write “International unit” |
| 3.<br>4. | Q.D. and<br>Q.O.D<br>(latin abbreviations for once daily and every other day) | Mistaken for each other.<br><br>The period after the Q can be mistaken for an “I” and the “O” can be mistaken for an “I” | Write “daily” and “every other day” |
| 5.<br>6. | Trailing Zero (X.0 mg),<br><br>Lack of leading zero (.X mg) | Decimal point is missed | Never write a zero by itself after a decimal point<br><br>(X mg), and always use a zero before a decimal point (0.X mg) |
| 7.<br>8.<br>9. | MS<br>MSO4<br>MgSO4 | Confused for one another. Can mean morphine sulfate or magnesium sulfate. | Write “morphine sulfate” or “magnesium sulfate” |
| 10. | c.c. (for cubic centimeter) | Mistaken for U (units) when poorly written | Write “ml” for milliliters |
| 11. | ug (for microgram) | Mistaken for mg (milligrams) resulting in thousand-fold dosing overdose | Write “mcg” |
| 12. | TIW (three times a week) | Mistaken as “three times a day” | Don’t use this abbreviation. |

Figure 4. JCAHO Prohibited Abbreviations. Courtesy UVHS.

To further compound the problem, hand-written prescriptions are often written in a rushed and nearly indiscernible manner. Most people have received a written prescription at least once in their life and have probably asked the question, "How can anyone read this?" Even trained professionals may have difficulty in interpreting a written order, such as the one depicted in Figure 5.

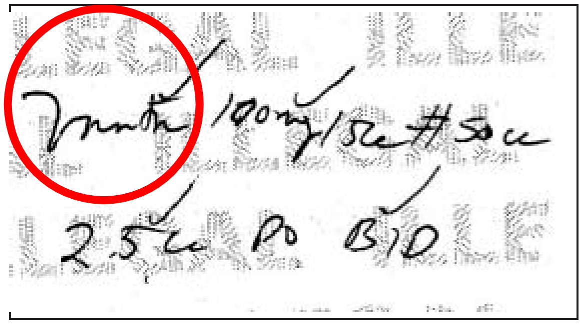

Figure 5. Ambiguous Prescription. Courtesy State of Ohio Medical Board

In this case, the dispensing pharmacists misread a prescription for *Vantin* as *Motrin*. Each pharmacist member of the Pharmacy Board in turn examined the written prescription and saw the same thing (State of Ohio Medical Board, 2003). This case illuminates the complexity of this type of error because there is uncertainty in where the blame lies. The physician wrote what he meant to write and the pharmacists unanimously agreed as to what it said (albeit wrong). Because of this, the pharmacists did not contact the physician for clarification, because in their view, there was no ambiguity. This case is also an excellent example of how an "error chain" can be initiated. In this scenario, two glaring questions come to mind; 1) with such scarce resources (i.e., people and time) is it necessary to have to form a committee for the sole purpose of translating a single word? and, 2) how difficult would it have been to take a few extra seconds to write legibly in order to have prevented this medication error in the first place?

**4. "A pharmacy technician trainee was working in IV medication preparation room at the time"**

Although some of the factors that may have contributed to the mislabeling of the "50 ml bottle of *Diprivan*" as "*Diflucan* 100 mg/50 mL" have been covered earlier, it is interesting to stop for a moment and understand how this specific type of error occurred. Mainly, the pharmacy technician's working environment was conducive to error, similar looking drug labels were being used, and the technician was a trainee. As was previously stated, even the most experienced technicians are not immune to this type of error. When an unsupervised trainee works alone in this environment the chance of unabated error greatly increases.

One of the key cognitive problems this technician may have faced was the *see what you want to see syndrome.* Just as it sounds, people are apt to see something because they *expect to see it.* This lowering of perceptual discrimination may be due to complacency, boredom, fatigue, environmental conditions, lack of experience, inadequate or lack of training, or any combination of these.

As an aviation trainer, the author has casually experimented with pilots in a simulator to observe the effects of the *see what you want to see syndrome.* The scenario was set up like this: Just before the crew initiated the Before Landing Checklist, the reading of a pressure gauge was dropped from 1500 to 0 p.s.i. There was also a small amber annunciator light that illuminated when the pressure dropped below a critical value. Part of the Before Landing Checklist included a check of this gauge to verify the pressure was "in the green" (normal range, about 1500 p.s.i). Interestingly, when the crew came to this checklist item, approximately 80% of the pilots *looked at the gauge* and announced that the "pressure was in the green" even though it was indicating 0 p.s.i *and* the annunciator light was illuminated. This scenario is analogous to medical procedures, and a high amount of vigilance is required to counteract these effects.

### 5 "The nurse had been 'yelled at' the day before by another physician—she attributed her immediate and total diversion of attention in large part to her fear of a similar episode"

The fifth and final factor in this case study illuminates a deficiency in human performance that was precipitated by a mismatch in the L-L interface (see Figure 1). Recall that the additional "L" was added to the SHELL Model because not only were people interfacing with the environment, software, and hardware, but also with *other people*. Unfortunately, this interface is highly susceptible to errors; specifically, errors in the communication process. In this case, the nurse sensed that there was something amiss when a glass bottle containing an opaque liquid arrived instead of the plastic bag containing a clear solution that she expected. This was a good catch on her part but unfortunately she was not able to trap the error at that point because of a distraction that required immediate attention. When the nurse returned to the patient, she forgot that there was a discrepancy with the medication and proceeded to connect the bottle of Diprivan to the patient's subclavian line. It was only after the IV pump alarmed due to air in the line that the nurse remembered that the wrong medication was being administered.

Although the nurse’s distraction caused this error-chain to perpetuate, the most disturbing finding might be the nurse's fear of being "yelled at" by a physician. Fear should not be part of a nurse's job, as it will only compound these types of errors. Instead, a synergistic environment needs to be adopted by all medical teams where effective and professional interaction is critical to patient safety. Unfortunately, there is a steep hierarchical structure that makes subordinates afraid to speak up or challenge the person in charge (typically the physician, surgeon, anesthesiologist, etc.). Rather than "makes waves," the person lower on the hierarchy will tend to agree with, or go along with, higher-level decisions simply because they fear repercussions from other staff, or worse, being labeled as a "complainer" and possibly losing their job.

Aviation has addressed, among other things, communication and group dynamic processes by mandating Crew Resource Management (CRM) training for all airline pilots. CRM has been shown to be efficacious in advocating other crewmembers speak up and challenge the captain when an uncomfortable situation or "red flag" exists. This type of training is slowly gaining acceptance in medicine, but until that happens, these barriers will continue to exist.

Physicians need to understand that some of their best resources are the people who surround them and it is the input from these people that can help to prevent unmitigated errors from causing harm to patients.

One final word on this fifth factor of the case study: Even though memory was addressed earlier in this paper, it is worth speaking briefly about the nurse's failure to remember what she had been doing before being distracted. This is known as prospective memory, or remembering to do things in the future. Prospective memory is one of the weakest parts of human memory function. Even with great retrospective memory (remembering things from the past), people have a hard time remembering to do things in the future. This is an innate human fallibility and one of the reasons why people tie ribbons on their fingers, use day planners, and write reminders on their hands.

In aviation, NASA has conducted research that addresses prospective memory in airline pilots. One such study conducted by Dismukes, Loukopoulos, and Jobe (n.d., cited in Baron, 2004) found that, in an informal analysis of 37 National Transportation Safety Board (NTSB) reports involving crew error, nearly half showed evidence of interruptions, distractions, or preoccupation with one task to the detriment of another task. Some recommendations by Dismukes, et al. include creating salient reminder cues, breaking concurrent tasks into subtasks and pausing between subtasks to monitor, and identifying specific things to monitor.

In another NASA study, Lang-Nowinski, Holbrook, and Dismukes (n.d., cited in Baron, 2004) found that out of a random sample of 1299 reports from NASA's anonymous Aviation Safety Reporting System (ASRS) database, 75 indicated memory errors by pilots, and out of those 75, only one described an instance of retrospective memory failure. The remainder involved some form of *prospective* memory failure.

NASA's memory research in aviation can be applied to any domain, and the transfer to another high-risk industry such as medicine is no exception. The nurse had to deal with a prospective task that was interrupted by a distraction; a significant precursor for error. The "fear factor" only made the working environment that much more difficult for her to perform to her fullest potential.

## Conclusion

This paper has discussed many of the cognitive factors that influence people in the medical profession. It was not meant to delve fully into all aspects of cognition, as that would require hundreds of pages. Instead, two Human Factors models were presented and a random case study was used to elucidate Human Factors error principles in the day-to-day activities of a typical hospital environment.

While aviation has addressed human factors and crew resource management as part of initial and recurrent training for airline pilots, healthcare has continued to work in a traditionally autonomous environment with little or no emphasis on human performance and group dynamics. That needs to change.

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