Human Factors Engineering Series

Introduction to the Human Factors Engineering Series

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Something bad just happened to a patient in the intensive care unit at Hospital ABC. Who's to blame? This question is rarely heard as new approaches to quality and safety are adopted in health care organizations around the United States and the rest of the world. Instead, new questions posed during a root cause analysis (RCA) seem to be more constructive but do not go deep enough—Why didn't the nurse get trained? Why didn't the physician follow the stated policy? and Why didn't the three quality improvement cycles stop that event? These kinds of questions lead to well-intentioned remedies, such as additional training and new policies. Yet if the RCA does not go deep enough, the remedies are likely to be ineffective and, worse, drain resources and good will.

Human factors engineering (HFE) concepts and tools can help organizations go deeper in their analyses of adverse events and develop more effective and lasting remedies. This introduction launches a new HFE series of articles for the *Joint Commission Journal on Quality and Safety.* Health care organizations are concerned about patient safety at every level, from chief executive officers defending their patient safety budgets to medical students struggling to contribute at their first RCA meeting. These articles will provide concrete advice backed by science and evidenced-based evaluation. Each article will follow the same general format: case study, analysis of the HFE factors involved, and recommendations on how to address those factors to ensure lasting solutions.

Briefly, HFE is the discipline that studies human capabilities and limitations and applies that information to designing safe, effective, and comfortable system design.[1] For example, methods and findings from cognitive psychology and biomechanics are used to develop and improve systems such as software and hand tools, respectively. Several decades old, HFE has been applied in various organizations facing HFE design issues (which reflect specific human limitations and capabilities), such as the following[2]:

- Not enough information is available to the operator to make decisions
- Too much information is presented to the user, and some of it is irrelevant to the task at hand
- Information is difficult to find, view, or interpret
- Information is not presented in an effective format
- Information is not in a format that makes apparent how it influences the operators' decisions (information visualization)
- The navigation scheme or structure of the tasks or process flow is not obvious or visible to the user, creating the likelihood of getting lost within the system
- Default settings are not appropriate, or it is difficult to change default settings
- It is difficult to review data that have been input into the system
- Users easily get lost in the system; it is difficult to tell where they are in an activity or a process, and it is difficult to tell what to do next
- It is difficult to detect errors in data entry
- Recovery from errors is difficult or cumbersome

One can use HFE methods to develop solutions (Table 1, page 216) to these issues. Efficiency, reliability, and ease of use are best achieved when design recognizes human limitations and takes advantage of strong human capabilities. The main HFE methods are listed in Table 2 (page 217).

Table 1. Sample Human Limitations and Capabilities

Human Limitations	Implications
Perceptual ■ Contrast of lettering to background ■ Detection/identification of signals (information) with noise (extraneous information) in the background ■ Lighting levels ■ Differentiation of colors, shapes, and words *Cognitive* ■ Short-/long-term memory ■ Integrating information from spatially separated sources ■ Interpreting meaningful information from raw data (numbers) *Physical* ■ Time/accuracy trade-offs of gross motor tasks ■ Reach limitations ■ Strength/endurance limitations	Human factors design guidelines for the following: ■ Design of labeling ■ Design of warnings or alarms ■ Design of software programs ■ Design of information display ■ Design of paper forms ■ Design of process/activity flow ■ Design of workplace ■ Design of training/education ■ Design of cognitive aids ■ Design of decision support systems ■ Design of policies and protocols
Human Capabilities	
Perceptual ■ Ability to detect visual or auditory information when made salient ■ Ability to perceive trend information when data is presented graphically ■ Ability to differentiate and identify different auditory or visual signals *Cognitive* ■ Ability to understand complex relationships and make diagnoses ■ Ability to formulate, plan, and carry out multistep solutions ■ Ability to troubleshoot in new situations ■ Ability to coordinate and cooperate *Physical* ■ Ability to learn complex motor tasks	

Applying HFE to health care design and safety issues is not new.[3] In 1975 several authors participated in a symposium and book on human factors and health care, which featured several contributions of HFE to patient safety.[4] The application of HFE to anesthesiology[5] contributed to the creation of the Anesthesia Patient Safety Foundation.[6] Other HFE researchers, including Gopher et al.,[7] have addressed many aspects of patient safety epidemiology. By the end of the 1990s, many engineers and health care professionals were spreading the word about the key role of HFE in safe medical device design,[8,9] health care facility operations,[10] and patient safety processes.[2]

More recently, health care professionals have used HFE in very specific design challenges, such as layout of medications in code cart drawers.[11] Other organizations have used HFE in important ways to make lasting patient safety improvements, such as procurement system changes[12] and education and training regarding safety processes.[13]

The aim of this series of articles is to bring to life the types of patient safety activities to which HFE can contribute (Table 3, page 218). The case study in each article will illustrate or provide a bridge to one or two key HFE principles and methods; this approach is often used to introduce HFE to new audiences.[14] The authors represent both "hybrids"—health care persons who

Table 2. Overview of Human Factors Engineering Methods*

Human Factors Analysis Activity	General Description	Analysis Products
Field Observations	Unobtrusively observe actual users in the typical work environment carrying out typical tasks. Take note of how work is carried out, who carries it out, what they use to carry it out, who they interact with, environmental factors (e.g., light levels, noise, crowding from equipment or people).	Characterizes typical work environment, identifies factors that might affect how clinicians perform (e.g., limitations of equipment, low light levels, high risk or time pressure, frequent distractions).
Simulation or Bench Tests	Simulate a process or an operation of a device, using different scenarios (e.g., different tasks, time pressure, lighting, errors that one must recover from). Simulation involves end users, whereas bench tests can be performed by the analyst.	Mapping of the system structure (e.g., where do all the menus in a software program lead? Where does the pharmacist have to go to retrieve XYZ?).
Information Requirements or Functional Needs Assessment	Information requirements analysis identifies what information a user needs to carry out specific tasks or activities (from micro to macro—How can a user tell he must push that button next? How does a user know he must perform that task next? How does he or she know whom to contact to relay information?). Similarly, a functional needs assessment identifies what tools or information a user requires to accomplish a task.	Information and functional needs of the user. Identifies task-related activities that depend on short-/long-term memory, identifies where information should be supplied and how it should be supplied, and identifies what tools a user needs to accomplish a task.
Heuristic Evaluation	Evaluates equipment or a process against a set of human factors principles.* Sample questions might include Does the software provide functionality needed by the user? Are buttons grouped in a logical fashion? Is there sufficient feedback to tell the user he or she has completed a task correctly? Is it obvious what a user must do next?	Identifies areas where human factors principles are violated, which may lead to unwanted consequences, such as frequent user errors, slips, high mental work load, user frustration, inefficient or inaccurate task completion, misunderstanding of policies, and deviation from prescribed guidelines or procedures.
Cognitive Walkthrough	A user is asked to demonstrate or walk through a device or process, thinking out loud or providing commentary on what he or she is doing and thinking at each step of the task or process.	Characterizes where human decision making is involved in a task, factors that influence decision making, including, for example, expertise a user might rely on, where information is retrieved from, strategies adopted, and workarounds invented to circumvent a deficiency.

* See Gosbee J.W., Lin L.: The role of human factors engineering in medical device and medical system errors. In Vincent C. (ed.): *Clinical Risk Management: Enhancing Patient Safety,* 2nd ed. London: BMJ Press, 2001, pp. 301–317 for a list of sample questions that should be asked when conducting an evaluation.

Table 3. Summary of Patient Safety Activities That Can Incorporate Human Factor Engineering (HFE)*

Candidate Activities for HFE	HFE Concepts/Methods That Should Be Applicable	Purpose of Applying HFE Methods
Development Activities		
■ In-house device/software design/development ■ Policy/guideline design/development ■ Training and education curriculum design/development ■ Paper forms (e.g., labels, order forms, charts, instruction sheets)	■ User-centered design, iterative design and testing, HFE factors analyses, user testing ■ Human factors analyses, user testing	■ Output from applying HFE: provide functional requirements, guide design concepts, validate design concepts, promote user acceptance ■ Overall goal: Ensure usability (efficient, functional, easy to learn, easy to use, low mental workload)
Evaluation Activities		
■ Procurement (of devices, software, training programs) ■ Adverse event investigation: RCAs, HFMEAs, and reporting systems		■ Output from applying HFE: usability data for comparing products from competing vendors, identification of HFE issues or user—system interaction problems that may be causing errors ■ Overall goal: Identify usability issues with prospective or existing equipment, software, or training programs or existing policies and procedures that may lead to errors

* See Table 2 (page 217) for a description of HFE methods). RCA, root cause analysis; HFMEA, Healthcare Failure Mode and Effects Analysis.

learned HFE and vice versa. Some of the authors will highlight the link from the HFE analysis to more commonly understood safety and quality processes in health care, such as RCA, procurement of new devices, and morbidity and mortality conferences. Other authors will use HFE principles to analyze or anticipate the promises and pitfalls of safety remedies, such as warning labels and computerized order entry. Most importantly, the authors will provide recommendations specific enough for most readers to do something or change something in their organization within days or weeks. We hope the ideas presented in this series will inspire you and your organization to help all our patients. J

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