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The science of human factors: separating fact from fiction

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ABSTRACT

Background Interest in human factors has increased across healthcare communities and institutions as the value of human centred design in healthcare becomes increasingly clear. However, as human factors is becoming more prominent, there is growing evidence of confusion about human factors science, both anecdotally and in scientific literature. Some of the misconceptions about human factors may inadvertently create missed opportunities for healthcare improvement.

Methods The objective of this article is to describe the scientific discipline of human factors and provide common ground for partnerships between healthcare and human factors communities.

Results The primary goal of human factors science is to promote efficiency, safety and effectiveness by improving the design of technologies, processes and work systems. As described in this article, human factors also provides insight on when training is likely (or unlikely) to be effective for improving patient safety. Finally, we outline human factors specialty areas that may be particularly relevant for improving healthcare delivery and provide examples to demonstrate their value.

Conclusions The human factors concepts presented in this article may foster interdisciplinary collaborations to yield new, sustainable solutions for healthcare quality and patient safety.

INTRODUCTION

“Human error in medicine, and the adverse events that may follow, are problems of psychology and engineering, not of medicine.”¹

Medicine is devoted to human health and healing, but the science behind why errors occur, and how to reduce the likelihood of preventable harm to individuals, are well described in human factors literature. Human factors—a

science at the intersection of psychology and engineering—is dedicated to designing all aspects of a work system to support human performance and safety. Human factors, also known as ergonomics, uses scientific methods to improve system performance and prevent accidental harm.² The goals of human factors in healthcare are twofold: (1) support the cognitive and physical work of healthcare professionals³ and (2) promote high quality, safe care for patients.⁴

Human factors knowledge has been suggested as a promising mechanism with which to improve healthcare delivery,^{5–7} yet this body of knowledge remains largely untapped. The reasons for this are not fully known. Gurses *et al*⁸ posit that safety efforts have been sluggish due to the inadequate integration of human factors principles and methods into healthcare. Their article provides valuable recommendations to accelerate the uptake of human factors. In addition, we believe that common misconceptions about human factors may slow the integration of human factors into healthcare and hinder healthcare improvement. The term ‘human factors’ itself can be misleading and may result in fundamental misunderstandings. It appears that several misconceptions about human factors science are beginning to take root in peer-reviewed medical literature.^{9–16} For example, some papers refer to ‘failures’ of people as the underlying cause of adverse events or broken healthcare delivery processes,^{17–19} a stance that is contrary to human factors science and counterproductive for advancing patient safety.^{20 21}

Other literature describe the application of human factors for specific applications or select healthcare audiences.^{22 23} The goal of this paper is to provide a general introduction to human

factors, directed at a broad audience, by presenting five fundamental human factors concepts.

SEPARATING FACT FROM FICTION

Fact #1: *Human factors is about designing systems that are resilient to unanticipated events.*

Fiction: *Human factors is about eliminating human error.*

In early childhood, most of us learnt that 'everyone makes mistakes'. Errors are inevitable, and attempting to eliminate human imperfections in healthcare or any other industry is a futile goal.²⁴ Therefore, human factors experts gather data about *human characteristics and human interactions with the work environment* to design systems and tools that support physical and cognitive abilities of humans and are resilient to unanticipated events.⁴ This includes gathering data on:

- ▶ *Human physical characteristics*, for example, anthropometric measurements on the patient population to redesign hospital beds and reduce the risk of patient entrapment²⁵
- ▶ *Human cognitive characteristics*, for example, a cognitive task analysis with intensive care unit staff to inform the design of decision support for ventilator settings and reduce the risk of errors²⁶ and
- ▶ *Human interactions with the overall work system*, for example, how procedural policies, work hour restrictions and patient load can be coordinated to mitigate errors during transfers of care.³ The study of the overall work system is formally known as macroergonomics.²⁷ Cognitive engineering is another well-known framework for studying and designing complex systems.^{28 29}

Human factors is a term that could easily be misunderstood to refer to the failures of people. This position, sometimes expressed in terms of 'the human factor' or 'caused by human factors', is in opposition

to human factors science, which attempts to design systems that support human performance and are resilient to unanticipated events.² A human factors approach can also foster a culture of safety, promote a learning environment, and encourage the development of a culture where unintentional errors are reported without fear of retaliation and findings are used to improve various system components to yield sustainable change.³⁰

Fact #2: *Human factors addresses problems by modifying the design of the system to better aid people.*

Fiction: *Human factors addresses problems by teaching people to modify their behaviour.*

Work systems often create challenges for people. Human factors aims to identify what aspects of work are challenging or made the 'wrong action' seem reasonable in context, and modify these aspects of system design to aid people in the workplace and promote safety.³ This most frequently involves changing technologies, processes, tools and other inanimate work system components.

While it is critical that healthcare professionals and staff have the education and training necessarily to perform their role, training itself is generally a weak safety intervention.² Table 1 outlines when training is likely to be effective or ineffective for improving patient safety, and can serve as a guide to patient safety professionals. In general, human factors approaches strive to avoid using training to compensate for poor system design; rather the focus is on redesigning systems, tools and techniques to yield sustainable improvements in safety.³⁸ Emphasis is placed on first evaluating organisational components, prior to implementing any training programmes, to ensure that the system design supports safety.³⁹ However,

Table 1 Overview of when training may or may not be appropriate as a human factors approach to improve patient safety

Training is likely an <i>appropriate</i> human factors approach to patient safety if...	Training is likely an <i>inappropriate</i> human factors approach to patient safety if...
<p>A. The goal is for individuals to become <i>familiar</i> with <i>new</i> technologies, tools or devices to learn about the available options and functions (eg, training a physician when s/he is <i>first</i> introduced to an electronic health record; training when first learning how to use laparoscopic tools). Training should include knowledge about strengths and limitations of specific technologies.³¹</p> <p>B. It allows individuals to <i>develop and test</i> new techniques or <i>practice</i> evidence-based techniques in a safe, low risk environment (eg, simulation of operating room to practice a team communication technique that has been demonstrated to improve situational awareness.³²)</p> <p>C. It provides a mechanism for individuals to <i>gain experience</i> with specialised techniques that involve sensorimotor skills (eg, performing surgeries and catheter insertions with supervision or in a simulated environment).</p> <p>D. It is used to instantiate knowledge in realistic scenarios,^{33 34} such as to <i>practice or test</i> procedures for emergency situations (eg, rapid response).</p> <p>E. Other system components are considered <i>first</i>, redesigned, and addressed using human factors expertise and principles and no other system changes can possibly be made.</p>	<p>A. The goal is for individuals to stop using technologies, tools or devices 'in the wrong way'. (This is described as the 'bad apple' fallacy.^{35 36})</p> <p>B. It is an attempt to change innate human characteristics or imperfections (eg, staff meeting to 'be more vigilant' unlikely to lead to sustainable safety improvements.²)</p> <p>C. It is intended to address a type of error that is occurring across multiple people. (This indicates the system design does not match human characteristics³⁷ and that system changes, not training, are needed.)</p> <p>D. Individuals have been previously trained about the safety issue(s) and the problem persists. (Additional training is unlikely to be effective. The phenomenon above indicates there is an issue with other system components.²⁰)</p> <p>E. Training is the only safety intervention or the primary intervention used, especially when other system components have <i>not</i> been carefully considered and modified first.</p>

human factors can also provide valuable input on training, particularly in the context of improving team processes and interactions. In these instances, sophisticated training programmes are often developed, and tend to include goals such as increasing awareness about human characteristics (eg, the potential impact of and strategies for avoiding fatigue, stressors, and cognitive overload); practicing sensorimotor skills or new techniques through experiential simulations; and providing trainees with a broad range of experience in a simulated environment to enhance the system's resilience to unanticipated events.^{32 40 41}

Understandably, 'human factors' can sometimes be mistakenly equated with 'training' or 'non-technical skills' and confused with strategies that are intended to change human behaviour. For example, a recent slide set by The Joint Commission lists 'human factors' as one of the root causes of sentinel event data, and portrays it as a set of issues typically associated with human resource management such as '... in-service education, competency assessment, staff supervision, resident supervision, medical staff credentialing/privileging...', and other descriptors that are not aligned with human factors science.⁴² When a review of a patient safety event leads to a determination that the cause is 'human error', it is not uncommon for healthcare organisations to try and modify the behaviour of the individual or group through counsel or retraining, an approach which has been referred to as the 'bad apple' fallacy.^{35 36} Rather than correcting human behavior, human factors approaches focus on improving system design.^{3 43} With this approach, deeper investigation into 'human error' often uncovers opportunities to improve technology design, organisational structures or procedures.²⁴

Fact #3: Human factors work ranges from the individual to the organisational level.

Fiction: Human factors is focused only on individuals.

Individual-level human factors research in healthcare has included the redesign of electronic health records, computerised provider order entry systems, bar code medication administration systems, workstations and laparoscopic tools to support healthcare professionals.^{4 44} However, human factors work is not limited to the individual level, but ranges from individual to organisational levels, and thus can bring other potential contributions to healthcare. Human factors approaches can examine how the performance and safety of individuals and teams are impacted by organisational design, policies and procedures. For example, this may include:

- ▶ Developing techniques to facilitate closed-loop communication and situation awareness across teams.^{2 32}
- ▶ Understanding how organisational decisions for equipment purchases impact the performance of clinicians that use the equipment. For example, a hospital may purchase infusion pumps based on the needs of

anaesthesiologists in the operating room, and then distribute them for use throughout the hospital. The pumps were designed to be at eye level for a sitting user, but in the emergency department, they are mounted on bedrails at the user's waist level. The change in viewing position leads to 'erroneous' key pressing, and a 100-fold overdose of a vasoactive medication.⁴⁵

- ▶ Evaluating how organisational or national level policies can filter down to affect clinician workload and patient safety. For example, to accelerate patient care timelines, a national VA directive mandates that specialists address electronic consult requests from primary care providers within 7 days. To meet the mandated timeline and avoid penalisation, specialists often deny consults that lack key information, restarting the clock on the performance tracking system. To proceed with the consult, the requesting provider must re-enter all of the information again. Thus, the policy, in combination with other aspects of the system design, increases clinician workload, and can potentially impact patient safety by delaying patient diagnosis and treatment (eg, colonoscopy/colon cancer).⁴⁶

Efforts focused on designing systems to support individuals in their work environment are important and necessary. However, much work is also needed to ensure that broader organisational components are effectively designed and coordinated to achieve the desired outcomes.

Fact #4: Human factors is a scientific discipline that requires years of training; most human factors professionals hold relevant graduate degrees.

Fiction: Human factors consists of a limited set of principles that can be learnt during brief training.

Many core human factors methods involve qualitative techniques, such as interviews and observations, which appear to be simple and easy. Similarly, the best, most elegant human factors solutions to problems often seem simple in hindsight: *after* a problem has been reframed in a novel and constructive way. This apparent simplicity belies the expertise required to understand a work domain, its goals and constraints. Human factors expertise cannot be rapidly acquired by means of a brief workshop or seminar, and attempting to apply human factors techniques without proper training and experience is likely to be ineffective³⁵ or lead to incomplete or misleading analyses and interventions. In some cases, human factors concepts and methods have been misrepresented in the literature. For example, a recent article conducted a closed-ended survey of healthcare professionals, along with a retrospective chart review, in an effort to identify systems factors that contribute to errors in emergency departments.⁴⁷ Although the article claims to be in accordance with human factors principles, the methodologies overlook many key system factors that would typically be included in a human factors analysis, such as how the design of technologies and contextual interactions in the system contribute to

adverse events.⁴⁸ The article discussion implies that more nurses are needed to intercept errors. This conclusion places the burden on people to prevent harm, rather than redesigning system components to promote safer care.

Through the week-long course, Systems Engineering Initiative for Patient Safety, offered by faculty at the University of Wisconsin-Madison, over 300 physicians, nurses, pharmacists and vendor staff have received training on human factors principles for patient safety and health information technology.⁴⁹ This type of intensive training enables health professionals and human factors experts to work together in an advanced and substantive manner. Healthcare professionals can help human factors experts understand what is (and is not) clinically meaningful, while human factors experts can bring new theories and methods to the work of improvement. Ideally, partnerships are formed during the early stages of project development to promote success. Improving the safety and effectiveness of care by means of human factors methods will require the development of substantive,

long-term partnerships between human factors and healthcare communities.

Fact #5: Human factors professionals are bound together by the common goal of improving design for human use, but represent different specialty areas and methodological skills sets.

Fiction: Human factors scientists and engineers all have the same expertise.

Similar to the field of medicine, human factors professionals receive general human factors training, but often specialise in a particular human factors domain. Human factors draws upon knowledge of engineering and psychology; thus, fundamental human factors training is most commonly offered by industrial and systems engineering or psychology departments. The majority of individuals with human factors expertise receive training at the graduate level, although some exceptions include a few undergraduate programmes and postdoctoral fellowship training programmes. A human factors specialisation is most commonly acquired through a variety of coursework and pursuit

Table 2 Some of the human factors focus areas that are applicable to healthcare

Specialisation	Description	Example for healthcare
Ageing	Human factors applications to meet the needs, capabilities, and limitations of the elderly and other special populations	Applying human factors principles to reduce inpatient falls ⁵⁰
Augmented cognition	"Development and application of real-time physiological and neurophysiological sensing technologies that can ascertain a human's cognitive state while interacting with computing-based systems"	Designing tools that can transmit feedback to the surgeon to improve laparoscopic grasp control ⁴⁴
Cognitive engineering and decision making	"Research on human cognition and decision making and the application of this knowledge to the design of systems and training programmes"	Identifying cues and strategies experienced nurses use to recognise infants at risk for sepsis and necrotising enterocolitis to guide the design of training and decision support ^{51 52}
Communication	Human-to-human communication, especially when mediated by technology	Comparing the information accuracy of manual versus electronic patient status boards in emergency departments ⁵³
Human performance modelling	"Development and application of predictive, reliable and executable quantitative models of human performance"	Model-based simulations to investigate how and why age and localised muscle fatigue affect postural control and fall risks ⁵⁴
Industrial ergonomics	"Application of ergonomics data and principles for improving safety, productivity and quality of work in industry"	The design of a workstation for radiologists using appropriate ergonomic and biomechanics data
Macroergonomics	"Organisational design and management issues in human factors and ergonomics as well as work system design and human-organisation interface technology"	Evaluating system components at various organisational levels (eg, drug route; nurse to patient ratios; medication administration policies) and modifying them in a coordinated manner to aid safe medication administration during shift change ²⁷
Perception and performance	"Perception and its relation to human performance"	Designing and evaluating visual, audio and combined displays for anesthesiologists ⁵⁵
Product design	"Developing consumer products that are useful, usable, safe and desirable"	Redesigning epinephrine autoinjectors for patients in an effort to reduce injection errors during anaphylaxis ⁵⁶
Safety	"Development and application of human factors technology as it relates to safety"	Integrating human factors principles into the design of a kit for central line insertion to reduce cognitive burden for healthcare workers, promote best practices and prevent infections ⁵⁷
Training	"Training system design and evaluation, innovative technologies for training, and instructional design and implementation"	Developing evidence-based practices for debriefing medical teams, as a mechanism for training and the development of a learning environment ⁵⁸
Usability	Measurement of the quality of a user's experience when interacting with a product or system ⁵⁹	Comparative, usability evaluation with clinicians to assess two different designs for computerised clinical reminders ⁴⁶

Unless otherwise noted, descriptions, including those in quotations, are derived from the Human Factors and Ergonomics Society Technical Groups.⁶⁰

of a master's thesis or doctoral dissertation. Each university tends to emphasise particular areas of the discipline, based on the strengths of the human factors faculty at that institution. This results in human factors professionals who possess different specialised knowledge and methodological skill sets.

Table 2 outlines some of the specialised focus areas within human factors that may be useful in collaborations aimed at healthcare safety and improvement. While some larger healthcare organisations may find it feasible and beneficial to develop a human factors office or department, we recognise that this is not practical for many hospitals. Gurses *et al* provide several recommendations to build human factors capacity in healthcare.⁸ In addition, healthcare stakeholders may find it helpful to target human factors specialty areas that are most aligned with their organisational goals when recruiting for a position or developing collaborations.

For instance: hospitals that want to improve overall quality of patient care may seek expertise in macroergonomics; hospitals with a dearth of safety expertise could consider human factors professionals with expertise in safety; and commercial vendors of devices and technologies may benefit from expertise in product design and/or usability. The specialisations in table 2 are not as distinct and differentiated as those found in the practice of medicine, and there are cases where one individual may have expertise in two or three areas. While all human factors scientists strive to improve work systems for human performance and safety, human factors professionals acquire different skill sets that they can bring to healthcare improvement.

SUMMARY

Human factors is an established body of science that is positioned to assist with the challenge of improving healthcare delivery and safety for patients. Human factors and healthcare professionals can work together to identify problems and solutions that may not be apparent by traditional means. While human factors does not promise instant solutions for healthcare improvement, it can provide a wealth of scientific resources for sustainable progress.^{61–63} Here, we have attempted to clarify the goals of human factors and pave the way for interdisciplinary collaborations that may yield new, sustainable solutions for healthcare quality and patient safety.

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