



Time to accelerate integration of human factors and ergonomics in patient safety

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ABSTRACT

Progress toward improving patient safety has been slow despite engagement of the health care community in improvement efforts. A potential reason for this sluggish pace is the inadequate integration of human factors and ergonomics principles and methods in these efforts. Patient safety problems are complex and rarely caused by one factor or component of a work system. Thus, health care would benefit from human factors and ergonomics evaluations to systematically identify the problems, prioritize the right ones, and develop effective and practical solutions. This paper gives an overview of the discipline of human factors and ergonomics and describes its role in improving patient safety. We provide examples of how human factors and ergonomics principles and methods have improved both care processes and patient outcomes. We provide five major recommendations to better integrate human factors and ergonomics in patient safety improvement efforts: build capacity among health care workers to understand human factors and ergonomics, create market forces that demand the integration of human factors and ergonomics design principles into medical technologies, increase the number of human factors and ergonomic practitioners in health care organizations, expand investments in improvement efforts informed by human factors and ergonomics, and support interdisciplinary research to improve patient safety. In conclusion, human factors and ergonomics must play a more prominent role in health care if we want to increase the pace in improving patient safety.

Safety experts have recently questioned the limited improvements made in patient safety.^{1–3} News clips of harmful radiation therapy overdoses, tubing and catheter misconnections, healthcare-acquired infections, and inaccurate results from diagnostic tests are commonly reported by the media. They have plenty of fodder: an estimated 13.5% of discharged Medicare patients in October 2008 experienced at least one adverse event during their hospitalisation.⁴

The healthcare community is engaged in patient safety improvement efforts, although the majority has a narrow focus. Few efforts have integrated the principles and methods of human factors and ergonomics (HFE), which is comprehensive and deliberate, systematically studying each piece to determine how it fits best in the puzzle. Human factors and ergonomic specialists view individuals as an integral part of healthcare systems and believe their abilities and limitations must be accounted for when optimising the overall system's performance (eg, safety of care). For example, while other engineering subspecialties (eg, mechanical) typically focus on designing better technologies (eg, more energy-efficient engines or robots that perform surgery), HFE specialists focus on designing user-friendly interfaces that can improve the user's performance and reduce human error. These specialists study the interactions between people and elements of the system in which they work (physical environment, tasks, tools/technologies, and organisational conditions), and redesign systems while systematically considering all of these interactions with the goal of joint optimisation of social and technical elements of a system.⁵ For example, instead of designing each service (eg, emergency department, intensive care unit) of a care system separately and assuming they will work seamlessly together, HFE specialists study and design an integrated whole (eg, hospital) to maximise the system's overall performance, including patient safety, efficiency, and clinicians' quality of working life.

The HFE field consists of three specialty domains. Physical ergonomics identifies the physical strengths and limitations of humans and designs work environments considering

Table 1 Domains of specialisation within the human factors and ergonomics discipline

Domain	Sample topics	Sample patient safety related applications
Physical ergonomics	Lifting/handling tasks Repetitive movements Physical workload (Re)design of physical space and layout	Design of patient rooms to reduce falls Number and placement of sinks at healthcare facilities to increase compliance with hand-washing guidelines Making sure adequate lighting is available in medication dispensing areas
Cognitive ergonomics	Training programme development Design and evaluation of tools and technologies Decision-making under time pressure Mental workload	Development of training programmes to improve safety of care Usability testing of smart intravenous pumps Development of decision support tools to reduce diagnostic errors
Macro ergonomics	Coordination Teamwork Safety culture Large-scale organisational change Participatory approach to (re)design efforts Job design (eg, scheduling, breaks, nature of tasks)	Reducing readmissions through improved discharge planning and coordination Studying the impact of new health information technologies on work system, processes and outcomes

these physical characteristics. Cognitive ergonomics focuses on the components of a system and the cognitive abilities and limitations of its users. Macroergonomics deals with the design of the overall work system, considering the interactions and the fit between different components in the system (table 1).⁵ In most cases, patient safety problems or improvement efforts require the use of principles, methods and tools from multiple domains. For example, designing an electronic health record interface logically falls in the cognitive ergonomics domain, but it also needs a macro-ergonomics assessment to evaluate its implementation and use in a healthcare organisation.

The HFE specialist can both prospectively and retrospectively assess the structural and process-related factors that contribute to unsafe care; healthcare has a limited understanding of these factors.⁶ If elements of a system and the interactions of these elements are designed using HFE principles and methods, then healthcare processes will improve, resulting in the improvement of healthcare professionals' performance and outcomes.⁷ A straightforward example is the interaction between healthcare providers and medical devices. Devices that are designed using HFE principles could dramatically reduce the over 1 million device-related medical errors that occur annually in the USA.⁸

ROLE IN PATIENT SAFETY

Researchers and patient safety experts recommend the use of HFE principles, theories, tools and methods to

improve patient safety.⁶ In 2005, the Institute of Medicine and the National Academy of Engineering identified HFE as one tool needed to design better healthcare systems.⁹ Yet, healthcare has been slow to incorporate HFE. It is the only high-risk industry in which operators (eg, physicians, nurses), sometimes supported by lawyers and administrators, investigate adverse events and develop solutions without the experts who understand people, systems and how they interact to impact safety. Thus, the top recommendations from these investigations are to 're-educate' staff or warn them to be 'more careful'.

In the commercial aviation and nuclear power industries, safety improvement efforts are led by HFE specialists, who systematically identify safety hazards and develop effective and feasible solutions that fit in the existing work system. The National Transportation Safety Board includes HFE specialists on their accident investigation teams. These experts most often recommend 'designing out' potential human errors rather than re-educating employees or exhorting them to be more careful.

Healthcare organisations can proactively reduce safety risks in their processes and functions using HFE principles, tools and methods. Different medical device brands could undergo test runs (usability testing) to avoid costly purchases of inadequate or unsafe products and reduce device errors. The HFE specialist could apply socio-technical systems theory, principles and methods¹⁰ to identify potential unintended consequences from implementing new technologies so

precautions can be taken. These specialists could apply physical ergonomics to design or redesign a clinical space that shortens the transport time of post-operative patients from the operating room to the intensive care unit, which is a particularly vulnerable time period. They could also identify the underlying causes of communication and teamwork failures and develop and implement effective and practical solutions such as tools/cognitive aids (eg, checklists, shared displays) to improve shared situational awareness and coordination, with the goal of reducing preventable harm. Finally, HFE specialists could guide efforts that teach team-related skills to make providers more effective team members.

Such HFE expertise is an imperative piece of the puzzle in understanding and moving safety improvements forward. Many patient safety improvement efforts involve interventions that were developed with a myopic view, without adequately considering how and whether an intervention would fit with other elements of the care system or lead to unintended consequences. Rather than looking for quick fixes, the healthcare industry needs to realise the importance of incorporating the theories, methods and tools of HFE when designing, implementing and evaluating interventions for achieving significant and sustainable improvements.¹¹ The HFE approach will integrate data from over 50 pieces of electronic equipment in an intensive care unit rather than one or two pieces for example, presenting it in a concise yet information-rich format to improve cognition and collaborative decision-making among clinicians.

When the principles and methods of HFE were applied in healthcare, impressive results were achieved. The Keystone ICU Project used HFE principles and methods and dramatically reduced central line-associated bloodstream infections.¹² For example, the checklist (called a 'cognitive artifact' by HFE specialists) made central line insertion unambiguous and behaviourally specific.¹³ The central line cart made it easy for care providers to comply with the evidence-based insertion guidelines (principle of simplification) and access vital supplies to complete the task (principle of importance). The daily goals sheet put everyone on the same page and improved care¹⁴ and was based on the principle that well designed cognitive artifacts can improve performance by improving situational awareness, communication and coordination among team members.¹⁵ The Comprehensive Unit-based Safety Program emphasised the importance of safety culture in achieving sustainable patient safety improvements. It focused on improving culture at the local unit because culture is local and front-line care providers have critical knowledge concerning safety risks.¹⁶

Nonetheless, patient safety research is interdisciplinary and HFE is just one of many disciplines needed to reduce preventable harm. A HFE specialist with safety expertise can understand and analyse a system in depth to identify potential risks or investigate the causes of adverse events with the goal of designing and implementing effective, feasible and sustainable solutions. Typically, they are not trained in outcomes research. Therefore, they need to collaborate with health services researchers and economists to measure and evaluate the impact of HFE-designed systems on patient safety.

INTEGRATING HUMAN FACTORS AND ERGONOMICS IN PATIENT SAFETY IMPROVEMENT EFFORTS

Healthcare could take the following steps to better incorporate HFE.

Build capacity among current and future healthcare providers and administrators to understand HFE. Few hospitals in the USA have HFE specialists, and few staff members have training to use these principles and methods. Healthcare can increase HFE awareness and skills by:

1. Incorporating a basic patient-safety-oriented HFE course in the education of physicians, nurses, healthcare administrators and other healthcare professionals.
2. Requiring healthcare professionals to undertake a patient safety improvement project that applies the principles and methods of HFE. For example, it could be an assignment for medical students during a required rotation.
3. Designing dual degree programs (MD/masters in HFE, nursing and masters in HFE) to produce a larger pool of skilled patient safety practitioners.
4. Adding HFE workshops and short training programmes to continuing education requirements for clinicians and healthcare administrators. We recently offered a workshop to clinicians at the Johns Hopkins Medical Institutions and received positive feedback from all clinician types, including nurses, physicians, patient safety researchers, administrators and quality improvement specialists.
5. Expanding the master's and doctoral training programmes in HFE with a focus on healthcare systems.

A laudable and encouraging step towards incorporating HFE into healthcare was the inclusion of Systems-Based Practice as a core competency in 2001 by the American Board of Medical Specialties and the Accreditation Council for Graduate Medical Education.¹⁷ Few residency programmes, however, have experts to teach these concepts, and few medical schools have HFE experts among their faculty. These experts are needed alongside

social scientists, health services researchers, and economists to teach the science of healthcare delivery.

Create market forces for manufacturers to produce safer products that incorporate HFE principles and techniques. The most efficient and cost-effective way to reduce technology-related hazards is to design safety into the products themselves. For example, if manufacturers could design lines that make it impossible to connect an epidural catheter with an intravenous catheter (incompatibility by design), then the 'less effective' and more costly in-hospital interventions could be avoided.¹⁸ Although healthcare organisations can individually demand better designed products, such uncoordinated and isolated efforts will likely be insufficient to move market forces or prompt manufacturers to incorporate HFE expertise to design safer products. Healthcare organisations, insurers, regulators and healthcare consumers should partner and demand safer and user-centred product designs that are based on evidence. The Leapfrog Group's efforts to improve safety in intensive care units nationwide could be a model.¹⁹

Substantially increase the number of HFE practitioners in healthcare organisations. While healthcare can significantly benefit from HFE expertise, there are few incentives to hire and use them. Regulatory or market forces could change this. Regulators could mandate that HFE specialists participate in incident investigations and proactive risk assessments. As healthcare reform creates stronger market signals in public reporting and pay for performance, hospitals will have a stronger economic incentive to implement effective and practical solutions that improve safety, and most likely will seek out HFE expertise.

Expand investments in patient safety improvement efforts with HFE. The limited progress in patient safety is perhaps not surprising because many improvement interventions were developed without safety sciences such as HFE. Safety is the property of systems, and healthcare requires a much larger investment in HFE to help solve complex patient safety problems. When science guides the way, safety will improve and costs will decrease.^{14 20}

Increase research collaboration between clinicians, social scientists, health services researchers and HFE researchers. The HFE researcher typically has limited access to healthcare settings and clinician collaborators. Clinicians often have limited time to devote to patient safety improvements. Such collaborations can significantly advance the science and improve patient safety.¹ Our research group created a 'mixing bowl', wherein clinical disciplines and methodological disciplines, including HFE, biostatistics, health services research, economics, epidemiology, sociology, psychology and informatics meet and collaborate on research. Other healthcare organisations could

organise similar interdisciplinary groups and expand cutting-edge research in patient safety.

Although healthcare has embraced the notion that 'safety is a systems problem', it has not fully embraced the need to include HFE experts to improve the system. This is likely one reason for the limited progress in improving patient safety. HFE specialists have improved safety in several industries including commercial aviation, nuclear power, etc. However, improvement has been limited within the areas of medicine. Healthcare must fully embrace HFE to make progress in improving patient safety.

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Competing interests None.

Contributors Dr Gurses is a human factors engineer whose research primarily focuses on patient safety and quality improvement in healthcare. Her expertise includes teamwork/communication and coordination of care, transitions of care, risk analysis, and healthcare working conditions. Dr Ozok is a human-computer interaction expert with a research focus on healthcare technology design and evaluation, and medication adherence among older people. Dr Pronovost is a practicing anaesthesiologist and intensivist, and has extensive experience as a health services researcher. His expertise in the rigorous design, implementation, and evaluation of patient safety and quality improvement research is well known. This article was written as a result of the authors' longstanding interest and collaboration in using human factors and systems engineering to improve patient safety. APG wrote the first draft, AAO and PJP contributed with critical input and providing revisions for the several drafts of the manuscript. APG is guarantor.

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REFERENCES

1. Pronovost PJ, Berenholtz SM, Morlock LL. Is quality of care improving in the UK? *BMJ* 2011;342:c6646.
2. Wachter RM. Patient safety at ten: unmistakable progress, troubling gaps. *Health Aff (Millwood)* 2010;29:165–73.
3. Leape L, Berwick D, Clancy C, et al. Transforming healthcare: a safety imperative. *Qual Saf Health Care* 2009;18:424–8.
4. Office of Inspector General. *Adverse Events in Hospitals: National Incidence Among Medicare Beneficiaries*. Rockville, Maryland: Department of Health and Human Services, 2010. (DHHS publication no. OEI-06-09-00090).
5. International Ergonomics Association. *The Discipline of Ergonomics*. <http://www.iea.cc/> (accessed 12 Oct 2011).
6. Leape LL, Berwick DM, Bates DW. What practices will most improve safety? Evidence-based medicine meets patient safety. *JAMA* 2002;288:501–7.
7. Carayon P, Schoofs Hundt A, Karsh BT, et al. Work system design for patient safety: the SEIPS model. *Qual Saf Health Care* 2006;15: i50–8.

8. Bright RA, Brown SL. Medical device epidemiology. In: Brown SL, Bright RA, Tavris DR, eds. *Medical Device Epidemiology and Surveillance*. England, UK: John Wiley & Sons Ltd, 2007:27.
9. Institute of Medicine. *Building a Better Delivery System: A New Engineering/Health Care Partnership*. Washington, DC: National Academies Press, 2005.
10. Pasmore WA. *Designing Effective Organisations: The Sociotechnical Systems Perspective*. Hoboken, NJ: John Wiley & Sons, 1988.
11. Foy R, Ovretveit J, Shekelle PG, et al. The role of theory in research to develop and evaluate the implementation of patient safety practices. *BMJ Qual Saf* 2011;20:453–9.
12. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006;355:2725–32.
13. Gurses AP, Seidl KL, Vaidya V, et al. Systems ambiguity and guideline compliance: a qualitative study of how intensive care units follow evidence-based guidelines to reduce healthcare-associated infections. *Qual Saf Health Care* 2008;17:351–9.
14. Pronovost P, Berenholtz S, Dorman T, et al. Improving communication in the ICU using daily goals. *J Crit Care* 2003;18:71–5.
15. Hutchins E. How a cockpit remembers its speeds. *Cognitive Sci* 1995;19:265–88.
16. Weick K. Organizational culture as a source of high reliability. *California Manage Rev* 2011;29:112–17.
17. Dyne PL, Strauss RW, Rinnert S. Systems-based practice: the sixth core competency. *Acad Emerg Med* 2002;9:1270–7.
18. Smetzer J, Baker C, Byrne FD, et al. Shaping systems for better behavioral choices: lessons learned from a fatal medication error. *Jt Comm J Qual Patient Saf* 2010;36:152–63.
19. Pronovost PJ, Goeschel CA, Olsen KL, et al. Reducing health care hazards: lessons from the commercial aviation safety team. *Health Aff (Millwood)* 2009;28:w479–89.
20. Neily J, Mills PD, Young-Xu Y, et al. Association between implementation of a medical team training program and surgical mortality. *JAMA* 2010;302:1721–2.

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