DISCUSSION ARTICLE

INTEGRATING PATIENT SAFETY AND CLINICIAN WELLBEING

By Michael R. Privitera, MD, MS, and Kate MacNamee, MS

ABSTRACT: In the dynamic and stressful environment of healthcare, leadership training has not evolved to incorporate the rapid technology advancement with the connectivity and enhanced accountability that has come with it. Hence, there is a gap in leader best practice to account for human adaptation lagging behind technological advances in healthcare. Leadership's basic level understanding of human factors could help prevent or mitigate negative impact from the variety of externally imposed expectations on clinicians that currently drive many hospital leader decisions. The new models proposed here build on traditional safety models of systemic barriers or defenses used in complex systems but integrate a consideration for human factors affecting outcomes. This framework can help leaders more realistically weigh risks and benefits of healthcare initiatives to avoid negative consequences of their decisions.

CLINICIAN BURNOUT EXPRESSES ITSELF AS A complex and dynamic set of symptoms. Those suffering from the condition commonly experience "emotional exhaustion, depersonalization, and a sense of reduced personal accomplishment."[1] Many researchers acknowledge that clinician burnout intersects substantially with patient safety and healthcare quality concerns.[2-5] Despite growing awareness of such a relationship, multiple forces in the healthcare environment such as complex payment systems, nonstrategic regulations, increasing accumulation of occupational expectations, and the conflation of busy work with virtuous work continue to cause, perpetuate, or exacerbate clinicians' burnout.[6,7]

To achieve optimal outcomes and minimize unintended consequences, healthcare leaders must quickly grasp complex concepts from existing scientific literature that are relevant to their potential decision outcomes. However many physician leaders may have little time or training to curate the relevant research or fully understand the implications of findings. New research describes the results of acute and chronic occupational stress in clinicians, including cognitive, physiologic, and neuroanatomical changes.

In this article, we provide a set of translational models[8] that build on traditional safety models of systemic barriers or defenses used in complex systems, but integrate consideration for human factors affecting outcome in conditions that thwart good care. The literature, and thereby the models, illustrate preventable environmental factors that cause high cognitive load, which leads to latent medical errors, negative impact on clinician health with diminished patient safety.

Improving the experience of providing care, seen as human factors in the delivery of care, historically has not been understood by health system decision makers to be as critical as evidence shows it to be. The framework of healthcare delivery reform since 2008 advised focusing on three aims: reduce costs, improve patient experience, and improve quality of care.[9]

Thus, when focusing on this Triple Aim model, it can be difficult for leaders to be sufficiently aware of the dangers posed when policy, regulation, law, or workflow design fail to account for human factors in the delivery of care. This problem is especially true in hospital systems that have a high level of hierarchy and gatekeeping, which discourage access of frontline clinicians to senior leaders, insulating them from care delivery issues.

We propose augmenting current safety models with models that acknowledge the human (*i.e.*, clinician) as part of the broader system at hand, thus accounting for potential cognition-related consequences of implementing a given safety or quality intervention. Inclusion of human-centric models would produce more accurate risk/benefit analyses, reducing the chance of unintended consequences for new initiatives.

After a literature review, we illustrate how two related models can help leaders more rapidly understand the neuropsychological downstream impact involved in the decisions they are required to make by integrating patient safety with clinician wellbeing. These integrative models are composed of

(1) a "Bird's-eye System View" demonstrating the experience of providing care and (2) a detailed "Zoom-in View" illustrating mitigable environmental factors and the complex cognitive process they both catalyze and perpetuate.

The models build upon — and provide broader systemic context for — a widely recognized error assessment tool known as Reason's Swiss Cheese Model.[10,11] The layers of swiss cheese are successive layers of systemic barriers, policies, and other defenses put in place to help prevent error. When the holes in the layers line up (multiple barriers fail), hazards make it through all barriers, and errors occur. However, this Swiss Cheese Model alone includes no built-in consideration of the fact that too many layers or low-quality layers may produce the opposite of the effect intended, thwarting good care by lowering clinician performance and ultimately causing error.

Many national, state, local, and industry mandates require input from hospital leadership as to how those mandates should be implemented. This article is meant to help leaders integrate clinician wellbeing into the calculations and analyses surrounding patient safety. We provide foundational human factors principles to assist leaders in implementation that would be superior to siloed consideration of patient safety or clinician wellbeing alone.[12]

Combined, these two new models detail the relationships among factors involved in balancing patient safety, cost-control initiatives, and clinician wellbeing initiatives. We provide a textual walkthrough of each model and provide examples of ways in which these may be applied in the decision-making process.

LITERATURE REVIEW

Parallels between Mechanical and Organic Systems

When building automobiles and airplanes, engineers must assess the system's operational limits to determine how much heat, cold, speed, air pressure, and other parameters the mechanical system can withstand before it becomes unsafe or breaks down. Operational limits (expectations) of the human brain of healthcare workers can be considered in a similar framework. When human operational limits are exceeded (*e.g.,* too many demands are placed on the individual), breakdowns in performance and wellbeing occur. These breakdowns pose real danger to the clinician and, subsequently, the patient.[13,14]

Problematic aspects of the culture of medicine enable excessive expectations to persist, and they remain largely unaddressed. Busy work is conflated with virtuous work, and concerns — for various reasons — are not sufficiently raised.[15] In clinicians' immediate work environment, they are immersed in a culture where people are pushing themselves to do excessive work. Thus, clinicians' immediate environment invalidates their own feedback system, which signals the danger of high cognitive load and its unsustainable nature.

The Paradox of Clinical Practice Environments

A study at the University of Rochester demonstrated a dose-related (*i.e.*, chronic, incremental) effect of exposure to the clinical healthcare practice environment on burnout prevalence. Job positions with a higher proportion of clinical work had higher burnout rates, yet in the same sample, the factor that provided the greatest sense of meaning was providing patient care.

Although seemingly paradoxical, researchers concluded that the more clinical work an individual performed, the more dose exposure they had to inordinately stressful occupational environments. Participants in the study reported that their stressors included high expectations from systemic or organizational mandates (national/state or industry), leadership's low awareness of the intrusion of clinicians' work life into their home life, electronic medical record design, educational requirements without appropriate time allocated to do them, and difficult workflows.[16] Each of these stressors adds to clinician cognitive load and decreases their ability to cognitively perform at a high level.

These findings suggest that factors and metrics touted as "quality" or "patient safety-related" in total may be thwarting high-quality care when implemented. This leads to clinicians wearing down and burning out over time, through consistent, incremental exposure to occupational stressors and high cognitive load.

Cognitive Load Theory Applied in Healthcare Delivery

Cognitive Load Theory provides useful terminology and framework with which to assess the cognitive resources required of clinicians when delivering care to patients (*intrinsic* and *germane* cognitive load). The theory also describes elements and tasks considered as *extraneous* cognitive load, which can be lessened or removed through better design.[17]

Intrinsic cognitive load (ICL) is the inherent level of difficulty, thought to be an immutable load (*e.g.*, cognitive load needed to diagnose congestive heart failure). Germane cognitive load (GCL) is the load created by efforts associated with creating the mental model of information.

Extraneous cognitive load (ECL) is the mental load imposed by the (lack of) organization of information of a task. ECL can be exemplified in the amount of mental effort needed to understand what is needed to comply with potentially opposing metrics, learning how to navigate software for different sources of computer-based training (CBT), finding out who needs to be notified of adverse events, interrupting clinical work, and determining where to get the time needed to accomplish assigned tasks that exceeded the time allotted.

When ECL increases, it steals limited working memory, reducing humans' ability to attend to complex information required in patient care.[18-20] When neural resources are spent, cognitive flexible memory needed in differential diagnosis and a quality care plan is reduced, and the brain reverts to automatic processes. Automatic thought applied inappropriately (*i.e.*, to the wrong stimulus or at the wrong time) is a key cause of medical error.

In a depleted neural resource condition, *goal shielding* also occurs. This keeps the brain hyper focused on the brain's automatic actions and disallows (shields out) new information from changing course on achieving the goal. This goal-shielding process poses still more risk for clinical error.[21]

Cognitive workload, fatigue, and attentional capacity are some of the human factors considered in work high-reliability sectors such as aviation, nuclear power plants, air traffic control, and others. The stakes in the healthcare industry are equally high. In the airline industry, for example, the Federal Aviation Administration may turn down certain proposed safety procedures because they are foreseen to negatively affect overall pilot performance.[22]

The Impact of Burnout on Clinician Biology

Human cognitive capabilities such memory, attention, and decision-making depend on limited biological resources (*e.g.*, glucose).[23-25] Such cognitive functions are positively correlated with task performance and successful goal completion across multiple paradigms.[26,27] Many of the resources on which cognitive functions depend are depleted during high-stress and chronic-stress situations, lowering overall cognitive performance.[28-30]

Over time, high levels of occupational stress leading to burnout alter neural anatomy, hormone production, and neurotransmitter levels.[31] Notable structural and functional changes include:

- Thinning of the pre-frontal cortex and medial pre-frontal cortex, thereby reducing executive function and decision-making capabilities.[32]
- Enlargement of the amygdala, contributing to increased reactivity to stress.[33]
- Decreased connectivity to anterior cingulate cortex, suggesting decline in emotional distress modulation.[28]
- DNA changes: telomere shortening (cellular aging) six times faster than controls.[34]
- Neurotoxic levels of glutamate release, leading to decreased gray matter in the basal ganglia, decreasing fine-motor control.[28]
- Effects on the hippocampus causing decrease of short-term memory capacity (4–6 weeks of high, chronic stress) and long-term memory capacity (12 weeks of high, chronic stress).[22,31,35]

Each of these neurocognitive changes negatively affects clinicians' ability to perform the tasks required to provide patients with optimal care.

The higher the severity of burnout from excessive cognitive load, the higher the risk of that individual having a major depressive disorder, which further hinders performance potential.[35,36] Recent research has outlined cognitive impairments with major depressive disorder to include problems with[37]:

- Attention.
- Verbal and nonverbal learning.
- Short-term and working memory.
- Visual and auditory processing.
- Problem solving.
- Processing speed.
- Motor functioning.

Decreased quality of any of these functions can lower a clinician's ability to provide adequate care to patients and can increase risk of error.

In many cases, ease of usability and the application of human factors science are tightly linked. Research strongly suggests that cognitive load created by workflow impairment is counterproductive to patient safety.[38,13] Nuanced understanding and balance between safety metrics and human limitations is required to optimize patient care and improve patient outcomes.

A Way Out: Good Leadership at All Levels

Most incidents in healthcare occur due to systemic, latent errors, as delineated in the IOM report of 2000.[39] Efforts to address latent errors by identifying the upstream factors and taking a human factors approach have been well documented as a viable and effective means of risk mitigation.[3,39] In particular, identifying how systemic decisions affect cognitive workload downstream is extremely relevant when working to identify latent conditions that cause acute stress and error.

Administrators and managers could apply this human-centered approach to problem solving by understanding basic mechanisms of human limitations to ascertain the "root cause" of incidents. Identifying the root cause is important because it allows identification of optimal mitigation strategies to avoid incidents in the future.

Participants in one institution's experience with teaching leaders adapted human factor science, called human factor based leadership (HFBL), deemed that approximately 90 percent of the material taught was useful for healthcare leaders, and 100 percent of the leaders (21/21) reported that the content taught would substantially reduce latent error and burnout in clinicians.[14]

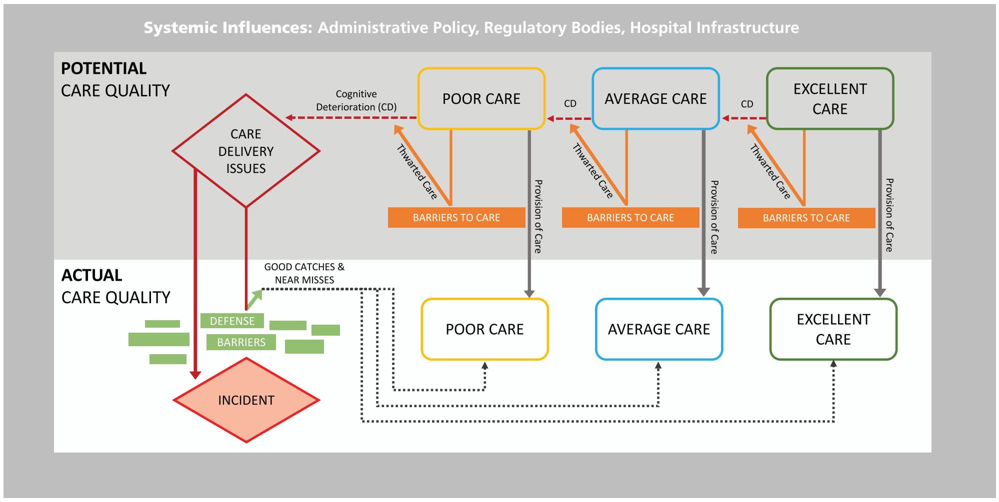
Most often, leaders may identify money, space, equipment, or personnel as limited resources in healthcare delivery. A key desired outcome of applying the proposed models is to expand concepts of limited resources to include the limited neural/cognitive resource (brainpower) of highly trained clinicians. Needless expenditure of clinician neural resource is unsafe for patients and unsafe for the clinicians doing the work; therefore, it makes operational sense that neural resources must also be budgeted.[40,18]

INTEGRATED MODELS: STRUCTURE AND APPLICATION

The integrative models for patient safety and clinician wellbeing are visual summaries of existing literature that convey the mechanisms of how high occupational stress and burnout affect the individual, the healthcare ecosystem, and patients the clinicians see.[2,6]

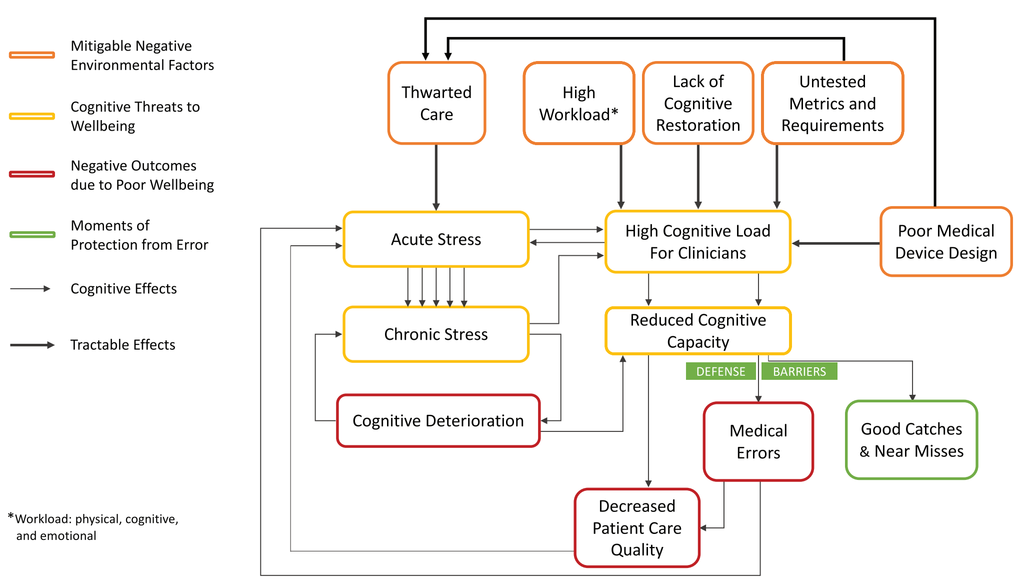
Figure 1 represents a broader view as to how factors can have biopsychosocial effects on the clinician that devolve the capacity of the care they can give. Figure 2 is a zoom-in on a section of Figure 1 that focuses on the clinician brain and the "downward spiral" relationship between cognitive load and clinical error.

FIGURE 1: "BIRDS-EYE" SYSTEM VIEW OF THE EXPERIENCE OF PROVIDING CARE AND ITS RELATIONSHIP TO CARE QUALITY



Systemic Influences: Can create positive conditions for safety and quality or latent conditions for error and burnout.
Care Delivery Issues: Errors, unsafe acts, and violations that may lead to harm.
Thwarted Care: Excessive interruptions, hard stops, poor usability of EMR and other medical devices, poor workflows, excessive mandates, unproven quality metrics or regulations, insurance care denials.
Defense Barriers: Well-designed, judicious use of error and violation detection to prevent patient harm.
Good Catch: An error or violation detected before it resulted in harm.
Near Miss: An error that, given a slight change in circumstance, would result in harm.

FIGURE 2: "ZOOM-IN VIEW." COMPOUNDING EFFECTS OF NEGATIVE ENVIRONMENTAL FACTORS ON COGNITIVE LOAD, CLINICIAN WELLBEING, AND PATIENT OUTCOMES



Systemic contributions either can create positive conditions for good quality care or create latent conditions that contribute to active error and burnout downstream at the point of care. In the models, acute ECL can lead to error; moreover, when these ECL factors become chronic, the clinician must regularly expend brainpower to compensate for deficits in design. This creates conditions that lead to physiological changes to neural structure and function resulting in burnout.

A clinician may begin with the potential to give excellent quality of care. If he or she continues to be exposed to toxic factors that thwart care, neuroanatomic and functional changes create cognitive deterioration that decreases the capacity to give high-quality care. Having to do work-related work outside of their work time (*e.g.*, regularly finishing clinical documentation at home) prevents physical and cognitive restoration and the emotional restoration of having a life outside of medicine.

We illustrate the barriers to providing care using the same shape as good defense barriers (but different colors), to illustrate that proposed procedures, mandates, laws, policies, or even insurance cost-control methods may appear to be good barriers; however, because they are excessive, non-evidenced based, and/or nonstrategic in their use, they drastically affect workflows and acute or chronic overwhelm occurs. These models illustrate the critical need to differentiate a good defense barrier from a care-thwarting barrier.

TABLE 1: TRACTABLE OCCUPATIONAL STRESSORS THAT LEAD TO BURNOUT

Excessive physical work
Excessive cognitive work
Excessive emotional work
Lack of control or input
Poor balance of effort and reward
Lack of community
Lack of fairness/transparency
Conflicting values

APPLYING THE MODELS IN HEALTHCARE FACILITIES

Table 1 outlines the categories of occupational stress that contribute to burnout, as determined by Maslach and Leiter.[41]

Table 2 summarizes demanding scenarios that needlessly expend available neural (brain) resources, which could be more deliberately budgeted such that they are most frequently allocated during clinical encounters with patients.[13,14,18-20,23,24,36] Table 2 also provides examples of human-centered interventions that could decrease ECL, thereby reducing burnout and increasing patient safety and quality care.

DISCUSSION

Incorporating human factor/ergonomic (HFE) science in decision making empowers leaders to find solutions that can achieve optimized healthcare delivery performance while preserving the wellbeing of the healthcare worker.

Patient safety is one component of optimized system performance. Being aware of the impact of HFE science is a first

TABLE 2: EXAMPLES OF COGNITIVELY EXPENSIVE PHENOMENA, THEIR DEFINITIONS, WHEN THEY MIGHT ARISE IN HEALTHCARE, AND HOW TO AVOID NEEDLESS RESOURCE SPENDING

"Expensive" Cognitive Activity	Definition of Expensive Activity	Situation(s) Forcing Expensive Activity	Solution(s) to Avoid Expensive Activity
Extraneous information processing	Responding to or processing information unrelated to primary diagnostic or procedural goals.	Required screening questions are unrelated to the patient's reason for their visit.	Enter patient data via website or waiting room to help save clinician cognitive resource for key clinical issue.
Unintuitive interface navigation	Resolving conflict between expectation and outcome, regulating frustration, working through confusion and ambiguity.	Medical device not purposefully designed, requires large number of disjointed actions to achieve goals.	Create multiple pathways for clinician input on technology design, workflow problems and purchasing decisions (*e.g.* Provider Advisory Council or PAC). Clinician builder program to collaborate with non-clinician builders to optimize architecture and workflows.
Goal maintenance and working memory	Maintaining and manipulating information in your head while performing other tasks.	Software design requires multiple pages and pop-ups to complete task. ——— Clinical data stored in unintuitive locations.	Implement software with dashboards that create action pathways accessible from a single location. Health information management team in direct collaboration with active clinician team to negotiate best location or best labeling of clinical data stored in EMR.
Controlled processing	Cognitive functions associate with paying attention, filtering, and organizing.	Poorly labeled storage systems for ancillary tools requiring hunting through storage that is without schema or order.	Organize storage by tool type, brand, models, etc. Label the outside of drawers/containers to prevent the need to open them during search.

TABLE 2: EXAMPLES OF COGNITIVELY EXPENSIVE PHENOMENA, THEIR DEFINITIONS, WHEN THEY MIGHT ARISE IN HEALTHCARE, AND HOW TO AVOID NEEDLESS RESOURCE SPENDING (*CONTINUED*)

"Expensive" Cognitive Activity	Definition of Expensive Activity	Situation(s) Forcing Expensive Activity	Solution(s) to Avoid Expensive Activity
Multitasking/ Interruptions	Attempting to perform two tasks in parallel, resulting in rapid switching between tasks, and decreasing either accuracy or efficiency.	Nurse interrupted passing meds. ____ Clinicians asked non-urgent question from other during procedures.	Nursing medication room policy implemented to prevent intrusions. ____ System implemented to ensure pended questions for clinician to be addressed between tasks or cases.
Inhibition and self-control	The brain self-regulating, making an effort to prevent unwanted signals from becoming behavior. Emotion may be triggered but need to stay logical and on task.	Patient or family member threatening toward clinician. ____ Series of many patients with severe injury or illness.	Close collaboration with Public Safety or Security team coupled with de-escalation training to empower clinician to avoid further violence. ____ Establish formal culture of esprit de corps, clinicians supporting each other tangibly, emotionally, and informationally.
Emotional labor	Regulating one's own emotions while also counseling grieving families or anxious patients.	Death in Operating Room, next case wheeled in. Giving support to grieving families.	Establish debriefing routines (provide effective communication framework), create peer support groups, build institutional culture of expecting clinician to be able to take a break to recuperate.
Prioritization	The act of determining the importance and value of one or more elements compared to a series of others. Requires deep engagement with concepts/material.	Busywork conflated with virtuous work expected in the calling of going into Medicine.	Acknowledge halo bias on how some requirements may need to be done and termed safety related, but not to lose big picture on what is foremost importance. Leaders and clinicians cooperate to identify effective and ineffective metrics. Organize the increasing number of educational mandates in one place to keep track of total mandatory load. Determine what is satisfactory and sufficient to meet requirement, then other material as voluntary if clinician interested to learn more. Consider enduring material repository to call up information when clinically needed. Employ human factors experts as part of full-time hospital staff or as consultants collaboratively with clinicians.
High stimulus density	Constant information processing and constant need to respond to people or the environment.	Shortened patient visits to increase through-put, push for high Relative Value Units (RVUs) in clinical time.	Leadership work with clinicians to create 'credit' for all missions of the institution: Teaching, patient care, research. Hire additional staff to increase patient volumes, rather than increase load of current staff.
Negative transfer	Incorporating previously learned behaviors while learning new procedures.	Hospital purchased IV pumps from multiple vendors, and key elements of their interfaces conflict.	Standardization of IV pump equipment across the institution. Participatory management for clinician input into device purchasing.
Lack of cognitive restoration	An individual is unable to eat, sleep, or create a restorative cognitive environment between draining events, leaving them less equipped to perform at their peak during the second of the two events.	Writing clinical notes in the evening or on weekends when home, unable to engage with significant other, children, friends or hobbies. ____ Maintenance of Certification (MOC) requirements that require activities over and above what occurs in daily clinical practice.	Implement culture change campaign explicitly discouraging work outside of work. Work with risk management, billing, compliance, and patient wafety efforts to eliminate "note bloat" which adds no clinical value to documentation. ____ As an institution, coordinate activities that count for MOC requirements for conservation of energy, economy of scale.

step in thinking through needed solutions. This is especially relevant today when many forces and agencies have a voice in healthcare delivery by affecting financial viability, regulation, and accreditation, yet in ways that do not harmonize with each other's requirements. Disjointed implementations and initiatives at the hospital level can amplify chaos that trickles down to healthcare workers who need to comply.

Being more aware of HFE concepts can illuminate what was invisible to clinicians and administrators, although they knew something was wrong. It also illuminates the factors that are creating burnout and latent conditions for medical error.

For example, clinicians must comply with the numerous mandatory education requirements that come from a variety of authoritative sources. Institutions can organize the education requirements so they are easily accessible in one place. In the face of limited time and cognitive resource, clinicians can make better decisions regarding what content is necessary and sufficient to meet requirements and what content they can have available on a voluntarily basis to harness their intrinsic desire to improve themselves when time is available. In addition, material can be developed that can serve as a helpful resource for clinicians in their care of patients, to be called up when needed.

Using HFE concepts it becomes clear that too many interruptions, like best practice alerts (BPAs) in the electronic medical record, need to be strategically thought through as to whether the risk of the interruption may be greater than the safety factor to which intended attention is called. Calling attention to an issue is less cognitively taxing than demanding attention to an issue.[42] Attention to safety issues may be called out without creating hard stops where all other activity must cease to address the issue raised in a best practice alert. More creative solutions can satisfy safety concerns while preserving wellbeing and optimal performance of clinicians.

CONCLUSION

The proposed integrated models raise awareness of the nuanced but profound factors previously not incorporated into most healthcare decision-making models. Scientific literature has already identified the need to train leaders regarding the importance of finding solutions to the current environment of over-expectation and cognitive over-exertion.

Using these models, leaders at all levels of the healthcare ecosystem can better grasp their role in mitigating the deleterious effects of the care environment on clinician cognition and help create better working systems in their institutions. Doing so integrates patient safety with clinician wellbeing, creating the necessary conditions for clinicians to provide their patients with excellent care.

When understood from the dimensions of human factors science, the Quadruple Aim framework of costs, population health, quality patient experience, and clinician experience of providing care[43,44] would help national, state, industry, C-Suite and other healthcare decision makers incorporate consideration of human strengths and limitations when creating new initiatives, rollouts, technical advances, mandates, laws, and regulations.

Michael R. Privitera, MD, MS, is professor of psychiatry and medical director of the Medical Faculty and Clinical Wellness Program at the University of Rochester Medical Center (URMC). He has written for The Joint Commission, the American Hospital Association, National Patient Safety Foundation, Medscape, the *Journal of Hospital Administration* and the *Journal of Legal Medicine* on physician burnout.
Michael_Privitera@URMC.Rochester.edu

Kate MacNamee, MS, is director of design research at Ximedica.
KMacNamee@Ximedica.com

REFERENCES

1. Bianchi R, Schonfeld IS. Defining Physician Burnout, and Differentiating Between Burnout and Depression—I. *Mayo Clin Proc.* 2017; *92*(9):1455.
2. Salyers M, Bonfils K, Luther L, Firmin R, *et al*. The Relationship Between Professional Burnout and Quality and Safety in Healthcare: A Meta-Analysis. *J Gen Intern Med*. 2017;32(4):475-82.
3. Privitera MR, Plessow F, Rosenstein AH. Burnout as a Safety Issue: How Physician Cognitive Workload Impacts Care. National Patient Safety Foundation e-News. August 24, 2015. http://npsf.site-ym.com/blogpost/1158873/224974/Burnout-as-a-Safety-Issue--How-Physician-Cognitive-Workload-Impacts-Care
4. Lyndon A. Burnout Among Health Professionals and Its Effect on Patient Safety. AHRQ PS Net. Perspectives on Safety. February 2016.
5. Wallace JE, Lemaire JB, Ghali WA. Physician Wellness: A Missing Quality Indicator. *Lancet*. 2009;374(9702):1714-21.
6. Privitera MR. Addressing Human Factors in Burnout and the Delivery of Healthcare: Quality & Safety Imperative of the Quadruple Aim. *Health*. 2018;10(05):629-44.
7. Sinsky CA, Privitera MR. Creating a Manageable Cockpit for Clinicians: A Shared Responsibility. *JAMA IM*. 2018;178(6):741-42.
8. Privitera MR, Bowen B, Bowie V. Translational Models of Workplace Violence in Healthcare. *Violence Vict*. 2015;30(2):293-307.
9. Berwick DM, Nolan TW, Whittington J. The Triple Aim: Care, Health And Cost. *Health Aff (Millwood).* 2008 May-Jun; 27(3):759-69. doi: 10.1377/hlthaff.27.3.759
10. Reason, J. *Managing the Risks of Organizational Accidents.* Burlington, VT: Ashgate Publishing; 1997.
11. Reason J. Human Error: Models and Management. *BMG*. 2000;320(7237):768-70.
12. Martin R. How Successful Leaders Think. *Harv Bus Rev.* 2007;85(6):60-67.
13. Privitera MR, Plessow F, Rosenstein AH. Burnout as a Safety Issue: How Physician Cognitive Workload Impacts Care. *National Patient Safety Foundation e-News.* August 24, 2015 http://npsf.site-ym.com/blogpost/1158873/224974/Burnout-as-a-Safety-Issue--How-Physician-Cognitive-Workload-Impacts-Care
14. Arnsten AFT. The Biology of Being Frazzled. *Science*. 1998;280(5370):1711-12.
15. Shanafelt TD, Schein E. *et al*. Healing the Professional Culture of Medicine. *Mayo Clin Proc*. 2019;94(8):1556-66.

16. Anandarajah A, Quill T, Privitera MR. Adopting the Quadruple Aim. The University of Rochester Medical Center Experience. Moving from Physician Burnout to Physician Resilience. *Am J Med*. 2018;131(8):979-86.

17. Sweller J. Cognitive Load During Problem Solving: Effects on Learning, *Cognitive Science*. 1988;12:257-85.

18. Rock D. *Your Brain At Work. Strategies for Overcoming Distraction, Regaining Focus and Working Smarter All Day Long*. NY: Harper Collins; 2009.

19. Plessow F, Schade S, Kirschbaum C, Fischer R. Better Not to Deal with Two Tasks at the Same Time When Stressed? Acute Psychosocial Stress Reduces Task Shielding in Dual-Task Performance. *Cogn Affect Behav Neurosci*. 2012;12:557-70. https://doi.org/10.3758/s13415-012-0098-6.

20. Muraven M, Baumeister RF. Self-Regulation and Depletion of Limited Resources: Does Self Control Resemble a Muscle? *Psychol Bull*. 2000;126(2):247-59. https://doi.org/10.1037/0033-2909.126.2.247

21. Plessow F, Fischer R, Kirschbaum C, Goschke T. Inflexibility Focused under Stress: Acute Psychosocial Stress Increases Shielding of Action Goals at the Expense of Reduced Cognitive Flexibility with Increasing Time Lag to Stressor. *J Cogn Neurosci*. 2011;23(11):3218-27. https://doi.org/10.1162/jocn_a_00024

22. US Code of Federal Regulations. Flight crewmember duties. 2014. 14 CFR §121.542.

23. Vohs KD, Baumeister RF, Schmeichel B, Twenge JM, *et al*. Making Choices Impairs Subsequent Self-control: A Limited Resource Account of Decision-making, Self-regulation, and Active Initiative. *J Pers Soc Psychol*. 2008;94(5): 883-898.

24. Gold PE. Role of Glucose in Regulating the Brain and Cognition. *Am J Clin Nutr.* 1995;61(4 Suppl):987S–95S.

25. Benton D, Parker PY. Breakfast, Blood Glucose, and Cognition. *Am J Clin Nutr.* 1998;67(4 Suppl):772S–78S.

26. Kane MJ, Engle RW. Working-memory Capacity and the Control of Attention: The Contributions of Goal Neglect, Response Competition, and Task Set to Stroop Interference. *J Exp Psychol Gen*. 2003;132(1):47-70.

27. McVay JC, Kane MJ. Conducting the Train of Thought: Working Memory Capacity, Goal Neglect, and Mind Wandering in an Executive-control Task. *J Exp Psychol*: *Learn, Mem, Cogn*. 2009;35(1):196-204.

28. Alkadhi K. Brain Physiology and Pathophysiology in Mental Stress. *International Scholarly Research Notices*, vol. 2013, Article ID 806104, 23 pages.

29. Diamond A. Executive Functions. *Annu. Rev. Psychol*. 2013;64:135-68.

30. Deligkaris P, Panagopoulou E, Montgomery AJ, Masoura E. Job Burnout and Cognitive Functioning: A Systematic Review. *Work & Stress;* 2014;28(2):107-23.

31. Michel A. Burnout and the Brain. (February 2016) *Observer*. 2016;29(2). www.psychologicalscience.org/index.php/publications/observer/2016 /february-16/burnout-and-the-brain.html.

32. Savic I. Structural Changes of the Brain in Relation to Occupational Stress. *Cerebral Cortex. 2015;25*:1554–64. doi:10.1093/cercor/bht348.

33. Golkar A, Johansson E, Kasahara M, *et al*. The Influence of Work-related Chronic Stress on the Regulation of Emotion and Functional Connectivity in the Brain. *PLoS One*. 2014;9(9): e104550. doi:10.1371/journal.pone.0104550.

34. Rideout KK, Ridout SJ, Guille C, Mata DA, *et al*. Physician Training Stress and Accelerated Cellular Aging. *Biol Psychiatry*. 2019;86(9):725-30. doi: 10.1016/j.biopsych.2019.04.030.

35. Wurm W, Vogel K, Holl A, *et al.* Depression-burnout Overlap in Physicians. *PLoS One.* 2016;11:e0149913.

36. Ahola K, Hakanen J, Perhoniemi R, Mutanen P. Relationship between Burnout and Depressive Symptoms: A Study Using the Person-centered Approach. *Burn Res*. 2014;1:29-37.

37. Ramsey D. Depression Related Cognitive Dysfunction. *Medscape*. August 26, 2019.

38. Franconeri SL, Alvarez GA, Cavanagh P. Flexible Cognitive Resources: Competitive Content Maps for Attention and Memory. *Trends in Cognitive Sciences.* 2013;17(3):134-41.

39. Kohn LT, Corrigan J, Donaldson MS. *To Err Is Human: Building a Safer Health System*. Washington, DC: National Academy of Sciences; 2000.

40. Levitin DJ. *The Organized Mind. Thinking Straight in the Age of Information Overload*. New York: Penguin Random House LLC; 2014.

41. Maslach C, Leiter MP. *The Truth about Burnout: How Organizations Cause Personal Stress and What to Do About It*. San Francisco: Jossey-Bass; 1997.

42. MacNamee K. Analysis: A Neurocognitive Approach to Developing Safer Medical Devices. *Biomed Instrum Technol.* 2020;54(1):28-36.

43. Bodenheimer T, Sinsky CA. From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider. *Ann Fam Med.* 2014;12(6):573-76. doi: 10.1370/afm.1713.

44. Sikka R, Morath JM, Leape L. The Quadruple Aim: Care, Health, Cost and Meaning in Work. *BMJ Qual Saf.* 2015;24:608–610.