

Frontiers of Improvement

# Human factors and ergonomics systems approach to the COVID-19 healthcare crisis

PASCALE CARAYON<sup>1</sup> and SHAWNA PERRY<sup>2</sup>

<sup>1</sup>Leon and Elizabeth Janssen Professor in the College of Engineering, Department of Industrial & Systems Engineering, Director of the Wisconsin Institute for Healthcare Systems Engineering; University of Wisconsin-Madison, 1550 Engineering Drive, Madison, WI 53705, USA, and <sup>2</sup>Associate Professor, Emergency Medicine, University of Florida Honorary Researcher, Center for Quality and Productivity Improvement (CPQI), College of Engineering, University of Wisconsin-Madison College of Medicine-Jacksonville, 655 8th St W, Jacksonville, FL 32209, USA

Address reprint requests to: Pascale Carayon, PhD, Leon and Elizabeth Janssen Professor in the College of Engineering, Department of Industrial & Systems Engineering, Director of the Wisconsin Institute for Healthcare Systems Engineering, University of Wisconsin-Madison, 3126 Engineering Centers Building, 1550 Engineering Drive, Madison, WI, 53706, USA. Tel: +1-608-265-0503; E-mail: [pcarayon@wisc.edu](mailto:pcarayon@wisc.edu)

Received 2 July 2020; Editorial Decision 24 August 2020; Revised 20 August 2020; Accepted 1 September 2020

## Abstract

A human factors and ergonomics (HFE) systems approach offers a model for adjusting work systems and care processes in response to a healthcare crisis such as COVID-19. Using the Systems Engineering Initiative for Patient Safety (SEIPS) model of work system and patient safety, we describe various work system barriers and facilitators experienced by healthcare workers during the COVID-19 crisis. We propose a set of five principles based on this HFE systems approach related to novel pandemic: (i) deferring to local expertise, (ii) facilitating adaptive behaviors, (iii) enhancing interactions between system elements and levels along the patient journey, (iv) re-purposing existing processes and (v) encouraging dynamic continuous learning.

**Key words:** human factors, ergonomics, workforce and workload, systems approach, resilience, patient safety, COVID-19

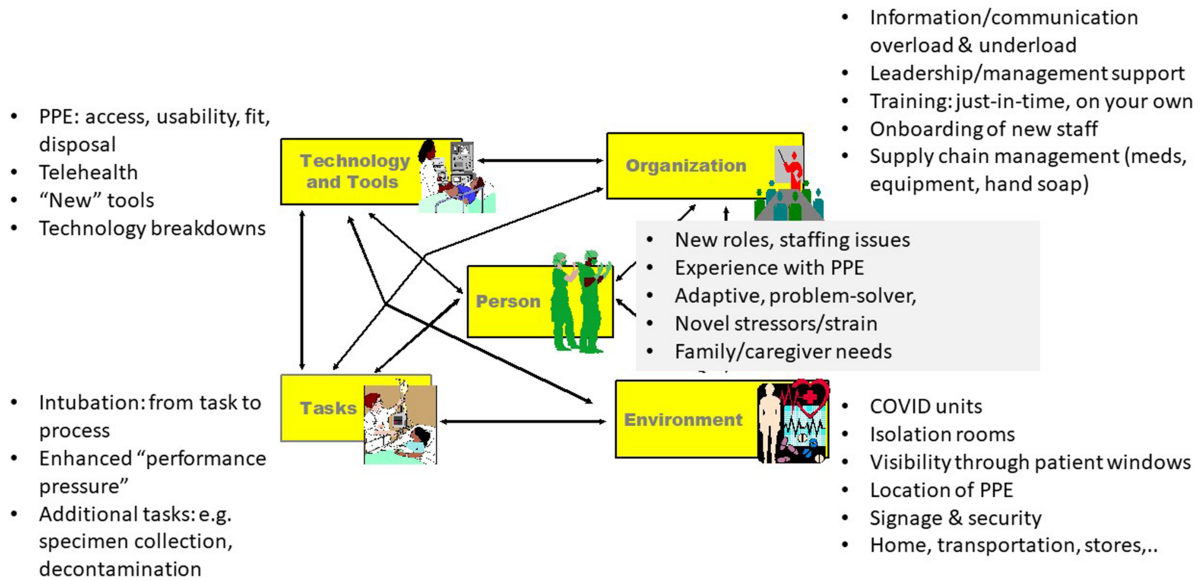
## Introduction

The COVID-19 pandemic is challenging healthcare organizations and their workers around the world. Healthcare workers, in particular those on the frontline, have experienced dramatic changes in their daily routine work as a result of the novel SARS-CoV-2 virus and its evolving presentations and associated risk. This has been compounded by a lack of (or limited) physical, technical, organizational and psychological resources to respond to unexpected disruptions precipitated with COVID-19, the disease, and the associated global pandemic. The remarkable degree of variance in work ‘pre-COVID-19’ and ‘post-COVID-19’ has had a negative impact upon healthcare workers, especially regarding their ability to provide high-quality safe care and their mental and physical health while attempting to cope with a continually changing clinical landscape [1]. The human factors and ergonomics (HFE) discipline can provide approaches and methods for analyzing and addressing these challenges in a systematic

manner. In this paper, we use an HFE systems approach, i.e. the Systems Engineering Initiative for Patient Safety (SEIPS) model [2, 3], to describe some of the work system barriers and facilitators experienced by healthcare workers and to suggest a range of HFE-based principles for moving forward with healthcare system improvement.

## Work system barriers and facilitators in COVID-19 healthcare context

The SEIPS model of work system and patient safety [2, 3] has been demonstrated to be useful within healthcare as a frame for identifying the variety of work system barriers and facilitators experienced by healthcare workers, such as tele-intensive care unit nurses [4] and healthcare professionals involved in pediatric trauma care [5]. Barriers and facilitators can be found in any of the elements of the work system and either hinder or support the ability of workers to



**Figure 1** Work system barriers and facilitators in COVID-19.

do their job. Based on data from the emerging literature, workplace stories, social media and personal experiences, we identified a range of work system barriers and facilitators within the COVID-19 healthcare context (see Figure 1). In Figure 1, the work system barriers and facilitators are associated with each of the ‘five work system elements’: the ‘people’ (at the center of the work system), ‘tasks,’ ‘tools and technology,’ ‘physical environment’ and ‘organizational context.’ Some of these factors are clearly identified as barriers, such as information overload and underload, and breakdowns of existing technology. Other factors could be either a barrier or a facilitator depending on their characteristics, stance with regard to context (Decision X has administrative benefit but increases clinical workload), and methods of implementation, such as leadership/management communication and support. It is also important to emphasize that these work system barriers and facilitators are interconnected. For instance, ease of visualization of COVID-19 patients and their monitors through windows or clear doors could reduce the number of times nurses enter a patient room, with added benefit of reducing viral spread and utilization of scarce PPE (personal protective equipment) materials. This simple example demonstrates the interdependencies of ‘people’ (clinical workers/patients), ‘environment’ (glass doors/windows) and ‘technology/tools’ (monitors, PPE materials) within a work system. The SEIPS model provides a frame from which to begin to elucidate ‘hard to see’ features of health care, a very complex system, under inordinate and unexpected pressure during the COVID-19 pandemic.

It is important to recognize that the healthcare work system has become more dynamic than it was ‘pre-COVID-19,’ as knowledge about the nature of the virus, methods for its diagnosis and treatment constantly evolve. This has resulted in barriers and facilitators for work constantly changing and evolving at a rapid pace that has surprisingly been day-to-day (e.g. surges in infection rates, limited hospital capacity for admissions, supply and demand for testing and PPE materials). Healthcare workers have exhibited an amazing ability to adapt and learn from the ever changing conditions and constraints within their work system, in line with the concept of ‘resilience engineering’ and the ‘Safety II model’ [6]. For example, when faced with growing shortages of PPE, healthcare workers have devised methods for reducing the number of entries into rooms of

hospitalized COVID-19 patients by moving infusion pumps outside of the room for easier access. Adaptive behaviors such as this are positive local work-arounds aimed at supporting high-quality safe care during previously unheard-of system pressures. Understanding and learning from these types of work-arounds is critical as they are often potential solutions to complex problems [7].

### HFE systems approach to COVID-19

We suggest that an HFE systems approach to COVID-19 (and future pandemics and health crises) should be based on five principles: (i) deferring to local expertise, (ii) facilitating adaptive behaviors, (iii) enhancing interactions between system elements and levels along the patient journey, (iv) re-purposing existing processes and (v) encouraging dynamic continuous learning.

#### Local expertise

As with all work systems, healthcare work has barriers and facilitators. Unique work system barriers and facilitators will emerge as all systems are dynamic. In the context of the COVID-19 pandemic, the crisis has further exacerbated this feature (see Figure 1 for examples of work system barriers and facilitators). These barriers and facilitators often manifest as the outcome of organizational decisions from within healthcare organizations and various components of their external environments, e.g. leaders and supervisors of healthcare organizations, designers of equipment and technology and regulatory agencies. It is critical to understand the linkages between these decisions and the work system barriers and facilitators experienced within local contexts of healthcare workers. This can help to ensure that frontline workers have adequate control and resources to react to changing circumstances. This calls for ‘deference to local expertise,’ and requires dialogue with those on the frontline of clinical work [8].

#### Adaptive behaviors

Figuring out how to design, implement, evaluate and redesign care processes under novel disruptions to a work system is critical for rapidly evolving contexts. The COVID-19 crisis is characterized by multiple, rapid changes in processes, procedures, criteria for

diagnosis and recommendations for treatment. The rapid design–implementation–redesign process required needs to consider the actual ‘real-time’ work of healthcare workers facing the crisis day to day. Successful, sustainable changes in care processes cannot be based on what we ‘think’ they are doing, but what they ‘are’ actually doing [9]. Adaptive behaviors of healthcare workers are very useful sources of information about the creative ways they go about meeting the goals for their work. We need to support sharing such behaviors and learning from them.

### Enhancing system interactions

In addition to ensuring that individual system elements are well-designed, we must pay attention to how the various elements fit together; ‘this is the essence of the HFE systems approach.’ As described above, working through COVID-19 has spotlighted the interdependency of multiple elements of the work system: PPE, ventilators, monitoring equipment, staffing, work environment, etc. (see Figure 1). Acknowledging system interactions should be a priority, with an emphasis on enhancing work between connected work systems. This is even more important as we cope with COVID-19 and its impact on the clinical work for other types of patients. For instance, how do we support the safe journey of patients from an emergency department to an intensive care unit; or from the hospital to a long-term rehabilitation facility, each caring for a variety of non-COVID-19 patients as well?

### Re-purposing processes

In a crisis such as COVID-19, healthcare organizations need to have structures and processes that facilitate communication and information flow in all directions. Existing processes and mechanisms can be quickly re-purposed in order to ensure that information about work system barriers and facilitators is quickly captured and addressed. For instance, daily huddles for safety can support quick dissemination about important information, e.g. evolving diagnostic criteria for COVID-19. Nontraditional platforms can also be conduits for communication; for example, Twitter, local webinars, electronic bulletin boards, etc.

### Dynamic continuous learning

As ‘no crisis should go to waste,’ healthcare organizations need to institute short- and long-term learning processes. The COVID-19 crisis has exposed many weaknesses in the way healthcare work systems are designed, and its variety of barriers experienced by healthcare workers. As highlighted in the first four principles described, dynamic continuous learning about the response of healthcare work

systems to the COVID-19 pandemic must occur in real-time and not once it has passed. As the global system of healthcare struggles to adjust to its ‘new normal’ related to the SARS-CoV-2 virus, healthcare organizations must establish multidisciplinary committees charged to design greater adaptive capacity for their work systems [10]. The overarching goal for this redesign should be resilient health care that can quickly respond to perturbations and disruptions to clinical work [6]. Specific emphasis should be given to understanding the extemporaneous adaptive responses currently occurring within their systems during the COVID-19 pandemic. This is valuable for informing the development of new adaptive processes and recommendations for the future. An HFE systems approach such as the SEIPS model and the inclusion of experts in HFE and safety sciences will also be required.

### Funding

The papers were funded by ISQua. This publication was partially supported by the Clinical and Translational Science Award (CTSA) program, through the NIH National Center for Advancing Translational Sciences (NCATS), grant UL1TR002373. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

### References

1. Lai J, Ma S, Wang Y *et al.* Factors associated with mental health outcomes among health care workers exposed to coronavirus disease 2019. *JAMA Network Open* 2020;3:e203976-e.
2. Carayon P, Hundt AS, Karsh B-T *et al.* Work system design for patient safety: the SEIPS model. *Qual Saf Health Care* 2006;15:i50-i8.
3. Carayon P, Wetterneck TB, Rivera-Rodriguez AJ *et al.* Human factors systems approach to healthcare quality and patient safety. *Appl Ergon* 2014;45:14–25.
4. Hoonakker PL, Carayon P, McGuire K *et al.* Motivation and job satisfaction of tele-ICU nurses. *J Crit Care* 2013;28:315e13-e21.
5. Wooldridge AR, Carayon P, Hoonakker P *et al.* Work system barriers and facilitators in inpatient care transitions of pediatric trauma patients. *Appl Ergon* 2020;85:103059.
6. Hollnagel E, Wears RL, Braithwaite J. *From safety-I to safety-II: A White Paper*. The Resilient Health Care Net; University of Southern Denmark; University of Florida: USA; Macquarie University: Australia, 2015.
7. Perry SJ, Wears RL. Underground adaptations: case studies from health care. *Cognition, Technol Work* 2012;14:253–60.
8. Weick KE, Sutcliffe KM. *Managing the Unexpected: assuring High Performance in an Age of Complexity*. Jossey-Bass: San Francisco, CA, 2001.
9. Leplat J. Error analysis, instrument and object of task analysis. *Ergon* 1989;32:813–22.
10. The Lancet. No more normal. *The Lancet* 2020;396:143.