# Improving Safety: What are Leverage Points from a Macrocognition Perspective?

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**ABSTRACT**

Researchers and domain practitioners have identified five macrocognition functions that abstractly characterize work in complex domains: *detecting problems, sensemaking, re-planning, deciding,* and *coordinating*. To date, these functions have primarily provided a broad conceptual lens to aid in the description and thematic analysis of overwhelming, messy, inter-related observational and interview data from the cognitive field research. There is increasing interest in identifying how a macrocognition perspective enables the pursuit of promising leverage points for improving safety in complex, sociotechnical domains by taking advantage of the growing knowledge base without first having to conduct field research. In this panel, we will describe five perspectives on how this can be accomplished, and discuss potential implications for emerging principles and theoretical frameworks that can accelerate safety efforts across domains.

**KEYWORDS**

*Research; Cognitive Task Analysis; Sensemaking; Uncertainty Management; Health.*

## INTRODUCTION

Macrocognitive work systems are systems in which people use advanced technology to collaborate for the purpose of conducting work (Patterson and Hoffman, 2012). Their primary activity is macrocognitive, which is defined as the adaptation of cognition to address complexity (Klein, et al., 2003). In Naturalistic Decision Making (NDM) research, the domains are typically societally and economically important, such as air traffic control or military command. As such, macrocognitive work is carried out under constraints of organizational resources, requirements, and cultures. The work environment is typically stressful, high risk and high stakes, and work success depends on expert domain practitioners coordinating in specialized, defined roles (Woods, 2006).

Researchers and domain practitioners have identified five macrocognition functions that abstractly characterize work in complex domains: detecting problems, sensemaking, re-planning, deciding, and coordinating (Klein et al., 2012). There is a growing body of research that emphasizes authenticity of data from the perspective of the "sharp end" practitioner in that it tends to be observational, interviews of past events, or from high fidelity "human in the loop" simulations. Another common emphasis is on performing research to improve safety and support skilled performance – as opposed to improving efficiency, increasing profit, or improving the quality of working life.

To date, the utility of using a conceptual framework of macrocognition has primarily been to provide a broad conceptual lens to aid in the description and thematic analysis of overwhelming, messy, inter-related data from research conducted across domains of practice (Vicente 1999). Recently, there has been increasing interest in identifying how a macrocognition perspective enables the pursuit of promising leverage points for improving safety in complex, sociotechnical domains. The macrocognition perspective is contrasted with perspectives for improving safety that are based largely upon leverage points such as recruiting, automation (often called 'clinical decision support' in healthcare), evidence-based guidelines, individual personality, leadership characteristics or accountability. Although there is an emerging consensus that these leverage points are "not NDM", there is less clarity on defining clearly what initiatives to improve safety "are NDM". Specifically, it is not clear how to take advantage of the growing knowledge base and emerging consensus on what NDM is beyond needing to do field

research to understand the perspective of a sharp end practitioner based upon empirical authentic data that reveals expert strategies and trade-offs in naturalistic decision making.

In this panel, we will describe two perspectives from different work domains on how to improve safety for two related but distinct areas: unsafe workarounds and missed danger signals (warning lights, auditory alarms, computerized alerts, and more subtle cues embedded in common strategies, actions and documentation). We will discuss potential implications for emerging principles and theoretical frameworks that can accelerate safety efforts across domains.

**PERSPECTIVE: ADDRESSING RISKS FROM UNSAFE WORKAROUNDS**

Austin Mount-Campbell, PhD, will present a perspective on addressing risks from unsafe workarounds, primarily based upon research conducted with the use of Bar Code Medication Administration by his advisor, Emily Patterson, PhD, and nursing flowsheets in electronic health records and paper "brains" artifacts by nursing personnel for his dissertation research. This perspective assumes that macrocognition functions of sensemaking, replanning, detecting events, coordinating, and committing to decisions are performed by joint cognitive systems in ways that are constrained by organizational resources and mandates and influenced by measures that impact reputation of individuals and organizations. Most importantly, the NDM differs from a more common perspective in that a foundational assumption is that gaps between work-as-imagined and work-as-practiced are best reduced by improving the system to make it "easy to do the right thing right".

Workarounds are defined as a deviation from an intended work process. The leverage point for improving patient safety is reducing the gap between work-as-imagined (typically documented in policies and procedures) and work-as-practiced (typically based on direct observations). The starting assumption is that every domain of practice has a gap, if only because policies and procedures tend to describe "best practices", which by definition means that there are practitioners who have in the past pursued practices which deviate from these. It is impractical to assume 100% compliance immediately upon publishing a policy and procedure for the desired workflow, work practices, and processes.

Overall, workarounds can be both positive and negative. Positive workarounds tend to be unexpected uses for features that were designed for a different purpose, and are typically performed first by individuals and then spread through personal networks, infrequently being spread to all people in a particular role. Negative workarounds tend to be unsafe and improve efficiency or the quality of work life at the expense of safety. Safety can be for customers (patients, passengers on a plane), workers (exposure to radiation), or the community in general (nuclear power).

There are different reasons for workarounds. There are workarounds which are required because the system does not allow work to be done as imagined, workarounds which are done to improve efficiency while increasing safety risks, workarounds which are done because of misaligned organizational incentives, and workarounds which are sub-optimal and are done because of failing to move to better processes for a variety of reasons. Each of these different types of workarounds have different implications for how to address the risks.

There are different types of workarounds with relation to what is deviated from. Deviations include:

- Differences in what is done:
    - Who is supposed to do a task
    - When a task is supposed to be done based on a timestamp
    - When a task is supposed to be done in relation to other tasks in a normative sequence
    - When a task is expected to be initiated and completed
    - Whether a task is completed as expected in relation to other tasks
- Differences in what is documented as done:
    - Who documents a task
    - When a task is documented
    - Whether documentation is able to be modified without changes being tracked
    - Whether documentation is tied to specific, observable, and associated timestamps

Workarounds also differ based on the nature of the tasks themselves: whether tasks are self-paced or event-driven, whether there are multiple simultaneous processes or one task is being done at a time, how many interruptions occur during tasks and whether the interruptions are more important, and whether there is a level of flexibility in how a task is executed (Woods and Patterson, 2001, Klein 2007).

Workarounds are also influenced by what the legal and reputational impacts are, both for doing workarounds which are not allowed as well as workarounds which are done to avoid legal and reputational impacts from failing to follow mandated/recommended procedures.

Automatically generated measures also predictably influence the rate and types of workarounds that occur. In particular, it is likely that measures related to conducting a particular task or set of tasks will increase the priority of those tasks higher than would occur without measurement. For example, workarounds might be employed such that measured tasks are conducted even though they are sub-optimal or inappropriate for a particular situation.

**PERSPECTIVE: ADDRESSING RISKS FROM MISSED DANGER SIGNALS**

Emilie Roth, PhD, will present on addressing risks from missed danger signals, primarily based on safety research with train dispatching. Railroads use the phrase 'signals passed at danger' to mean 'missing a stop signal', which is typically a red light. Typically the stop signal has a high Positive Predictive Value (PPV) in that there are few reasons for false alarms. Based upon our study, the primary reason that train crews miss stop signals is that they are not expecting them, and thus their attention is focused elsewhere for a variety of reasons. There have been some attempts to use technology to prevent train crews from going beyond their limits of authority (e.g., passing red signals). Those attempts use automation to create new alerts and to actively stop the train if the automation decides it is needed. These new forms of automation result in false alarms and new vulnerabilities to risk, which is not surprising from a macrocognition perspective. Therefore, a preferred leverage point in addressing this risk requires going beyond blaming the individuals at the 'sharp end' – the train crews – and instead addressing the larger, sociotechnical factors contributing to risk.

Susan Moffatt-Bruce, MD, PhD, will present on missed telemetry alarm sonifications by registered nurses, which has direct implications for patient safety for patients with cardiac complications. In many domains, automatically generated 'danger signals' are used to alert practitioners to the possibility of an unsafe condition which requires immediate or near-term interventions. Typically, these danger signals are generated from sensors 'in the world' with the ability to detect parameters and match parameter values to pre-identified threshold cutoffs. With advanced signals, there is often some form of 'decision support' which is able to remove likely false alarms based upon context such as environmental conditions, missing data, failed sensors, or other factors. In all domains of which we are aware, danger signals which are generated in this fashion have high false alarm rates, and thus are at risk of being ignored or overridden, even in critically important situations. In this presentation, contributors identified from missed danger signals by train operators suggest emerging leverage points for increasing the informativeness of danger signals in all domains.

Laura Militello, MA, will discuss missed danger signals in the context of software alerts associated with electronic health records. Although the issue of alert fatigue has been highlighted in a range of contexts including intelligence analysis (Handel, 1980), nuclear power control rooms (Mumaw et al, 2000), and others, electronic health records are commonly designed to include alerts and notifications that vary in terms of urgency, priority, relevance, and purpose. As a result, true danger signals are hard to distinguish from the noise (Hysong, et al, 2010; Glassman, Belperio, Simon, Lanto, Lee, 2006; Glassman, Simon, Belperio, Lanto, 2002; Ko, et al, 2007). Furthermore, the presentation of lists of de-contextualized alerts makes it difficult for clinicians to mentally build the narrative required to determine which are urgent and/or high priority. For example, clinician's using the Veterans Administration's computerized patient record system (CPRS) resort to "detective work" to discover antecedent actions that may have triggered the alert, in addition to additional information seeking to determine whether the alert is relevant in this particular situation, and weigh potential outcomes and trade-offs to determine whether an action needs to be taken. In some cases, clinicians maintain a separate paper log to track the progress of a particular order through the system in order to ensure that the patient receives the care requested and that results are read and interpreted. This paper system is redundant with the electronic alerts available in the electronic health record, but allows for an uncluttered view of items of interest. Leverage points for improving the utility of electronic alerts and notifications include 1) presenting alerts with links to important context to reduce the amount of detective work required, and 2) designing visualizations that facilitate rapid stratification of alerts based on content. This presentation will include examples of alternative strategies for presenting update information to support storybuilding and sensemaking.

Rhona Flin, PhD, will argue that we also need to consider the sensemaking and decision making aspects of macrocognition from an individual difference perspective that may enable us to better understand the variation in levels of sensitivity to signals in these riskier domains. Research from the energy sector on managers' chronic unease (Fruhen, Flin & McLeod, 2014; Fruhen & Flin, 2015) and interpretation of ambiguity (Flin & Fruhen, 2015), as well as with surgeons into intra-operative risk assessment and decision making (Pauley et al, 2011) indicates the role of underlying disposition and attitudes in the detection and interpretation of hazards. Despite a general lack of interest in personality by cognitive and engineering researchers, designers of cognitive-based

safety systems might be advised to consider additional predictive variables as a leverage point in their analysis of human attention and decision making.

## DISCUSSION

There are emerging principles from considering these two areas. Leverage points in both areas reveal a return to the centrality of the role of the 'sharp end' practitioner in being responsible for improving safety, and thus increasing the flexibility to achieve that objective. The general stance is that automated systems and policies and procedures are not able to handle the messy complexity as practiced by sharp end practitioners. Therefore, they can provide support but should not strongly direct actions because it is unlikely that they will be able to understand the nuances of the complex situation as well as the sharp end practitioner. They do have an important role in providing guidance and directing the attention of the sharp end practitioner. From a macrocognition perspective, all of the functions are impacted by the ability to sense danger signals, decide how to change ongoing plans, and coordinate to execute changes to plans. An additional emerging theme is that automation and policies and procedures can be, and therefore likely will be predictably, used to increase the power of more distant designers and administrators, and that this trend should be reversed during initiatives to improve patient safety by empowering sharp end practitioners.

## ACKNOWLEDGMENTS

Funding was provided by the OSUMC Patient Safety Advancement Grant Initiative (PI Patterson) and the Naval Research Laboratory (PI Patterson). The views do not necessarily represent the views of the OSUMC or NRL.

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