Cognitive Resilience in Emergency Room Operations, a Theoretical Framework

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Abstract. System resilience implies practitioners' capacity to cope with unexpected events, i.e. cognitive resilience. To address it, we outline a framework based on the Skill-Rule-Knowledge model grounding it in the operators' sensitivity to the variety that normally occurs in complex systems activities. This variety can hide information enabling the organization to be proactive and to manage unexpected events. Each situation can be described with a SRK profile, according to the cognitive processes necessary to control it. Operators' reliability can therefore be analyzed by evaluating the match between their cognitive SRK profile and that demanded by the current situation. System resilience is ensured by the capacity of operators to: (i) choose the most suitable cognitive level; (ii) freely move along these levels according to the situation; (iii) be mindful towards variety; (iv) transfer their personal mindfulness into group dynamic adaptation. The outcome of these behaviors is a balance of mindfulness (constant attention to anomalous signals) and dynamic adaptation (organizational adjustment of existing rules according to the new information). This continuous equilibrium between chaos and order is the strategy followed by adaptive complex systems in order to evolve and can be successfully applied to high-risk organizations to enhance the emergence of resilient behaviors.

1 INTRODUCTION

According to recent views about safety and error, the major challenge for current theories, models and frameworks is to handle what Weick and Sutcliffe (2001) defined as “dynamic non-events” where human performance has a role that goes beyond the mere trade-off of correct and wrong actions (Hollnagel, 2004). Thinking about safety in terms of preventing human error is reductionist and simplistic and current approaches to system safety and human factors try to overcome these limitations (Hollnagel, 1998, Dekker, 2004).

In line with these new directions, in this paper we will develop a framework to account for a cognitive approach to system safety, assuming that safety is a system property which comes from thoughts and actions arisen in practitioners’ mind. We will apply the framework to ER operations, since they are characterized by their interesting balance between different cognitive processing demands, from automatic and skilled responses, to rule-based reasoning, up to the management of unknown and unpredicted situations.

2 A COMPLEX APPROACH TO COMPLEX SYSTEMS

High-risk organizations are characterized by several factors that make it necessary to change traditional attitudes towards safety, and to move towards an approach inspired by modern theories of complexity (Gell-Mann, 1994). These properties are: multiple hierarchical levels of organization, dynamic self-organization, concurrent interaction of several factors, unpredictability of some internal and external events, balance between order and chaos, development of schemes in order to manage complexity, optimization of variety to enhance system fitness.

Variety is the key concept of the framework we are proposing, since it can be understood as both a property of human performance variability (Hollnagel, 2004) and the source of unpredictability the system has to cope with. Variety is the positive side of chaos, since, if it’s optimized by the system, it can bring new order and, most of all, new complexity and better organization. Optimizing variety, for a practitioner, means not relying on the mere application of rules and procedures whenever the situation seems usual, but rather to be sensitive to the mismatch between the current circumstances and the abstract situation to which the rule applies. In fact, every rule is a generalization aimed at managing a simplified version of the countless contingencies that an operator will cope with. Moreover, human behaviour is a local optimization of abstract rules to the specific situation, this implies a gap between *normative* behaviours defined by rules and *normal* performances stemming from local adaptation. Sometimes this difference could leave room for anomalies to grow and proliferate, that is why it is important to be sensitive to variance and to make explicit the gap separating normative and normal behaviours. This gap could contain useful information to help the system prevent future accidents, therefore it is important to facilitate practitioners in developing such a sensitivity. Seen from this point of view, the classical notion of error is useless, since every variability in system performance will be a source of variety, and therefore, a source of information. This anomalous variety may improve system fitness also in the case of dangerous outcomes, because this new experience could help the system to learn more about the nature of accidents (Hollnagel, 2004).

3 RESILIENCE ENGINEERING, COMPLEXITY AND SAFETY

Recently, Resilience Engineering (Hollnagel, Woods and Leveson, 2006) has been proposed as a new way to think about system safety, characterized by a more proactive attitude which has the capacity to anticipate future events. However, in many publications and debates we notice emphasis placed on organizational issues concerning safety, whilst far less attention is given to cognitive implications (Hollnagel and Rigaud, 2007). Resilience is an emergent property of a complex system and, just like fitness for an organism, it comes from the joint interaction of a structure, its functions and an environment where they take place. Emergent properties arise at a specific level (e.g. organizational), but they can be formed only if precise conditions are satisfied at the lower levels (e.g., cognitive). If resilience concerns the ability to manage the unexpected, we know that very often, in high risk systems, there are hundreds of weak and anomalous signals preceding the accident that could be appositely sensed by frontline operators.

3.1 The SRK Framework

Every action could be the result of three general kinds of cognitive processing: at the lower stage we have the *skill-based level* (S level), whose behavior is fast but rigid, it doesn't require a lot of attentive resources to be accomplished since it involves only procedures and actions which have been over-learned. If we have to take a decision in applying a known rule, we are at the second stage, the *rule-based level* (R level), it is slower than S level, but more flexible and resource demanding. If we have not learned procedures because the situation is unknown we are at the *knowledge-based level* (K level), which is slow and time consuming, it implies a lot of cognitive effort and is very flexible and creative.

Within this framework, what defines a correct performance or a mistake is not only the resulting action - e.g. a skill/rule/knowledge-based error (Reason, 1990) - but how cognitive work demands are faced by the cognitive setting of the operator's mind. Actually, each situation can be represented according to its cognitive demands profile, for instance, it could require a lot of skills, many rules, and little knowledge-based reasoning. On the other hand, if it is a pioneering domain, it's management would need few skills, many rules, and a lot of K-based processing. A bureaucratic system should entail some skills, a large amount of rules and very few K-based tasks. The cognitive fitness of the operator can be described by how it matches with the set of cognitive demands of the situation. If an operator faces an unpredicted and novel emergency reasoning at the S and R level, she will probably undergo a maladaptive approach and bad performance will be the outcome.

In addition, the SRK framework can offer a visual model to help practitioners acquire a resilient cognitive attitude. We can represent the operator's cognitive setting with the SRK ladder: her thoughts and actions will climb or descend the three steps according to the situation (Fig. 1).

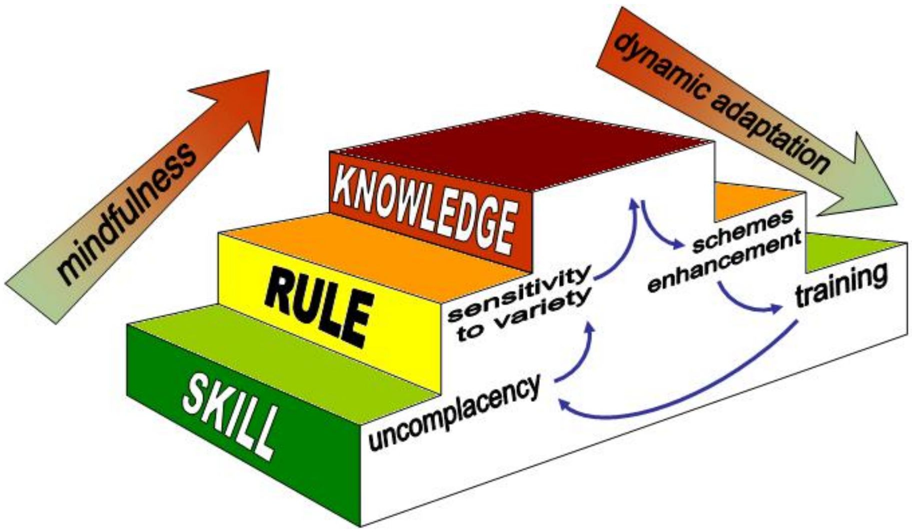

Fig. 1. The SRK framework for cognitive resilience. Moving from S to K means to be open to variety *(mindfulness)* and moving down from K to S means to metabolize this novel information into existing procedures *(dynamic adaptation)*. This open loop will enable the system to be prepared for future unknown events thanks to its sensitivity to weak and anomalous signals

According to the model we propose, the cognitively resilient system manages to dynamically maintain the circulation in the SRK framework: from the S-level an operator can move to the R-level if she avoids the complacency of repetitive, reliable, automatic processes. But applying the rules is not enough, in complex systems the sensitivity to variety helps the operator to follow the rules but also to notice the slight differences between the ideal situation, for which the rule has been conceived, and the present one. Paying attention to weak signals, the operator can understand if the rule already fits the real work conditions or if it needs to be revised. This process of sensitivity to variety from S to K-level can be called *mindfulness*. This aspect emphasizes the dynamic equilibration between regularity and randomness, therefore it can help to design work situations that enable practitioners to optimize performance variability: first of all, errors are not blamed but analyzed; secondarily, it encourages the detection of near misses and, most of all, weak signals and anomalous events. Defining some events as anomalous (etymologically: not fitting with normal rules) we do not only refer to those recognized as latent conditions, in Reason's terms, but also to occurrences almost regularly hidden in normal operations that may contain some useful information; these events are not part of any rule, are not considered in procedures, but could enrich them once detected and shared in the team.

However, it is not sufficient to climb up towards variety if this new information cannot be assimilated into rules and skills. Once the rule has been refined, enriched or modified by the discovery of new patterns of correlations, it can be transferred to a skill level by means of training. This process of variety assimilation form K to S-level can be called *dynamic adaptation* to variety, typical of every complex open system. Therefore, once the single practitioner has moved from S to R and to K, noticing anomalous events/information, she has to share this knowledge with the team members and with the other units of the organization, in order to openly discuss how and when this anomalous information occurred. This means to move, as a system, from K to R, because the analysis of anomalies can improve and adjust procedures and schemes, limiting or enriching them, according to the new information acquired by the single operator. After that, training can shift the group level from R to S, because after some time, it will be cost-free to notice and manage those events that had been previously detected. This dynamic process implies group flexibility, a just culture, the capacity to abandon hierarchical positions in favor of the emergent property of safety. Implicit team coordination has been correlated with higher group performance (Entin and Serfaty, 1999), but this requires shared mental models to be effective; a common view of how to face a situation can be built by making explicit what is implicit, thus moving as a single operator from S to K and later to share this K level with the group and bring the whole team to R and to S levels thanks to explicit communication.

According to this framework, cognitive resilience results from fluid circulation along the levels, a continuous balance between being mindful of variety and the adaptation of new information to one's goals, objectives, values, frames of mind. We claim that the cognitive ground of resilience is based on such a model, in particular on 4 abilities namely:

1. the capacity to *move freely* to the desired cognitive level: this may be blocked by factors which are internal (e.g., high workload or loss of situation awareness) or external (e.g., blame culture and commercial/operational pressures) inside a specific cognitive hierarchy of the ladder;
2. the capacity to choose the *proper level* according to the situation: each level has positive and negative aspects in trading-off flexibility and efficiency;
3. the *optimization of variety*, assured by mindfulness: the resilient operator will choose that rule, because the situation is best described by that set of data which require a specific procedure, but at the same time she is also aware of other regularities, other patterns of information that are not part of the schema but that can play a relevant role in future situation management;
4. the tendency to reduce K-level in favor of R and S-levels, assured by *dynamic adaptation* in order to save cognitive resources whenever it happens again.

Therefore, cognitive resilience helps us to see the difference between normal and normative situations; it optimizes the new information taken from the K-level and refines the written and unwritten procedures. The next step, if possible, requires moving from the R-level to the S-level, in order to save cognitive resources thanks to automatic processes consolidated with training. But the system is dynamically floating in a complex environment and a new cycle has to start, looking for new variety and new opportunities of adaptation. This continuous balance between mindfulness and adaptation is the cognitive counterpart of self-regulatory dynamics of complex systems, where exogenous information is adapted to the internal milieu and, as a consequence, this is modified by new variety.

This framework is in line with other models developed in human factors domain, such as the COCOM and ECOM models by Hollnagel (1998), where cognition is situated in context and described as several levels of control, from reactive tracking, to proactive targeting. Moreover, like the CREAM model (Hollnagel, 1998), our approach emphasizes the potential mismatch between context SRK setting and the operators' SRK settings and, in addition, this framework may be used as a tool for CREAM, because it is expressly aimed at assessing human situated cognition and its reliability according to practitioners capacity to adapt their cognitive setting to the context, to adopt the proper level when required, and to move along the levels in order to make information circulate from S to K and then back to S again.

3 A CASE STUDY: THE SRK FRAMEWORK IN ER SETTINGS

We shall now apply this framework to ER operations and specifically we describe a case that we have analyzed using the SRK ladder. Here is the context. ER of a small Italian hospital: 1 doctor, 3 nurses and 1 hospital assistant were at work. Average workload: some stretchers occupied by patients, some inmates waiting to be seen by a doctor, others in the waiting room before triage. Ambulance brings in a 43-year-old Moroccan patient lying on a stretcher, the bearers describe the situation to the assistant as follows: "he was at the police station as he had been involved in a brawl when he collapsed complaining of chest pain." The patient is then put on a chair in the inner corridor of the ER and is triaged as green by the assistant, who reports "contusions" in patient's file. After 5 minutes, the triage nurse, from his workstation, notices the facial aspect of the patient and decides to let him lie on a stretcher, he measures his arterial pressure, carries out an ECG and a blood test. He later shows the doctor the ECG, who decides to leave the patient with the green code. Soon after, the patient has further thoracic pain with vomit. No action is undertaken. Blood analysis is negative. An hour and a half after his arrival at the ER, the patient undergoes a thorax radiography, which is negative for both rib fractures and pleuro-parenchymal lesions. A hour later the patient still complains of thoracic pain and undergoes a second ECG which reveals alterations indicating myocardial ischemia and a blood test reveals high troponin levels, the enzyme increasing first when myocardial necrosis is going to occur. No action is undertaken. Cardiologic counseling is then provided and another ECG (without declared pain) is done, showing a reduction in trace abnormality. The patient is later admitted to the intensive care unit with the following diagnosis: "enzymatic and ECG alterations in thoracic trauma". He will eventually go through an angioplasty intervention due to an occluded coronary.

The patient was clearly suffering from myocardial infarction but no one, except the triage nurse, suspected this, even in front of patent diagnostic data. Why? The SRK profile of the situation was unusual, because in that ER unit it was quite common to see Moroccans with lesions due to brawls. The stretcher-bearers' description and the superficial decision of the hospital assistant contributed to set the SRK profile of the team at the S level, entering a cognitive tunnel that led them to treat this as a routine case (lack of abilities 2 and 3). Nobody, including the doctor, moved from their cognitive level at the S stage, since they did not recognize either the ECG or the blood data as signs of an infarction, which required a move to the R level (lack of ability 1). Several factors blocked them at the wrong level: novelty of the situation, workload and time pressure, and maybe also some preconceptions of that category of patients, known for their intemperance. To evaluate the organizational aspect within this framework, let us consider the behavior of the triage nurse, the only one who suddenly suspected an infarction. He did not enter the cognitive tunnel because he was not present at the patient's arrival and when he saw his face he soon realized the proper level to move to was R since he was free of the biasing factors affecting ability 1. After that "near miss", the case had not received any attention by the team doctors and managers (lack of ability 1), but the nurse described these events to one of the authors, convinced that such an experience had to be known and analyzed. He was mindful in considering the whole team's anomalous behavior as dangerous. According to our model, we can say that he moved at the K level, since he considered what happened in the ER as productive variety. But this sensitivity would not be useful, if it remains in individual practitioners' mind; that is why he tried to reconsider the case and analyze it with the other team members. Unfortunately there is a risk, in such situations, of underestimating the information hidden in anomalous events since they did not have fatal or dangerous consequences (lack of ability 4). The case described here shows how normal performance was quite different from the normative one (bearers and assistant were not allowed to do the triage coding, the infarction symptoms were misjudged, too much time passed after the patient's arrival, etc.) due to several internal (expectations) and external (work conditions) factors. There was a lot of variety, hidden in these anomalous events, that could have been detected with the SRK framework. Heuristically, it can become a useful tool for training practitioners in performance analysis, as they consider the matching between their cognitive SRK setting and contextual SRK demands. This helps them in assessing their ability to move and choose the right level without restraints, and to pay attention to the overall performance circularity, balancing mindfulness and dynamic adaptation within the contingency of daily operations.

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