

## Improvisation in High-Reliability Organizing (HRO): 2. A Function that Closes Gaps

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### Abstract

We encounter the unexpected without previous preparation. Likely, this occurs from energy entering our environment as a forcing function or causing abrupt change. Some rules continue to apply while others do not – and we cannot know which is which. Our theories and concepts become separated from our practice and what we are experiencing. Improvisation closes that gap, but not through trial and error. We act and begin learning by doing. As we learn, we adjust our actions to changing situations – this is motor cognition. Our actions generate information and create structure. Responding at the local level leads us to self-organizing improvisation. Improvisation is optimism. Improvisation is where resilience begins.

**“Critically, improvisation operates in the transitional, or liminal, state between stability and the flux of events from uncontrolled energy (3). The brain rapidly adapts cognition and behaviors to abrupt change. Lastly, improvisation is optimism – if there is not a path now, we will soon develop one.”**

### Introduction

The problem of improvisation is its reputation of “trial and error,” the “cowboy,” and “freelancing,” or the question posed by a new PICU nurse, “Do you know what you’re doing?” (Personal experience, DvS.) Nevertheless, improvisation solves the gap between theory and practice (1) or between classical logic and logic practice (2). Critically, improvisation operates in the transitional, or liminal, state between stability and the flux of events from uncontrolled energy (3). The brain rapidly adapts cognition and behaviors to abrupt change. Lastly, *improvisation is optimism* – if there is not a path now, we will soon develop one.

Improvisation describes our actions when encountering an unexpected event (4, 5). This is not an element of HRO, a tool in an already heavy toolkit, nor a skill learned in training. Improvisation is how the High-Reliability Organization organizes into High-Reliability

Organizing. Improvisation is the function of High-Reliability Operations.

We may encounter the unexpected without previous preparation. Our initial responses are “spur of the moment” before we become aware of the magnitude of the situation. Often, we have only immediately available resources. Initial leadership is the first person to identify a discrepancy or encounter a disruption. Hope will not help you. If you do not have it, then it does not exist. We do have improvisation.

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The improvisation functions have adaptive significance for survival value. The act of improvising initiates *motor cognition* to support *learning by doing*. Significant information is generated, and structure forms as improvisation continues.

### Trial, Error, Cowboys, and Freelancers

The first belief we encounter during discussions about improvisation is that individuals will “go rogue,” randomly use “trial and error,” operate as if they were renegade “cowboys,” or irresponsibly “freelance.” As indicated, the organization can address any maladaptive behavior through education or discipline. However, the organization that depreciates improvisation as an adaptive operation should also become prepared to fail.

#### *Trial and Error*

Duncan Dieterly (6) described the three elements of a problem: the situation, intervention, and objective. Knowing all three makes the problem *trivial* and quickly dealt with using rules and protocols. Knowing the situation defines the problem; we only need to identify an effective intervention or acceptable objective. Knowing the initial situation leads us to select the decision tree, algorithm, or clinical pathway. The trivial and defined problem focuses on the proper diagnosis and appropriate efforts to diagnose.

In this manner, the problem is prepared for the problem-solver solution space. That is, the individual operates in a precisely specifiable domain where the solution is known to lie. These limitations on uncertainty form what Herbert Simon (7) defined as the “well-structured problem.” Herbert Simon defined these problems as having a precisely specified process of trial and error that will lead to a desired solution in a practical amount of time (7).

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Error has come to be considered as an action deviating from what is prescribed rather than a means of identifying novel or changing circumstances. We, too, readily think of trial and error as a non-selective search for information and a rapid, cursory evaluation of data. The person only considers limited alternatives and does not review their decisions. Thought processes are simplistic and easily disrupted. If an action is not fruitful, the person develops a new action plan, continuing this cycle in response to local successes and failures.

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However, Irving Janis and Leon Mann (8) identified this pattern as *hypervigilance*. This is one of five patterns of *conflicted decision-making* they identified as responses to abrupt stress. The other four patterns are unconflicted adherence, unconflicted change, defensive avoidance, and vigilance. Janis and Mann studied stress from unexpected threats, specifically when faced with time pressure, having no good choices, restrictions on activity, sensory deprivation, and lack of contact with supportive people.

However, problem-solving as trial and error is directed toward a solution rather than a random selection of actions. The individual has some knowledge and insight toward a solution to the direction in which a solution might lie. Trial and error approaches are better described as trial, fail, learn, revise, and then trial again (8). This is not a random selection of an action to see what works or the gratuitously pejorative phrase, “Throw it on the wall to see what sticks.”

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***“ Instead, on hazardous cattle drives in areas of unreliably enforced law, cowboys would keep the cattle calm, fed, and watered. Breaking the rules and loud, boisterous behavior disrupted camp life, could stampede the cattle, and likely lead to someone’s death.”***

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### *The Cowboy*

Cowboys are considered rule breakers and renegades. This image derives from 19<sup>th</sup> Century novels and 20<sup>th</sup> Century movies and television. Instead, on hazardous cattle drives in areas of unreliably enforced law, cowboys would keep the cattle calm, fed, and watered. Breaking the rules and loud, boisterous behavior disrupted camp life, could stampede the cattle, and likely lead to someone’s death.

Most cowboys did not have a gun. Partly for their safety, as having a gun made one a target. As described by one cowboy, ‘If someone were going to shoot me, he would most likely shoot me first.’ Some outfits forbade the possession of guns. Also forbidden was gambling and often alcohol. Trail drivers maintained discipline and

expected cowboys to keep their differences under control. Cowboys would calm the herd at night by singing to prevent stampeding cattle. Over time, they learned that cattle liked slow, mournful songs (9, 10).

“At noon, you would see the men throw them [the cattle] off the trail, and half the crew would go to dinner while the other half would graze them onto water. No orders were given; every man knew his place and what to do,” CE “Teddy Blue” Abbott, 1955 (9).

“I borrowed fifty cents from her [Calamity Jane in a random meeting] to buy a meal. I thanked her for the fifty cents and said: “Some day I’ll pay you.”... “I never saw her again until twenty-four years later. It was in 1907, and she was standing on a street in Gilt Edge... I walked up to her and said, “Do you know me?” and gave her the fifty cents.” CE “Teddy Blue” Abbott, 1955 (9).

Maybe we should all be cowboys.

### *Freelancing*

While one of the authors (DvS) was writing a book that presented HRO for healthcare, the editor requested a definition of “freelancing” as used in healthcare. The author found one article in the medical literature that used the term. Non-medical literature considers the freelancer to have an honorable position in their industry.

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***“ The freelancer is derided as a “loose cannon” who lacks the control necessary to join others, conform to medical practice, or follow medical direction. This latter situation is an educational problem rather than a result of using HRO.”***

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How the authors of these *Neonatology Today* articles use deference to expertise, initiative, creativity, and decision migration was codified from naval air operations, military operations, and wild-land firefighting. For healthcare professionals, a context-independent translation allows unconstrained “freelance” behavior. The freelancer is derided as a “loose cannon” who lacks the control necessary to join others, conform to medical practice, or follow medical direction. This latter situation is an educational problem rather than a result of using HRO.

### **The Color of Noise**

#### *White Noise*

No energy frequency dominates in the white noise environments. Data *decreases* variance, making the environment information sensitive. We focus on clarification of the study question and precision of the data measurements. The decreasing variance from the increase in data then forms the Gaussian curve. We can now calculate descriptive statistics and probability predictions. We can assume white noise when we linearize the curve. That is, we work with short-time segments that have little temporal variation. Long frequencies, a characteristic of red noise, may appear as white noise if the segment is longer than our experience in the environment. Pink noise causes abrupt change that appears out of a white noise environment, such as earthquakes.

We develop our theories, concepts, and models in a white noise environment, for example, evidence-based medicine from prospective studies using randomized controlled trials. This is not to

say such research does not function in reddened noise environments. We must consider that. Classifications and standards developed in white noise environments may not fit during red noise forcing functions or encountering abrupt pink noise events. We must guard against allowing principles and practices developed in white noise environments to become expectations.

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**Red and Pink Noise**

Environments may experience energy fluxes over long periods. The more extended periods are like the longer frequencies of red light and are called “red noise” (11). Longer wavelengths carry more power than shorter wavelengths, which are also forms of red noise. The longer wavelengths force a response by elements within the environment; these surges of energy are called *forcing functions*. A unique pattern occurs at the  $1/f$  frequency when an abrupt but rare event occurs. This is called “pink noise” because it has a frequency midway between white and red noise (12) (Table 1).

On the other hand, energy fluxes may occur in environments from long time wavelengths such that events are few and far between. These wavelengths carry the power to force a response, and they are called forcing functions. During red noise forcing functions, rules conflict or compete, or gaps form between rules. The abrupt change from a pink noise event not only alters the relevance of rules, but the abruptness distorts cognition, and we observe stress-induced symptoms, fear circuitry behaviors, and amygdala-driven behaviors (13, 14). More mild situational cognitive distortions can affect people who otherwise are capable leaders or performers (14, 15). Unfortunately, these are not regularly distinguishable and commonly have become normative in most organizations.

**Table 1. Patterns and Characteristics of Noise (11)**

Color	Structure	Variance	Distribution
<b>White</b>	No frequencies dominate Flattened spectrum Spectral density has equal amounts of all frequencies	Data <i>decreases</i> variance  Forms Gaussian curve	Gaussian distribution  <ul style="list-style-type: none"> <li>• Elements fully independent</li> <li>• No autocorrelation</li> </ul>
<b>Red</b>	Low frequencies dominate  Long-period cycles	Data <i>increases</i> variance  Forms power distribution	Power law distribution  <ul style="list-style-type: none"> <li>• Elements <i>not</i> independent</li> <li>• Mutual/ reciprocal relations</li> </ul>
<b>Pink</b>	The midpoint of red noise The slope lies <i>exactly</i> midway between white noise and brown (random) noise	Data <i>continuously increases</i> variance  Distinguishes pink noise from reddened spectra	Power law distribution  <ul style="list-style-type: none"> <li>• No well-defined long-term mean</li> <li>• No well-defined value at a single point</li> </ul>

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Common cognitive distortions include (16, 17):

- Anger
- Frustration
- Avoidance
  - Complete or avoid tasks
  - Focus on inconsequential tasks
  - Addressing easily accomplished tasks first
- Distractive comments
  - Responding to distractions
- Freeze (“attentive freeze”)
- Actual cognitive or physical freezing
- Nausea and avoidance
  - Urge to urinate or defecate
- Confusion
- Mental freeze
  - Inability to solve simple problems
  - Failure to recall knowledge
  - Impaired working memory

**The Actual World**

Forcing functions and abrupt change can be described by the energy flux (VUCA-2T) or the affective experience. The VUCA-2T environment disrupts order and bedevils classification systems. We can borrow from art historians to evaluate the visible amount

of structure and degree of randomness present (18). The structure is a measure of complexity that identifies discrete objects through borders and edges, demarcating change and flat surfaces denoting continuity. Randomness is a measure of entropy that measures disorder and uncertainty, a fuzziness that disconnects various parts of what we can observe, making invisible the causes and effects (19).

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***The VUCA-2T Environment***

The military concept of “VUCA” describes the new global environment at the end of the Cold War (20, 21) – *volatile, uncertain, complex, and ambiguous*. As a *military* concept, VUCA carries the implicit assumption of a dangerous and lethal environment (Table 2). Consequently, the concept of threat is not translated into civilian applications (15). Discussions between a special group in SOCOM (Special Operations Command) and the author (DvS) led to the separation of time compression from volatility. Time compression has meaning and carries special environmental information, distinguishing these events from urgency or time dependence (15, 22). The group now uses VUCA-2T or VUCA-T<sup>2</sup> (Sean McKay, personal communication) (23).

**Table 2. VUCA-2T (3)**

Volatility	Rapid, abrupt change in events
Uncertainty	Lack of precise knowledge, need for more information, unavailability of necessary information
Complexity	A large number of interconnected, changing parts
Ambiguity	Multiple interpretations, causes, or outcomes
Threat	Impaired cognition and decision-making
Time Compression	Limitations acquiring information, deciding, or acting before consequential changes

***The Liminal Environment***

VUCA-2T fits the anthropological experience of liminality as a transition (24) and the operational environment of the HRO. The liminal zone is the space between the world we know and the world we do not. Old rules do not apply, we have not learned new rules, and we do not know what rules will work. In this area of experience, we must engage the situation to leave, yet we do not know what works (25).

Liminality magnifies the gap between theory and practice (1), discrete concepts and continuous perceptions (26), abstractions

and concreteness (Karl Weick, personal communication), and the static normative stance and the pragmatic stance from within the trajectory of events (27).

***“Liminal zones are not continuous with routine operations or with each other. Abrupt changes disrupt operations. Our treatments may abruptly disrupt the disease process and the neonate’s physiology.”***

Liminal zones are not continuous with routine operations or with each other. Abrupt changes disrupt operations. Our treatments may abruptly disrupt the disease process and the neonate’s physiology. Such a sequence of experiences creates the more common “punctuated experience” of resuscitation that necessitates constant evaluation and re-evaluation. Rather than sensemaking guiding us from the immediate past to the immediate future. “HRO is a trajectory of engagement that fuses now with the experience of then into simultaneous inquiry and redescription,” Karl Weick (personal communication). Karl Weick describes the repeated presentation of abrupt changes as “punctuated sensemaking” (personal communication). Every action is a failure, and every action creates an unrelated or disconnected experience (Table 3).

**Table 3. Liminality (3)**

Conventional Operations	Liminal Operations
Familiar	Threshold of Transition
Structured	Passage for travel, but not traveling
Knowledge by description	Gaps in knowledge (28)
Hierarchical support	Alone
Standards	Learn by doing
Known rules	Old rules do not apply
Familiar relations	New rules unknown
Prevent Failure	Consequence driven

***The Self-Organizing Environment***

Self-organization promotes stability and stable patterns. A volatile event may not seem to be achieving stability, but all elements reach a lower energy state through self-organization. Volatility develops as energy enters the open system or is released in a closed system.

Order comes out of chaos through self-organization (29). These systems stabilize and develop order by self-organizing through local, nonlinear feedback. Positive feedback contributes to growth and structure, while negative feedback restricts growth. These oscillatory, self-organizing processes bring stability and order to the environment, but the nonlinear interactions degrade any ability for predictions. Environmental self-organizing processes create stochastic noise that can increase to a level that forces a system or population to respond. The system or population responses to these forcing functions are also self-organizing oscillatory processes with poor predictability of outcomes. The noise process is independent of timescale or magnitude. We need not characterize normal environmental variation differently from catastrophes (30).

The events that we engage in are made up of many small interactions (complexity science) and a few nonlinear rate-dependent interactions (deterministic chaos (31)). Novel properties then emerge from these interacting interactions. We must respond to these emerging exigencies with the capabilities we have.

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### Engaging the Gap

Gaps are insidious. Operating in a single environment or context normalizes experience and keeps gaps from being visible. The observer will likely interpret the gap as due to the other side being wrong. Nevertheless, gaps form at various levels of analysis – prevention and response, planning, training, organizing, logistics, prevention, recovery, et cetera. The essential basis for gaps in a high-reliability system is between order and disorder. We can thus use entropy to explain the origins of gaps.

Without being trite, we will call disorder the absence of order. A cardiac arrest on the ward is a disorder in the hospital, yet the ICU has an ordered response to a cardiac arrest. A fire in the ICU is disorder, but the responding fire department has an ordered response, and so forth. HROs address the gap that develops from unexpected disorders.

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The most basic gap is that between *abstractions and context*. Concepts are abstractions that support theory. Concepts as ordered images of reality must not be mistaken for reality. Context is the actual world as experienced; it is the domain of practice. Discrete, abstract concepts, in a reality of continuous perceptions, thus create gaps that are subject to misspecification, misidentification, and misunderstanding (26). Contextual systems are those systems where the environment interacts with and changes the problem (32). These are the fundamental gaps between theory and practice (1) or between classical logic and logic practice (2).

Engagement generates information and creates structure during the flux of events. The environment is self-organizing through local nonlinear interactions in response to local entropy changes

over time. Humans bring local internal processes for the self-organization of these systems. The emergence of order is a complex phenomenon that resolves the crisis (33).

Engagement as an extemporaneous activity using immediately available resources. Engagement *is* improvisation.

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### What We Engage

Exigencies from forcing functions and abrupt change create a VUCA-2T environment. Stated in this manner, the urgency for good planning, protocols, and rules seems obvious. The event itself, however, is experienced by those within the situation – they may not have full awareness of events or available resources. The event transforms from what is stable and familiar to a world with threat and flux. However, both are actual worlds. People have entered a liminal space that distorts their cognitions.

We need not have special training or experience. On December 2, 2015, an active shooter incident occurred near a state center for the medical care of disabled children.

“A shooting victim with an injured arm had escaped and reached an office where a pediatrician was evaluating children. The victim was pale and feeling faint but did say there had been a shooting in the conference room, and they needed a doctor. The pediatrician used the victim’s sweater to improvise a sling for her arm, then went to the building where his associates were working on the second floor” (22).

[Because the pediatrician thought the assailants were in the conference room, he ran upstairs to check on his friends. He realized his friends likely thought he was a shooter and that law enforcement might also think he was a shooter because he was of Middle Eastern descent. He returned to his office to aid those suffering severe emotional trauma during the incident. Two minutes elapsed between the shooter’s escape and the arrival of law enforcement.

Another example of improvisation on a larger scale is the *Pasadena Chemical Complex Explosion* in Pasadena, TX, on October 23, 1989.

Responders to an industrial emergency usually depend on the available plant personnel to bring them up to speed. The people who knew anything were dead, hurt, or gone at the Pasadena explosion.

With the human element on-site so completely incapacitated, Doug Miller, fire chief at a nearby chemical plant, fell back on what emergency responders call “pre-planning.” Pre-plans include structural diagrams, details about available fire protection systems, and, most importantly, an inventory of hazardous materials. The emergency pre-plan became critical at Pasadena with no

management personnel immediately available.

However, pre-plans have limitations. In an emergency, the plant trained workers to report to pre-arranged assembly points where headcounts would be conducted. Panic drove the evacuation at Pasadena. Understandably, those still able to move put as much distance between themselves and the plant as humanly possible.

The pre-plan broke down in other critical ways. Triage means assigning the injured to one location where they can be assessed as to who gets treated first. Seriously injured are treated before the walking wounded, and so on. Responders at Pasadena — police, fire, and ambulance — too often grabbed the first injured person they found and rushed them to the hospital. Others with more life-threatening injuries had to wait.

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Doug had more to worry about than just the polyethylene facility. He was now in charge of a badly damaged industrial complex the size of a small city.

“It was nearly a mile long and a quarter mile wide,” he said. “There was hydrocarbon everywhere. It was packed with possibilities with risks. I bounced a lot of ideas off others about what could be the next high risk we were going to have to deal with.”

Most important, Doug needed a large-diameter hose. The blast sheared off most of the fire hydrants at ground level. Shut-off valves to prevent water loss were out of reach in the burning wreckage.

Firefighting water would have to be brought in using a hose laid to remote sources — settling ponds, a cooling tower, a water main at a neighboring plant, and even the ship channel. Every drop of water became precious. Backhoes dug ditches on Highway 146 to the west to capture the runoff from the plant’s damaged water system. Pumpers drafted from those ditches to bring the escaping water back to the plant.

“Most industrial chiefs didn’t see the need for five-inch hose because their plants had a fire hydrant on every block and monitors attached to the fire hydrants,” Joe said. “We had all these appliances that could deliver water on the fire. We didn’t think in terms of delivering it from anything but an internal source.”

One of the Lessons Learned: “Pre-plans cannot cover every eventuality. The key to a good pre-plan is providing a structure while *remaining flexible enough to adapt to the changing situation.*” (34) [Emphasis the authors, article courtesy of Bruce K. Vaughn]

In each situation, the individual acted extemporaneously without a plan.

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#### **Adaptive Significance**

You cannot improvise unless you have taken some action, initiating motor cognition for *thinking while acting*. Improvisation plays off knowledge, experience, and the immediate past responses to actions (35), incorporating common sense and tacit knowledge (36). Improvisation as a knowledge-based tactic or strategy (37) for an event transcends rules and experience (38, 39). Physical actions taken to initiate improvisation initiate thinking and learning by doing.

#### **Motor Cognition**

Motor cognition describes how we adjust our actions to changing situations and learn through physical actions (40). Effective action responding to a changing environment integrates, from opposite ends of the brain, perception, hastily created plans and motor activity. The dorsolateral prefrontal cortex (DPFC) and the posterior parietal cortex (PPC) functionally cooperate during time-based contingencies between continuous perception and emerging motor action (41).

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The cognitive function for this to occur must include timing and coordination, the mode of information analysis of environmental events, and the temporal sequencing of the analytic processes as concurrent, reciprocal processing (42). The *executive functions*, acting hierarchically, coordinate temporary behavioral structures and “integrate actions with perceptions in the presence of novelty and complexity” (42).

Motor cognition comes from the coupling of perception and action, which is also the mechanism of *common sense*. During mo-

tor cognition, the parietal cortex distinguishes oneself from others, an essential aspect of agency (43). As social knowledge, common sense is the background knowledge for expectations, meaning, and the “rules of the game.” It gives the ability to share activities with others (44-46) spontaneously. Contextual understanding and motor cognition increase the capacity for attunement the ability to appreciate and be involved with the mental states of others (44).

Motor cognition contributes to somatic common sense when actively engaging in an uncertain situation. Tacit knowledge is both somatic and cognitive. “Somatic knowledge,” a form of biological knowledge like riding a bicycle, is difficult to describe but easy to demonstrate. Therefore, it provides little contribution to Artificial Intelligence (45). Motor cognition is missing as combined somatic and cognitive knowledge, enhancing thinking while acting (46).

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***“I cannot know what I think until I act. Intention cannot cause our actions because conscious intention occurs after preparatory brain activity in the frontal and parietal brain areas (47). It would make sense that purposive action derives from intention, which would mediate between cognitive desires and purposive motor behavior. Rather than mediating, the two distinct brain operations, cognitive intention and motor behavior, must coordinate.”***

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*I cannot know what I think until I act.* Intention cannot cause our actions because conscious intention occurs *after* preparatory brain activity in the frontal and parietal brain areas (47). It would make sense that purposive action derives from intention, which would mediate between cognitive desires and purposive motor behavior. Rather than mediating, the two distinct brain operations, cognitive intention and motor behavior, must coordinate. This is the “Interface Problem,” made difficult because of the importance of motor representations in creating purposive behavior (48)

Karl Weick’s ‘sensemaking recipe’ now applies to topological events: “*How can I know what I think until I see what I say?*” (49).

Consider the process implied by the phrase, “How can I know what I think until I see what I say.” There are four verbs and four actions in the sensemaking recipe: to know, to think, to see, and to say. Organizing around those four verbs can be done in ways that enact higher reliability. Think about what happens when someone asks you about the story or your opinion. When you start describing your opinion, you often listen to what you are saying and discover that your opinion is a little different than you thought it was. You and I always do this when we try to make sense of things. When we make sense, we talk; we look back over what we said, and finally, we discover what we were thinking. People need to act in order to discover what they face, they need to talk in order to discover what they think, and they need to feel in order to discover what things mean when you say something that involves action and animation; when you see what you said, that involves directed observation; and when you conclude what your words mean, that finally tells you what you’ve been thinking.

Usually, we assume that we think and then we act. We do that less often than it appears we do. Instead, we often make sense using the opposite sequence. We act in order to think; we think while acting, our thoughts are defined by what we do. If you substitute planning for thinking, you can see the relevance for this gathering. How can I know what I’ve planned until I see what I’ve checked off? Plans reflect the words you use to describe something and what you see in those words. You act your way into plans rather than plan your way into acts. This is why sensemaking is not the same thing as decision-making. And this is why sensemaking affects your decisions.

—Karl Weick (personal communication)

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***“Actions create what we think, which continuously changes until we finish acting. During our behavioral interactions with the environment, our brain specifies desirable actions as the environment changes (50). Through the motor system, continuous, bottom-up feedback for sensorimotor control detects prediction errors, updating ongoing action. This feedback enhances or cancels some sensorimotor signals.”***

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Actions create what we think, which continuously changes until we finish acting. During our *behavioral* interactions with the environment, our brain specifies desirable actions as the environment changes (50). Through the motor system, continuous, bottom-up feedback for sensorimotor control detects prediction errors, updating ongoing action. This feedback enhances or cancels some sensorimotor signals. Self-generated cancellation as a motor function also explains why we cannot tickle ourselves. It is due to the sensory feedback through the motor system (51). Alternative actions continue to be mentally processed (50). This may extend to language comprehension, social cognition (52), and interpreting sensory signals (53). This makes it visible.

“The clash between a mistaken old belief and an updated belief would seem to be a form of dissonance...The more you engage in dynamic reasoning [processes], the less chance there is for dissonance between the old belief and the updated, [improving] belief to develop, the fewer errors you make, but at risk of a new set of cues being neglected.”

Karl Weick (personal communication)

Motor cognition is how we understand our movement and how movement helps us understand events.

#### *Learning by Doing*

Some problems involve unknown or uncertain pathways, inexact or unknown interventions, and other difficulties. These are ill-structured problems (7). Learning by doing almost always addresses ill-structured problems (8). Learning by doing in the HRO differs from the manufacturing sense (54) in that the HRO uses motor cognition. Improvisation is learning by doing.

Improvisation through learning by doing generates solutions and

reduces damage in unforeseen ways. Engagement is the act of learning by doing in context, not an outcome of rational deliberation, and cannot be objectified for theory-making (1). Engaged action comes from insight and immediate feedback, with negative feedback marking the safe boundary of performance and positive feedback generating growth. All feedback generates information. “Mistakes” indicate a change in circumstances (55) or interference from the environment (8). Nevertheless, mistakes are observable and, therefore, correctable (56). Effective responsiveness brings strength through change and allostasis.

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#### *Structure and Information*

Reciprocal decision-making describes how we observe the response to our action and how that response guides our next action. We learn what works through action. Decisions linked to action are probes to learn structure, redirect trajectory, create structure, and engage a threat. This is not trial-by-error or random action but is focused on the objective and what is observed in the situation. It is also not simple feedback, a component of decision trees or algorithms.

You identify reality by the way it responds to you. While abstractions do not respond to your actions, many people do respond to abstractions. This differentiates reflective thought from thinking by acting and motor cognition. Acting gives constant feedback for updating and revision of beliefs.

It is dangerous during an emergency to think that people from different socio-economic statuses make their decisions differently. More likely, their decisions are influenced by stress and fear and are more alike than is recognized (17). Inexperienced or untrained people are equally likely to make decisions for the good of others.

***Negative and positive feedback.*** Feedback maintains homeostasis for stable operations within a VUCA-2T environment, supports safety, and generates self-organization WHILE simultaneously bringing resolution to the event. Negative feedback corrects deviations from our desired state, and positive feedback supports our strength and resilience. To an outside observer, this method of homeostasis may appear to be one of constant or repeated error rather than continuous assurance of effectiveness and safety.

A control system maintains *homeostasis* by monitoring distance from a set point. *Negative feedback* deviates from the desired set point that a corrective action can offset. Negative feedback marks our boundaries for safe operations.

Correcting negative feedback may be an error, but it is a mark of safety, resilience, and adaptability. As we operate in this unstable environment, we will also test the boundaries between our performance capabilities and the limits for safety and harm. These boundary checks can sometimes only be performed in real-world situations in real-time. Failures are helpful in these situations be-

cause they mark our performance *boundaries*. The outsider, not appreciating the exigencies of the situation, may have a different, negative interpretation of this level of operation.

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***“Hurricane damage forced several NICUs to improvise neonatal care for prolonged periods. In nearly all the published hurricane experiences we reviewed, problem-solving happened locally (57). One outside hospital directing evacuation efforts relied on a government agency’s report that all hospitals were empty.”***

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#### **NICU Improvisations**

Hurricane damage forced several NICUs to improvise neonatal care for prolonged periods. In nearly all the published hurricane experiences we reviewed, problem-solving happened locally (57). One outside hospital directing evacuation efforts relied on a government agency’s report that all hospitals were empty. Reached by a text message from a NICU following a circuitous route, they learned of an entrapped NICU and hospital. Neonatologists and NICU staff may look to government agencies and emergency services for help, but they must rely on their own capabilities and improvisations to save babies.

- One preterm neonate arrived in the NICU with umbilical catheters in place. While preparing for intubation and surfactant administration, the lights flickered and went out. “I grabbed my penlight and flashed it so that a nurse could see to position a baby’s Ambu bag,” reported a nurse (58).
- Without intubation, a nurse improvised CPAP for an infant with tubing and forced air. Her system supported the infant for the next ten hours and through evacuation to the other hospital. This is how she started her twenty-one-hour shift in a hurricane (58).
- The Israeli Defense Forces (State of Israel) Field Hospital (59) improvised neonatal care for a premature newborn of 31 weeks gestation, 1,520 grams. The preterm infant deteriorated to apnea with bradycardia. The team improvised a CPAP device for respiratory stability. They chose CPAP over intubation because the infant would be transported by ground ambulance for three hours.
- Premature neonates developed hypothermia during five hurricanes, including a tropical cyclone. Four were treated with skin-skin contact; other treatments included warming pads (peri-pads), plastic wrap, blankets, and multiples in a single incubator.
- An orthopedic surgery resident received a one-minute-in-service on hand ventilating a premature infant to enable transport by canoe (60)

The capability to improvise care attests to the quality of neonatal personnel (and orthopedic surgery residents).

#### **Self-organizing Improvisation**

The authors developed an After-Action Report for the San Bernardino (CA) County Fire Department for the previously described active shooter incident on December 2, 2015 (22). The Law Enforcement (LE) officers and SWAT team organized and improvised solutions to secure the building while at the same time initiating casualty care. Probation officers, who are not usually part of an

active shooter response, arrived early and organized themselves to provide aid to the wounded, extract casualties, and then drive them to Triage A. SBF D organized for a large number of casualties and organized a team to enter the warm zone, improvising as they approached. Then, these self-organizing units merged at various times to create larger self-organized groupings.

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***“The “leader-leader” (61) form of leadership contributed to the initiative and improvisation demonstrated throughout the event. “Visual communication” played a prominent role in these operations. Various small unit actions are self-organized to merge and rapidly improvise solutions on the spot, a type of “self-organizing improvisation.” This did not arise from a specific plan or training.”***

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The “leader-leader” (61) form of leadership contributed to the initiative and improvisation demonstrated throughout the event. “Visual communication” played a prominent role in these operations. Various small unit actions are self-organized to merge and rapidly improvise solutions on the spot, a type of “self-organizing improvisation.” This did not arise from a specific plan or training.

We characterize *self-organizing improvisation* as HRO made visible, emerging from each organization’s shared culture and leadership. Their plans were not improvised. Improvisation was the plan. Training can support this approach.

This active shooter incident drove actions (self-organization), and the incident drove their solutions (improvisation). This contrasts with abiding by a well-thought-out plan, which would have forced the first responders to wait for the accepted thresholds to be identified as having been reached prior to acting. Participants learned that the system may not have a solution to the problem, a belief supporting improvisation (4).

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***“This active shooter incident drove actions (self-organization), and the incident drove their solutions (improvisation). This contrasts with abiding by a well-thought-out plan, which would have forced the first responders to wait for the accepted thresholds to be identified as having been reached prior to acting.”***

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## **Conclusion**

Improvisation is operations in a liminal state. Everyone has ex-

perienced being thrust into an unfamiliar circumstance. We have crossed a threshold into an environment of exigency and flux where the rules we know do not apply. We have improvisation in this transition between a world we know and a world we are unsure of. When hope does not help us, we have to improvise. When everything we tried has failed, we have improvisation. Improvisation is not simply conceptual knowledge and application of those concepts. Though we may master concepts, we never master experience (25). Creating experience and extending knowledge come out of improvisation.

Improvisation can only come from a *first* action. Karl Weick addresses this in his “recipe” for improvisation. You cannot improvise unless you have taken some action. Improvisation plays off knowledge, experience, and the immediate past responses to actions (35). “HRO is a trajectory of engagement that fuses now with the experience of then into simultaneous inquiry and redescription,” Karl Weick (personal communication) said.

Jens Rasmussen also recognized this at the local level of a crisis. We rely on local or special knowledge when the particular is novel, such as deference to expertise (5). Rasmussen classifies these situations into a *knowledge-based* system.

“Operators are maintained in [complex technological] systems because they are flexible, can learn and do adapt to the peculiarities of the system, and thus they are expected to plug the holes in the designer’s imagination.”

*Jens Rasmussen (62)*

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***“When pre-plans cannot cover every eventuality or the designer’s imagination fails, as they will in a crisis, we must recover quickly. Those at the point of contact will improvise. Their improvisation, driven by their optimism, is when resilience begins.”***

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When pre-plans cannot cover every eventuality or the designer’s imagination fails, as they will in a crisis, we must recover quickly. Those at the point of contact will improvise. Their improvisation, driven by their optimism, is when resilience begins.

Improvisation is our adaptive survival function, encountering forcing functions and abrupt change. If improvisation is the “figuring out mechanism” for HRO, how do we figure out *how* to improvise? That is article #3 in *Neonatology Today’s* Improvisation Series.

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**Disclosures:** *There are no reported disclosures*

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**Acknowledgments**

Karl Weick, Rensis Likert Distinguished University Professor of Organizational Behavior and Psychology, Emeritus, University of Michigan

William J. Corr, formerly with the Los Angeles City Fire Department (retired)

Raymond Novaco, Professor, Psychology and Social Behavior, School of Social Ecology, University of California, Irvine, California

Ronald D. Stewart, Professor, Emergency Medical Services, Dalhousie University, Nova Scotia, Canada

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