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Implementation of High Reliability Organizing (HRO): The Inherent Vice of Stress, Fear, and Threat

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Abstract:

The human mind evolved to naturally engage adversity – whether in the environment or from an enemy. Behaviors and our environment will be unpredictable because they are continuously oscillating, creating frequencies, and some of those frequencies have long periods. The long period frequency, acting alone or with other long period frequencies, creates forcing functions. Individuals, organizations, and the environment must respond in some manner to these forcing functions. The human brain will release corticotropin-releasing factor (CRF), which goes to the hypothalamic-pituitary-adrenal axis (HPA), and the HPA terminates ongoing activity, suppresses the executive functions, and impairs abstract cognition. Concurrently, CRF enters the locus coeruleus-norepinephrine system (LC-NE) to reorient cognition for attention and arousal – adaptive cognition is started, the individual focuses on behaviors, and engagement follows.

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"During times of extreme stress, the brain takes the prefrontal cortex 'off-line' in favor of automated flight or fight responses." This is a common belief held by scientists, healthcare professionals, and the lay public. However, it is the extensive experience of the authors that one can, and must, think clearly in live-or-die situations. William J. Corr, fire captain, and WWII US Navy veteran, South Pacific, admonished firefighters, "When your body moves faster than your mind can work, slow down."

As demonstrated in the following vignettes, our brains have the 'inherent qualities' necessary to function well in the presence of sudden dangerous situations. These qualities, unfortunately, can act as latent defects that cause serious damage – an 'inherent vice.' Consequently, it is common to depreciate their effectiveness. People mislead themselves when they try to make sense of human responses to threats in a way that fits their understanding. These vignettes reveal the strength of our stress, fear, and threat responses.

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- A shooting victim from a mass shooting ran into a pediatric clinic for safety. After administering medical aid, the general pediatrician went to the building to see if his associates on the second floor needed help. Because the shooters were still thought to be in the room, he used the stairway next to the entry door of the conference room where the shooting occurred. There was no answer at the door, and police had not yet arrived. He then realized that he might be confused with an assailant because he was of Middle Eastern descent. He ran back to the clinic to continue giving aid to those suffering emotional trauma during the incident. He took these actions in less than six minutes (1).
- Upon hearing gunshots, teachers in an elementary school evacuated their students towards a back gate, then left the school grounds. They were leaving the school as a group as the first law enforcement officers arrived. There was no evacuation announcement and no discussions between teachers during the evacuation. They had not received 'active shooter' training, nor did the school have an active shooter plan. Some students thought they were going on a field trip. School staff had quietly evacuated about 400 children in less than seven minutes (2).
- A passenger ship with 581 guests and crew sailed into 40-knot winds and 9m-high (30ft) waves, began drifting sideways into the waves and listing back and forth. It was late at night. Chairs began sliding. Passengers moved to sit on the floor. A guitarist observed crew members wearing life jackets racing aft. The lights went out, replaced by emergency lighting. The cruise director reported that the captain had said they should prepare to abandon the ship. Not hearing instructions from the crew, the guitarist and a magician went below decks to learn more. They reached a bulkhead sealed off by water-tight doors. The ship must be taking on water (3).

  Some crew members had lowered lifeboats on the embarkation deck, taking on women and children. However, those in the lifeboats were disproportionately crew and senior officers. There had been no announcement, no alarm sounded.

The guitarist returned to the lower decks to learn more, but he could hear the sound of water flowing this time. The ship was sinking.

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The guitarist, cruise director, the magician, now joined by another magician and a few other mostly female entertainment staff, figured out how to release the lifeboats. They carried out the evacuation of guests. Passengers stopped asking about the ship's officers, realizing the entertainers were now in charge. After the launch of the last lifeboat, 220 people remained on board (4, 5).

The entertainers went to the bridge to seek assistance from the captain and senior officers. The bridge was empty. The guitarist called "Mayday" repeatedly on the radio. A voice answered, "Yes, what is your Mayday?" The guitarist explained that the ship was sinking (3).

"OK. How long have you got left to float?"

"I don't know - we've got the starboard railings in the water, we're rolling around, we've taken on a huge amount of water. We still have at least 200 people on board."

"OK. What is your position?" "What are your coordinates?" The guitarist had no idea.

"What rank are you?"

"Well, I'm not a rank - I'm a guitarist." A moment's silence.

"What are you doing on the bridge?"

"Well, there's nobody else here."

"Who's on the bridge with you?"

"It's me, my wife - the bass player, we've got a magician here…'"

The guitarist had no idea where the captain was. The crew remaining on the ship were mostly Filipino cooks and kitchen staff.

During the navy helicopter evacuation, one magician remained on the bridge for radio contact. Another magician joined a navy rescue diver in a Zodiac inflatable boat to rescue anyone who fell or jumped into the sea. The guitarist, bass player-singer, and the cruise director worked together to evacuate passengers by helicopter. The captain was one of the first people rescued by helicopter, stepping in front of elderly passengers. He stated he needed to direct the rescue from land (6).

No lives were lost in the sinking of the passenger ship.

[The captain remains with the ship because the captain knows the capability of the crew and ship, understands and has monitored the damage, and has the knowledge of the ship to direct damage control, salvage, and rescue operations. The crew cannot jettison lifeboats without the captain's order to abandon the ship because the captain needs the full crew to save the ship. Passengers are safer on the ship than in lifeboats. It would be considered mutiny for the crew to leave the ship on lifeboats without the captain's orders (TAM).]

- A combat medic treated American and allied soldiers after an artillery barrage hit their compound and damaged the perimeter. Treating the more seriously wounded soldiers used up his antibiotics. The allied soldiers made direct threats for him to treat the other wounded with antibiotics. Since the evening was approaching, the area commander denied helicopter pilots permission to evacuate the wounded. That would wait for morning. Enemy soldiers were 800 meters out. He thought he would be killed one way or another.

- In her first day at the school, a kindergarten teacher stood at the door of her classroom as all of her students ran out each of the four exit doors. The sky was black. The school had just received a tornado alert, then an announcement to move students to the designated shelter. Nearby teachers could not assist her because they were escorting their students to the shelter. She lost her students, and now she thought she would lose her job (personal communication from the medic and teacher, DvS).

  Helicopter pilots lifted off from their base despite the command to evacuate the wounded. Despite responsibility for their young students, the teachers gathered the scattering kindergarteners. The medic later understood he had a standard supply of antibiotics and learned they were victims of friendly fire. The teacher learned that a tornado had hit the school the year before, killing three students, friends of her kindergarteners. They had run away from fear.

  One of the authors (DvS) asked the army medic how he and his experience differed from the teacher and her experience. There was no difference, the medic answered. It was not the fault of either person. The helping responders were not supposed to help. And both individuals have the same brain and had the same response.

"Our circumstances shift between limits in the actual world, much like a pendulum. Some perturbations have long time periods where change has a slow but forceful appearance. Some perturbations are rare but catastrophic. By representing these as frequencies, there is no unique distinction between normal variation, exigencies, or catastrophes."

Introduction

Our circumstances shift between limits in the actual world, much like a pendulum. Some perturbations have long time periods where change has a slow but forceful appearance. Some perturbations are rare but catastrophic. By representing these as frequencies, there is no unique distinction between normal variation, exigencies, or catastrophes. They are the same but experienced at different time scales (7).

The extent of danger is not often apparent at first glance. The transition to "emergency mode" for subtle presentations is as fraught as the sudden appearance of danger. Individuals have their "normal" thinking processes and what they believe is their "emergency" thinking. Reliance on the singular "fight-or-flight" responses for a crisis is not only maladaptive during the crisis, but it also becomes too readily accepted for almost any demand. It is also not true.

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The experience of veteran operators belies the academic and management science focus on the fight-flight-freeze response to stress or fear for emergency operations (8, 9). "In potentially or unsafe situations, the ability to reorient attention to potential threats, mobilize energy resources, and take rapid unpremeditated action is critical to immediate survival" (10). The effective operator searches for "alternative tasks that may provide better solutions during a changing environment or when the present behavior is not optimally adaptive" (11).

For this to happen, the brain resets attention, reframes the situation, and changes its orientation from achieving a goal to performing specific tasks (12). Untrained neuromodulation, abstract thought, and top-down goals will bias one toward preferred signals. For an individual experienced with the situation, this acts as common sense. For the spectator or inexperienced operator, it can easily lead to harm (13). During an environmental change or temporal-spatial correlation, the individual neuromodulates responses to the context. Necessary, automatic bottom-up processes do not depend on top-down attention (10), hence the effectiveness.

For this rapid shift to occur, the brain must decrease the influence of the executive functions while enhancing motor behaviors and cognition. The amygdala responds to a perceived threat by causing the periventricular nucleus of the hypothalamus to secrete corticotropin-releasing factor (CRF). CRF simultaneously stimulates two systems: 1) the hypothalamic-pituitary-adrenal axis (HPA) to inhibit abstract thinking and memory and 2) the locus coeruleus-norepinephrine (LC-NE) system for adaptive thinking and behaviors. This initiates the adaptive cognitive shift necessary for survival.

People inexperienced operating in a dangerous context can combine the brain's emergency responses with flexible cognitive skills for agile, effective, thoughtful action. The vignettes describe these successes. The brain creates an effective stress response by parallel engagement of its cognitive, hormonal, and emergency functions. Because not all dangers are immediately obvious, the brain can rapidly reorient attention to subtle threats or potential threats.

Oscillations and oscillatory processes are fundamental to the functions of life and the physical world. The entry of noise energy into an open, nonlinear system increases these oscillations. Stochastic resonance amplifies weak or relatively small noise, creating and sustaining significant oscillations. Thus, through resonance, the happenstance of noise amplifies tolerable risk levels, converting small risks into crises.

These oscillatory processes form frequencies within the system, frequencies that can also resonate with other frequencies in neighboring systems. Events are no longer independent of preceding events, becoming autocorrelated (the current behavior correlates with previous behavior). Autocorrelated events are more susceptible to feedback loops, allowing even minor or mundane noise signals to achieve resonance, amplify, and generate meaningful events. More data does not bring more understanding. Rather, more data clouds whatever conclusions we attempt to reach.

The stress, fear, and threat responses of the HPA axis are necessary to engage environmental forcing functions. These qualities, however, can also harm the individual and organization – the 'inherent vice' of stress, fear, and threat. The LC-NE system and dopamine networks fill the space by enhancing adaptive cognition and behaviors. We think of stress, fear, and threat as fragile, but they are strengths that can cause fragility.

For operations in dangerous contexts or the liminal zone (9), we make the functional distinction between the drive to escape the threat, that is, to create distance between the individual and the threat, and the drive to disable the threat. The former we call *fear reactions* and the latter *threat reflexes*.

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Environment and the Color of Noise

We tend to think about and discuss stress, fear, and threat in danger or risk. Heini Hediger (14) described how animals have an 'escape reaction,' the animal moves to maintain a specific 'flight distance.' Within a 'defense distance,' the animal will attack in self-defense to escape. Because the danger need not be a predator, Hediger used the term "enemy."

The terms enemy, predator, threat, risk, and danger are subjective. They also too easily become terms for diminishing a person's perceptions of the stimulus or initiate shows of bravado in some individuals. We find the concept of "forcing functions" not only neutral but more descriptive. Forcing functions arise from reddened noise frequencies or sudden 'flicker' events in pink noise. Forcing functions may be singular due to long-period events or result from resonance between several red noise frequencies.

A system's frequencies generated by natural oscillating processes can be described by their 'color.' That is, 'white noise' with constrained variance describes a flattened spectrum where no frequencies dominate. Each time interval in a time series is independent of other intervals. The randomness, independence, and discrete-time intervals create a Gaussian distribution to calculate statistics and probabilities. White noise environments support mathematically tractable models and more concise theories while giving greater conceptual clarity (15, 16). White noise is the variance incorporated into academic and scientific models (17). While we use white noise for our mental representations of the environment, predictions, algorithms, rules, and protocols, we must not

mistake it for the actual world.

"Red and pink noise develop from autocorrelation, the feedback when the past influences the present or a system interacts with other systems. Red and pink noise has zero mean, increasing variance, and are autocorrelated in time by feedback. As power distributions, the non-Gaussian nature of red and pink noise distributions impairs our ability to use classical logic, rigid models, and strict concepts."

Red and pink noise develop from autocorrelation, the feedback when the past influences the present or a system interacts with other systems. Red and pink noise has zero mean, increasing variance with more data, and are autocorrelated in time by feedback. The data in these non-Gaussian systems create power distributions with events of greater magnitude having a lower frequency of occurrence. The non-Gaussian distributions impair our ability to use classical logic, rigid models, and strict concepts. "In comparisons of model predictions and real data, stochastic models often perform as poorly as deterministic ones, John M. Halley (7). Uncommon or long-period events have a greater influence on the system than the larger number of more frequent small events.

The development of autocorrelation, described above, converts white frequencies to red or pink noise. Not as a transition, but more like a phase change to new properties without a change in composition. The long periods of red frequencies or the rare flicker events of the pink frequency (1/*f*) can mislead us into believing we operate in a white noise environment. We can identify this difference when more data or collecting data over a longer time series does not produce a better norm or better stochastic models. Karl Weick (personal communication) described these environments as "a mix of white and red, and that red is the thing to be avoided. Pink is the com penetration of white and red and is the mess that sensemaking tries to untangle."

> "Pink noise shows no preference for short or long timescale disturbances. From seconds to millennia, all natural disturbances of various sizes can be seen as part of a seamless l/*f*-noise process. In this picture we need not make any special distinction between normal environmental variation and ecological 'catastrophes': it is the same thing seen at different scales."
>
> John M. Halley (7)

Autocorrelation

Autocorrelation is present when an observation or the value of data depends on what preceded the observation or measurement, or they depend on surrounding values. In research, the independent variable is not independent.

Time. In a time series, temporal autocorrelation occurs when a previous time interval influences a time interval.

Environment. Spatial autocorrelation describes the patchiness of people or things. Values can partly predict the value at any one locality at neighboring points. People and things are neither distributed uniformly nor randomly (19). They are near others for a reason, such as an environmental forcing function or an internal social process. Spatial autocorrelation can be positive or negative, representing aggregations versus scarcity. In epidemiology, spatial autocorrelation identifies disease clustering in a general or specific region. Spatial autocorrelation measures the degree of similarity between objects that are located near each other (20). *As a form of contextualization, spatial autocorrelation heavily influences stress, fear, and threat.*

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Color	Structure	Variance	Distribution
White	No frequencies dominate Flattened spectrum	Data *decreases* variance	Gaussian distribution - Elements fully independent - No autocorrelation
Red	Low frequencies dominate Long-period cycles	Data *increases* variance	Power law distribution - Elements *not* independent - Mutual/ reciprocal relations
Pink	The midpoint of red noise Slope lies *exactly* midway between white noise and brown (random) noise	Data *continuously increases* variance Distinguishes pink noise from reddened spectra	Power law distribution - No well-defined long-term mean - No well-defined value at a single point

Table 1. Patterns and Characteristics of Noise (18)

Spatial autocorrelation can cause the appearance of a 'false' gra-

dient. In a 'true' gradient, neighboring elements are not coordinated with each other, the changes in value deriving from their coordinates. In a false gradient, the change in value across space is caused by autocorrelation from the values and influences of its neighbors. The change in value is not due to its location (19).

Phylogenetic autocorrelation. Evolvable entities tend to have similar traits the closer the entities are to their recent ancestor (21). For example, in their response to stress, fear, and threat, healthcare specialties have greater similarities than public safety services.

Behavior. People, as social and learning organisms, demonstrate behavioral autocorrelation. Autocorrelation within a group creates culture, and the individual acculturates to that group through autocorrelation. Mirror neurons (22, 23) support team formation through autocorrelation. The autocorrelation of human behavior gives the reddened noise that confounds our ability to predict how others will act.

Forcing Functions

Triggered by environmental noise, mundane elements in our environment develop the power to force a system or population to respond to the environment. Such 'forcing functions' act on a variety of scales. Some simply occupy our attention while other low-frequency events erupt into major crises in our presence. Forcing functions introduce emergent new properties into the system.

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Even when there are no significant events, these unexpected circumstances carry a level of novelty and uncertainty that confounds us, producing a level of unpredictability challenging our ability to bring control to the situation. We can even marvel at the unfolding situation at a distance. We may change our approach, putting distance between us and the threat up close. Too sudden and too close brings out surprising reflexive survival behaviors we did not know we had.

Qualities of novelty, uncertainty, unpredictability, and uncontrollability are also the causes of the brain's stress responses to thinking and executive functions. The proximity of an emergent threat to the individual will stimulate fear reactions within the brain and subsequent behaviors. Rapid appearance or impending contact triggers threat reflexes and subsequent unconscious behaviors. We want to retain these inherent adaptive qualities while minimizing their inherent vice. We cannot protect ourselves from low-frequency events, but we can engage them.

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Stress, Fear, Threat

Nobel laureate, Niko Tinbergen, observed that "every animal has to cope in numerous ways with a hostile, at least uncooperative, environment." He posited that behavior is the most immediately adaptive method for the ability to cope and survive. We cannot identify the precedents of behavior, but we can discuss the *function* of behaviors. He described these functions as achievements to better understand the defensive cascade that protects the organism (24).

The primary defensive and survival functions are 1) hindered memory systems that limit abstract thought (stress responses), 2) volitional behaviors for self-preservation (fear reactions), and 3)

Condition	Cause	Characteristics	Location	Effects
Stress response	Novelty Uncertainty Uncontrollability	Objective Neurochemical release	SAM* HPA Axis** Cortisol	Retained motor memory Impaired declarative & working memory Impaired cognition
Fear reaction	Proximity	Subjective Feeling	Ventromedial Prefrontal cortex Periaqueductal Gray	Maintain distance by attentive freeze, flight, then fight
Threat reflex	Existential harm	Objective Behaviors	Amygdala Prefrontal cortex	Fight, anger Flight, avoid Freeze, vigilance Tonic immobility, nausea Dissociation

Table 2. Stress, Fear, and Threat (25)
* *SAM sympathetic-adrenal-medullary*
** *HPA hypothalamic-pituitary-adrenal axis*

reflexive, subcortical actions (threat reflexes). When faced with an exigency, our brain releases cortisol to constrain abstract thought, which permits us to focus cognitive functions on context and action (stress). An approaching threat is detected by our brain below the level of awareness and monitored for distance and direction; we are prepared to run or fight as necessary (fear). Proximal, imminent danger initiates reflexive protective behaviors while maintaining our cognitive functions (threat).

Novelty, uncertainty, and uncontrollability are the causes of objective *stress responses*. The proximity of a threat creates subjective *fear reactions*. Sudden, existential harm will trigger objective *threat reflexes* (Table 2).

We do not spend excess time lost in thinking of abstractions and theories through stress responses. We unconsciously maintain a safe working distance from the threat, and we act before our awareness recognizes the nearby threat. Our brain and body effectively engage in danger through stress, fear, and threat. These desirable qualities can become an undesired 'inherent vice' that causes internal damage to the person. The damage is not a cause; it is an effect.

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Confounding discussions of stress, fear, and threat are beliefs that represent a primitive brain, are instincts, cannot be modulated or prevent thinking. Instincts as behaviors develop from the genome and environment. The behavior is a programmed innate behavioral drive or a psychological need for behavior from genes (the genome). The gene is manifested as the phenotype, a set of behaviors that can act on and respond to the environment. It is instinctive that the behavior can be developed and expressed only in the proper environment (26-28). The behavior is not ballistic, though, acting out past a point of no return. Thinking and learning can be modified and modulated even when instinctual in origin.

Fight and flight are well-known threat reflexes but are also fear reactions. They have different functions as fear or threat, differing in their motor and affective components. While emotions are considered to have five components, discussions commonly combine the motor component and subjective experience rather than describe them separately (29). In some communities, the motor component may predominate, while in others, the subjective experiences of stress, fear, and threat predominate. In professional organizations such as healthcare, the subjective experience predominates. The individual expressing stress, fear, or threat as a subjective experience may deny the emotional state, while those who are the target of the emotion may not recognize the behavior as stress, fear, or threat emotion.

We present the maladaptive behaviors of stress, fear, and threat under the insurance term "inherent vice." "Inherent vice" means "any existing defects, diseases, decay or the inherent nature of the commodity which will cause it to deteriorate with a lapse of time" (30). "The decay of a perishable cargo is not a cause; it is an effect" (31). Maladaptive behaviors develop when the individual has not learned to modulate the behaviors, or they have become reinforced through operant conditioning

Cognitive Function

Stress, fear, and threat combine emotion, cognition, and behavior – a broad range for a singular theory. We have described the operational function, harm, and inherent vice of stress, fear, and threat and methods to overcome the problems (9, 25, 32-35). We have also searched the sciences for assistance to help with entry into the liminal zone and improve engagement in dangerous contexts.

Threat identified through the sympathetic-adrenal-medullary axis (SAM) stimulates the paraventricular nucleus of the hypothalamus to release corticotropin-releasing factor (CRF) into the anterior pituitary *and* the locus coeruleus (LC). This release activates both hypothalamic-pituitary-adrenal (HPA) axis and the locus coeruleus-norepinephrine (LC-NE) system. The HPA axis suppresses the executive functions to support engagement, while the LC-NE system supports the cognition and behaviors necessary for engagement. CRF from the central nucleus of the amygdala may also activate the LC.

Locus Coeruleus and Norepinephrine

The release of norepinephrine appears to terminate the resting cognitive state. The brain reorients from the current activity to a new behavioral response—cortical, subcortical, and autonomic activity shift to facilitate focused attention for task-oriented behaviors.

LC-NE system operates at three levels of tonic activity:

- low in the unaroused state, facilitating sleep and disengagement from the environment
- moderate when engaged in a focused task, enhancing performance, filtering out irrelevant stimuli
- high when not committed to a task, exploring the environment

Attention and arousal

From a thorough review of the literature, Jennifer Ross and Elisabeth Van Bockstaele (36) have identified the two themes of attention and arousal. More critical is their finding that LC-NE mediates selective attention for salient stimuli with concurrent silencing of irrelevant stimuli. During a challenge from threat, both excitation and inhibition occur simultaneously throughout the brain.

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While combined excitation and inhibition seem straightforward, the method used in the models is effective in engaging the threat. NE can silence some signals while enhancing others. The LC has

increased response to strong stimuli with decreased response to weak stimuli, enhancing the signal-to-noise ratio. The brain can encode and filter salience (36).

Attention and attentional modulation. Inhibitory neurons modulate attention by the ability to suppress the sensitivity of some stimuli while increasing high-frequency synchronous oscillations associated with other stimuli. Using red noise behavior to amplify desired signals (increased sensitivity and decreased noise correlations). This *inhibitory control,* or response inhibition, is the executive function that inhibits impulses and dominant, pre-planned (prepotent) behavioral responses to stimuli. This executive function helps select behaviors consistent with one's goals (37).

"Forcing function as a neutral term can drive investigation into the various reddened frequencies and stochastic interactions that make them so troublesome. Focus on error and safety as persuasion implies telling someone what they are not – mistaken and unsafe."

The focus on the effects of stress on attention led to the idea that active attention processes information from the top-down, and the individual directs attention to attain a goal. Passive attention processes information from the bottom-up, driven by environmental stimuli. Attention is intentionally focused (top-down) or attention is attracted (bottom-up) (36). Humans may innately and subcortically evaluate the environment before environmental cues reach awareness, trigger emotions, or initiate higher-order cognition (38).

Arousal from emotional events. Emotional events selectively enhance and impair perception and memory. Based on the priority of a stimulus, this arousal can enhance or suppress cognitive processes. Norepinephrine (NE) from the locus coeruleus influences perception and memory to select salient ensembles of signals while suppressing lower priority ensembles. To achieve this differential effect, glutamate and NE are co-released by arousal in prioritized regions for an excitatory effect. Magnifying the excitatory effect, NE intensifies suppression of weaker, low-priority responses through inhibitory processes, the inhibitory control of the executive functions (39). These signals produce oscillatory synchrony, a red noise effect that makes the signals relevant.

Salience. As stress research increased, the threat became the focus of the stimulus that caused stress. A threat can compromise survival. To suppress threats would involve any number of tasks. Specifically, it would involve selecting specific tasks at the opportune time. Ross and Van Bockstaele (36) posit that prioritizing tasks to meet the threat led to the consideration of salience as a cognitive process.

Large Scale Networks

We think of pathways when we discuss neurotransmitters. Neuroscientists recently identified brain regions connected through networks rather than nerve tracts or pathways. The understanding of the neural basis of cognition had shifted. These networks form Intrinsic Connectivity Networks (ICNs), highly connected large-scale brain regions active during a specific set of cognitive responses (36).

These networks operate independently, coming into opposition from environmental threats. As described below, the Ventral Attention Network interrupts the Dorsal Attention Network, and the central executive network suppresses the default mode network.

Dorsal and Ventral Attention Networks

Two neuroanatomically defined systems appear to control the top-down and bottom-up information processing during the orienting reflex. Environmental cues from a novel or infrequent events interrupt ongoing task-related cognitive activities. This bottom-up processing of sensory cues quickly reorients cognitive attention (40).

- Dorsal Attention Network (DAN), top-down cognitive information processing, task-related stimulus-response, pairs cognitive cues with motor responses
- Ventral Attention Network (VAN), bottom-up identification of salient or novel stimuli in the environment

DAN, left-lateralized in the prefrontal cortex, may control attention involved in motor responses to task-related stimuli. When encountering a novel or infrequent sensory stimulus, the right-lateralized VAN may facilitate reorientation. When VAN detects unexpected or novel stimuli, it interrupts DAN to reorient from the current activity to a new behavioral response. This VAN activity depends on norepinephrine delivered from the locus coeruleus (41).

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The Triple Network

Brain regions do not respond to stress in isolation. Organized, functional, dynamic networks interact across brain regions (42).

- *The salience network (SN)* responds to salient stimuli, orienting and coordinating attention towards internal or external information. SN may support hypervigilance.
- *The default mode network (DMN)* is activated during stimulus-independent tasks or internal thought, forming perceptions of others, or retrieving memories; usually suppressed during CEN activation
- *The central executive network (CEN)* supports higher-order cognitive tasks, attention, manipulating information, working memory, decision making for goal-directed behavior

Combined Networks

The science has not settled, causing inconsistent naming and regionalization. However, the SN (salience) is highest in the hierarchy. The Attention and Triple Networks interact, suggesting that cognition under stress is a balance between three core ICNs: DMN, CEN, and SN. From their coordination emerges cognition, goal-directed, and stimulus-directed behavior (36).

- Connections from SN (salience) and DAN (information processing) to DMN (stimulus-independent) are inhibitory, while reverse connections are weakly excitatory.
- Bidirectional connections between SN (salience) and DAN (information processing) are excitatory.
- VAN (environmental reorienting) has shared regions with SN

(salience).

Stress Research

In this paper, we presented stress research from the operator's perspective. Difficulties develop when we bring models created for conceptual clarity into a chaotic environment. The liminal environment, particularly in a dangerous context, may or may not be a source of stress for all participants (9). A typical team has people with various experiences and stress capacities, creating new social autocorrelations with each incident. No team is ever the same, even when the members do not change.

Science can, and should, inform practice. Though practice should inform science, it is impractical for a laboratory approach (43). Red noise, even pink noise, characterizes the fields that create stress during operations. Collecting more data increases variance. Below we describe how science can advance from science interactions, the environment, and the scientific operator. Specific to dangerous contexts, we honor the finding of Vanessa Heggie. About science and Mount Everest: "Predicting what would happen to the first human beings to climb that high [27,000 feet] was therefore literally a matter of life or death – here inaccurate models could kill" (44).

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Field Experience, Research

As stories that caution against discounting experience, we describe the attempts to climb Mount Everest, the development of cholera treatment, and assisted ventilation.

Mount Everest (8). From 1921to 1952, eleven expeditions to climb Everest failed to climb higher than about 27,000 feet (45-49), an attitude that seemed to the limit of human endurance. George Finch, a mountaineer and scientist with engineering skills, developed the oxygen equipment for the 1922 expedition. It would be similar to that used for the successful 1953 expedition. He believed that above 23,000 feet, the physical deterioration from poor sleep and appetite outweighed the benefit of acclimatization (50). He strongly advocated for better food, including pre-packed rations (50). Despite setting an altitude record of 27,320 feet on the 1922 Everest expedition, Finch was excluded from the 1924 expedition and had been denied membership to the London Alpine Club because of his personality. His ideas did not match the high altitude science at the time. Science developed in pressure chambers for aeronautics (50, 51).

International pressure forced the London Alpine Club to use science. In 1952, they brought in Gifford Pugh, a physiologist, experienced climber., and mountain warfare instructor. He focused on diet, oxygen, fatigue, and acclimatization. The expedition leader for the preparatory expedition suggested that the expedition "carry out experiments in the use of oxygen apparatus; to study physiological problems of high altitude climbing, such as acclimatization and deterioration, diet and liquid consumption; and test clothing and equipment" (52). In 1953, Sir Edmund Hillary and Tenzing Norgay reached the summit of Everest, smiled, removed their oxygen set, and took photos. John Hunt lauded Finch for showing how the physiological problems might be solved (51)

Cholera. For hundreds of years, treatments for cholera included fluids with salt and a form of sugar. SEATO and WHO research stations in South Asia studied treatments for cholera using skilled observation. One medical researcher stated, "The author places little reliance on clinical evidence of rehydration. He points out that there may be no difference in the appearance of an individual with a plasma-specific gravity of 1.037 (associated with an extracellular deficiency of 2 liters) and one well hydrated with a plasma-specific gravity of 1.027. Similarly, the plasma CO_2 can fall from the normal 28 mEq./litre to 18 without evident change in the clinical condition" Robert A. Phillips (53).

In 1962, a team of researchers, some had not yet completed their medical residencies, arrived in South Asia to research cholera treatment. By 1970, they overturned the current theory of cholera pathology: that cholera toxin poisoned the sodium pump. The use of a solution consisting of sugar, salts, and water could save the lives of severely dehydrated adults, children, and infants. However, the prevailing scientific theory prevented the publication of their research findings until 1983, when it became a chapter in a book on Diarrhea and Malnutrition (54, 55).

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Assisted ventilation. In the late 18th Century, it was "generally known that a child, born dead, may be brought to life by inflating its lungs, that the mother herself, or some other person, might have tried the experiment" (56). In 1814, a medical officer used mouth-to-mouth resuscitation: "there was reason to believe that life had not been long extinct. The child's lungs were, therefore, immediately inflated from my own, while the body was immersed in hot water, and volatile spirit occasionally applied to the nose, mouth, and chest." Again, "Interposing a piece of muslin inflated the lungs from my mouth, closing the nostrils by the pressure of my fingers. The thorax was compressed after each inflation, and thus artificial respiration was maintained, observing the natural periods of frequency, and keeping in mind the difference of capacity between the child's lungs and my own. In about half an hour, I felt a faint pulsation of the heart; a little fluttering, I thought I had perceived, once or twice at intervals, a few minutes before, but I was hardly sure of it." And again, several more times (57).

The officer also worked with spectators and scientists who told him it would not work. "I am aware this practice has been objected to. It has been urged that inflating the lungs with air so charged with carbonic acid gas is more likely to destroy than restore life. This objection is plausible but cannot possibly be true. Were it so, no case, such as those detailed where this method was used, could have been restored. A thing of which the uniform tendency is to destroy life, never can in a single instance reanimate, so that these cases show most satisfactorily that expired air may be taken not only safely, but salubriously, into the lungs of another… [B]ut I am sure the usual method of blowing into the lungs does

not merit that censure which has been cast upon it. While I would place my chief reliance on insufflation, persevering to repeat it at short intervals" (58).

We can use mouth-to-mouth resuscitation to model bag-valve-mask (BVM) resuscitation. BVM is associated with barotrauma and gastric insufflation (59, 60), complications rarely observed with mouth-to-mouth resuscitation. During mouth-to-mouth resuscitation, the rescuer feels the pressure change in lung compliance on inspiration and the end of expiration by the cheek. One of the author's (DvS) experience administering mouth-to-mouth breathing in the field to an infant, adolescent, and adult later informed his approach to BVM and mechanical ventilation for spontaneously breathing patients (61). As noted by Dr. Wilson in 1829, "I am aware this practice has been objected to."

Military combat. Several academicians criticized a study of soldiers in the operational area (62):

- As important as their study could be, however, problems in its design and execution limit any attempt to conclude it.
- [The authors] do not indicate that these quotes are statistically representative.
- [The authors] conclusions, if valid, would challenge the conventional wisdom about cohesion by showing that contrary to the consensus findings of the vast literature, the distinction between social and task cohesion is irrelevant.

"Strong research design and statistical analysis assume a Gaussian curve from a white noise environment. Conventional wisdom develops in an environment that is either white noise or long-period white noise and was encountered in several of the vignettes above."

Strong research design and statistical analysis assume a Gaussian curve from a white noise environment. Conventional wisdom develops in an environment that is either white noise or long-period white noise and was encountered in several of the vignettes above. The authors of the critiqued publication had deployed to an active war zone.

> "Interviews were conducted in the active combat zone with infantry soldiers who were fully armed and prepared to engage the enemy without notice. Each soldier or marine interviewed had at least one member of his organization wounded or killed in the preceding thirty days—several uniforms still bore bloodstains left by the evacuation of comrades—dark blotches over the chalky-white salt from daily living in 112-degree heat."
>
> "Is [it] scientifically appropriate to assume that the extensive work done in peaceful settings will necessarily generalize to combat?"
>
> "Previous work by the author that was based on data collected in combat has been criticized based on its ability to generalize to research done in routine, peaceful settings. The idea that behavioral and social scientists may test the robustness of their theories by studying the same phenomenon across *in extremis* settings is explored. Research involving human participants conducted in safe, peaceful settings will not necessarily generalize to combat; combat findings may differ from those developed elsewhere. The appropriate scientific approach is to replicate and extend, in the combat context, findings already well established in peacetime work."

Thomas A. Kolditz (63)

Conclusion

Forcing functions are an abiotic feature of ecosystems that influence, if not create, the organization's environment. By design, some organizations regularly operate in adverse environments while others prepare for the sporadic but expected red noise forcing function. The science of risk management addresses the possibility that all organizations must respond to a forcing function of some magnitude.

"Forcing functions are an abiotic feature of ecosystems that influence, if not create, the organization's environment. By design, some organizations regularly operate in adverse environments while others prepare for the sporadic but expected red noise forcing function. The science of risk management addresses the possibility that all organizations must respond to a forcing function of some magnitude. "

Individuals and organizations create and rely on the created structure. Patterns of defenses differ based on expected risk: predictability, controllability, variability, and the costs of defense (64). Note several elements are also causes of stress. Organizations that do not routinely experience forcing functions are more likely to use proactive defense mechanisms. Individuals, however, often use inducible reactive defense mechanisms, as illustrated by the vignettes in this article.

Risks will vary by location or over time, and defenses carry costs (64):

- Risks are predictable and controllable – proactive defenses have the greatest effectiveness
- Risks are increasingly unpredictable or uncontrollable – Reactive defenses are more effective and reliable
- Risks are consistently high, or defensive costs are low – fixed constitutive defenses become effective (spines, shells)
- Absence of the predator – vigilance, a defense cost, sustains the stress response with chronically elevated glucocorticoid levels (65, 66)

Inducible antipredator responses allow the selection of antipredator behaviors with variable expression, increased behaviors for elevated risks, and decreased expression as the risk abates [5]. We have an inducible antipredator response – terminate ongoing behaviors (the stress HPA axis) while initiating attention-arousal behaviors (the LC-NE system), which utilizes broad attention networks to sustain adequate cognition under stress.

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