High-Reliability Organizing (HRO): Engagement Matters, Is Personal, and Initiates Enactment 1. The Color of Noise Impairs Cognition

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Abstract

The characteristics of abrupt crises are the elements that cause stress and fear. Stress impairs cognition, fear generates defensive behaviors, and existential threat drives aggressive behaviors. Nobody wants this; organizations expend effort to prevent or mitigate stress and fear. Unfortunately, these efforts promulgate and normalize belief in the inevitability of stress. Fear becomes normalized through situationally accepted behaviors such as anger and intimidation, creating the ecology of fear. These same stress responses, fear reactions, and amygdala reflexes drive engagement in the situation. Engagement mitigates and resolves the crisis. Engagement also modulates the stress responses, fear reactions, and amygdala reflexes that enable that engagement. Counterintuitively, stress-impaired cognition, fear-circuit behaviors, and amygdala-driven reflexive behaviors caused by the crisis are necessary for engagement in that crisis.

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Introduction

Paramedics brought a pediatric motor vehicle collision victim into the trauma room. Staff became involved with the patient's care. The chief surgical resident for trauma entered, immediately calling out orders. Any miss brought a stiff rebuke from the chief resident. As the pediatric resident entered, the surgical resident demanded orders for specific drugs. The pediatric resident looked through a book and began calculating drug dosages. The surgical resident demanded a faster response. Everyone in the room worked rapidly, directing their attention toward the child rather than each other.

Later, the surgical resident ridiculed the pediatric resident for searching for drug doses in a book and using a calculator. The trauma residents were proud of their performance. What they saw was constant activity in response to their orders. One of the authors (DvS) had witnessed his first extensive resuscitation in a hospital and had a different view. The author observed the resuscitation team operating under the influence of fear.

The surgical resident did most of the talking, the tone tense, becoming louder as the resuscitation progressed. Communication only occurred from the chief resident to an individual. If people communicated at all, it was through eye contact and whispers. Coordination was about *not* interfering with each other rather than working together. Information was only given to the surgical resident when requested and only for that specific request. Nothing was volunteered. All actions followed direct orders from the resident; there was little independent action to fix an immediate problem.

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Was this resuscitation style effective, or did it impair performance? It depends on whether we value a top-down or bottom-up approach, tight control, or self-organized action. Undoubtedly, there was order during the resuscitation, but it was likely from a more normative approach than a pragmatic one. For the author, it was a stunning exhibition of what would *not* happen during a medical emergency in a dangerous setting. No one becomes angry in public safety and military operations – that is the fastest way to lose control of the incident or situation.

The author participated in a surgical emergency with a widely respected attending at a different hospital. The surgeon called for a chest tube. As nurses brought the chest tube, the surgeon stated it would be placed in the OR. Shortly afterward, the surgeon demanded to know where the chest tube was. They brought it back to the bedside. The surgeon asked why they were not taking the child to the OR, where they would place the chest tube. Each movement occupied 2-3 nurses who left resuscitation duties to address the chest tube. Presented to a group of fire chiefs, the chiefs, thinking this was a fire captain at a major emergency, assumed that the captain was relieved of command and referred to the department's EAP stress program. This occurrence is not an isolated situation. Two authors (DvS and SDK) have received reports about anger from other highly respected surgeons *during* an operation. The individuals requested anonymity, but the similarity of the descriptions is striking.

Uncontrollability, particularly the *sense* of uncontrollability, is perhaps the most significant driver of action during an emergency.

The sense of uncontrollability can drive a person to act faster than the mind can think. In time-compressed states, responses are immediate and visible. An individual learns quickly what works and what does not. Such quick responses reinforce this type of thinking and whether specific behaviors work. Often called "experience," these behaviors readily incorporate into one's identity. This incorporation leads to respect from those with less experience. This thinking is unchallenged and immune from disconfirmation by being ingrained into organizational knowledge.

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The belief too quickly forms that the stress of the situation impairs those who do not think fast. Their performance decreases as uncontrollability increases, an effect often described as the Yerkes-Dodson Curve (1). Increased stress impairs abstract thought to drive people toward concrete rules or to seek support and reassurance from nearby experts or leaders.

These approaches have become institutionalized to the degree that these behaviors have become beliefs – the expectation of performance decrements due to demands, as predicted by the Yerkes-Dodson curve. These beliefs and behaviors can also be observed in routine operations or informal leadership practices. Performance deficits from stress are expected and accepted.

What if we considered the debilitating effects of the stress-fear cascade as artifacts of the organization's culture and training? Individuals would terminate ongoing behaviors through the stress hypothalamic-pituitary-adrenal (HPA) axis while initiating attention-arousal behaviors through the locus coeruleus-norepinephrine (LC-NE) system. The system would support the modulation of stress-induced symptoms, fear circuitry behaviors, and amygdala-driven behaviors (2, 3).

Forcing functions and abrupt emergencies are part of life (4, 5), a routine part of the NICU. Rather than preventing, avoiding, or denying stress-induced symptoms and fear circuitry behaviors, we could recognize them for their utility. This recognition changes how we perceive and respond to the outlier and the salience, relevance, and meaning we give to information. Our decision approach is less linear and more reciprocal within the environment. Significantly, it means we change the logics we use to infer new information – constraining the use of classical logic that does not allow us to change the conclusion. We incorporate the more natural modal and paraconsistent logic (6, 7).

This first in our series of articles that describe impairments to engagement focuses less on alternatives and solutions and more on articulating the problem. Articulating the problem makes solutions visible and achievable. Critically, it directs the individual toward internalizing solutions.

We believe every individual acts in a way that makes sense to them. "What you do every day is what you do in an emergency," Jim Denney, Capt., LAFD, Vietnam Veteran (two tours), USN, Seabees. We have an idiosyncratic approach to solving everyday conditions that emerge from the unique interactions of experience, education, training, support, and our way of thinking. One is not better than another, only different.

However, we caution against reliance on approaches developed in predictable white noise environments. Most likely, they have not been tested in complex or chaotic circumstances and may not support the engagement of forcing functions or abrupt crises. On the other hand, approaches that emerge from effectively engaging forcing functions or abrupt crises can, and do, translate to routine operations.

> ***"Modulation of hormonal stress-induced cognitive disorders, fear circuitry behaviors, and amygdala-driven fear behavior allowed NICU staff to harness the inherent vices of stress. Through engagement, they converted stress and fear into strengths."***

In this HRO series published in *Neonatology Today,* we have described the responses of Neonatologists and NICU staff in extreme circumstances (8-10). They *used their routine operations to engage uncertainty and time compression during abrupt crises effectively*. What happened was their application of routine operations in a self-organizing manner but with the inclusion of the environment into their condition (5). While their plans and initial expectations came from outside administrators who use the full field view, Neonatologists and NICU staff engaged as local groupings (Table 1). They did not "bend" or "break" the rules. They had found themselves in that liminal zone *between* the rules, where engagement matters (11-13). Modulation of hormonal stress-induced cognitive disorders, fear circuitry behaviors, and amygdala-driven fear behavior allowed NICU staff to harness the inherent vices of stress (14). Through engagement, they converted stress and fear into strengths (2, 15, 16).

We will encounter the 'different person,' one who does not respond as we expect. We do not criticize them, though we may critique their actions. We support them. One of the HRO values identified by two authors (DvS, TAM) is empathy (12, 17, 18). HROs work in challenging situations where people will fail, which could be us failing.

Never use malice or ignorance if stress or fear will fully explain the member's behavior.

White Noise Thought, Red Noise Experience

Autocorrelation describes how a system responds to its feedback. Human behavior is an example. Autocorrelation creates long-period frequencies which carry greater power and hence more significant influence. This circumstance defines "red noise" from the longer red wavelengths in the electromagnetic light spectrum. Pink noise is midway between white and red noise (thus, "pink") and is characteristic of abrupt, catastrophic change. See Table 1.

Red and pink noise follow power distributions. Because they have a non-Gaussian distribution, statistical descriptions, and probability predictions do not apply. Increasing the amount of data will increase the variance, or spread, of the data. This spread creates more significant uncertainty in addition to the constantly changing situation. Frequent events have lower power in their power distributions, while infrequent, unpredictable events have greater power.

Red noise forcing functions and pink noise abrupt crises have the characteristics that cause stress and fear (Table 2).

If we follow the rules, then we succeed. However, a breach in the organization's structure and rules will allow energy dissipation (entropy) into the organization. These entropic changes demand an immediate response, or the breach will drive energy out of the organization, destabilizing vital structures. Identifying that breach and its causes assures the stability of operations going forward. This concept is the world as it is. That is, this is the world as a white noise environment.

However, when a system responds to itself internally, that is, when it has autocorrelations, the resulting fluctuations *support* stability. This stability can mask significant environmental fluctuations, giving the appearance of either a stable environment or a strong organization. The *non-HRO* executive or administrator then attributes stability and success to the organization and its "leadership."

Other missed causes of stability are long-period fluctuations that give the appearance of a stable environment, if not a stable world. Lost in sustained stability are the efforts of those who operate in an HRO fashion or recognize the inevitability of a forcing function

William Corr, a fire captain and WWII US Navy Veteran, South Pacific, shared this observation with one of the authors (DvS), "When I came on the fire department in 1948, the job of the administration was to support the firefighter. Today [1976], the job of the firefighter is to support the administration."

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Experience is the particulars and relations with meaning, values, and intention (21). Thinking is ongoing (22), contextual, and how we experience the environment and reach into and experience the environment (23). The engaged individual constantly thinks and makes judgments, using those judgments for the improvisation that directs self-organization (24) (22). This improvisation better describes the more accurate translation of René Descartes' dictum, *cogito ergo sum*, "I am *thinking*; therefore I exist" (22).

Biological systems exist in a world of random, stochastic variation. These systems must maintain stability far from any equilibrium state

Table 1. Patterns and Characteristics of Noise (19)

Color	Structure	Variance	Distribution
White	No frequencies dominate Flattened spectrum Spectral density has equal amounts of all frequencies	Data *decreases* variance Forms Gaussian curve	Gaussian distribution Elements fiully independent No autocorrelation
Red	Low frequencies dominate Long period cycles	Data *increases* variance Forms power distribution	Power law distribution Elements *not* independent Mutual/reciprocal relations
Pink	Midpoint of red noise The slope lies *precisely* 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 2. Characteristics of Noise and Fear Circuitry Traits

Red/Pink Noise	Characteristic	Challenge	Stress-Fear Cascade	Impairment	Engagement Function
Low frequencies (Red)	Slow variations, greater strength	Uncontrollability Threat proximity	Stress Fear	Cognition Distance	Thinking Defense
Abrupt change (Pink)	No single-point value Gaps	Unpredictability (Uncontrollability) Threat proximity Existential threat	Stress Fear Amygdala	Cognition Distance Survival	Motor cognition Defense Modulation
Self-organizing	Novel properties	Novelty Existential threat	Stress Amygdala	Cognition Survival	Motor cognition Modulation
Power distribution	Data increases variance	Uncertainty	Stress	Cognition	Information Motor cognition
Stochastic processes	Fluctuations Gaps	Uncontrollability Threat proximity	Stress Fear	Cognition Distance	Motor cognition Self-organizing
Power of incident	Gaps	Uncertainty Uncontrollability Threat proximity Existential threat	Stress Stress Fear Amygdala	Cognition Cognition Distance Survival	Information Motor cognition Defense Modulation

or abrupt change. Long-period frequencies have greater power that forces the system to respond. The autocorrelations that generate these frequencies are part of any system with human behavior or open to the environment.

This realization also leads to the trope "Armies prepare to fight their last war, rather than their next war." Viewing wars as pink noise events or reddened noise-forcing functions, we can recognize that the years between wars are not white noise periods of peace. Instead, they are periods of attention to forcing functions and preparation for abrupt change. This understanding is an operational approach that keeps military forces prepared. For example, part of the effectiveness of the US Navy's response to the Mt. Pinatubo eruption was the operational preparedness of the fleet at Subic Bay fresh from operations in support of Desert Storm.

The observation about "fighting the last war" comes from those outside the system or focusing on logistics, strategy, and administration. These top-down specifications produce a broader, 'whole field view' useful for quantitative analysis (Table 3). The whole field view risks decontextualizing the knowledge and experience gained from war.

This approach, however, overlooks the bottom-up specifications of operations, tactics, human readiness, and experience—the qualitative characteristics that emerge from the activities of 'local groupings' (Table 3). Overlooked are the methods used to increase human and system capabilities. The contextualization of experience counterintuitively supports translating experience and capabilities into new and different contexts.

Table 3: Specifications of the Whole Field View and Local Groupings (20)

Whole field view	Local groupings
Eulerian, quantitative	Lagrangian, qualitative
Decontextualized	Contextual
External, fixed point Select a viewing point Focus on a specific location	Within flow Select a starting point Focus on the individual moving parcel
Flow	Trajectory
Multiple fixed positions	Continuous measure with position and pressure
Rate of change of system	Individual parcels

(25, 26). Multiple degrees of freedom within the system allows *internal* fluctuations to create the necessary 'nonequilibrium dynamical system' (27). In the HRO, the necessary degrees of freedom emerge from cognitive, affective, and behavioral approaches that form the basis of HRO. The result is an HRO-maintained nonequilibrium dynamical balance.

In these cognitive, affective, and behavioral domains, we can identify the impairments of engagement.

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Stress, Fear, Amygdala

When faced with an abrupt change or approaching threat, our brain responds at the subcortical level to engage the situation. When modulated, this response generates effective engagement. Without modulation, however, hormonal stress-induced cognitive disorders, fear circuitry behaviors, and amygdala-driven fear behavior will co-opt the brain (2). This process can occur so insidiously that the individual does not notice it or considers such responses normal.

The ubiquity of these responses, often with immediate results, acts as operant conditioning that makes the behaviors seem natural if not desired. As a result, discussions usually focus on how they create dysfunction in everyone but the discussant. Stress, fear, and the amygdala have functions (2, 14, 28), arise from brain evolution as well as experience (2, 29), and can be separated into the motor and affective components (30). This division allows a less passionate discussion of stress, fear, and the amygdala.

The amygdala detects threats and then activates the sympathetic-adrenal-medullary (SAM) axis and the hypothalamic-pituitary-adrenal (HPA) axis, orchestrating the stress, fear, and threat cascade responses in the brain and body (31, 32).

- Cognitive consequences – direct inhibition of the prefrontal cortex and the executive functions
- Endocrine consequences – secretion of corticotropin-releasing hormone (CRH) from the periventricular nucleus of the hypothalamus, CRH releases adrenocorticotropic hormone (ACTH) from the pituitary, ACTH stimulates the secretion of glucocorticoids from the adrenal cortex
- Autonomic consequences – the brainstem activates the sympathetic nervous system throughout the body

These are all responses mediated by neurochemicals. They can come on with incredible speed and, when accepted as simple neurochemical effects, can be interrupted almost as quickly.

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Stress. Novelty, uncertainty, and uncontrollability, the domains of the executive functions, initiate the release of cortisol. Under stress, the brain "disarms" the executive functions to prevent the intrusion of abstractions and future thinking while limiting various memory systems. Even minor stress will impair executive functions (33).

Fear. An impending threat initiates fear circuitry behaviors below the level of awareness. Upon reaching awareness, the individual can augment or accelerate fear behaviors. Fear behaviors maintain a 'flight distance' from the threat, creating a safe distance ('fear flight'), or they create a safe distance should the threat breach the 'defense distance.' The individual will attack for self-defense and escape ('fear fight') (34).

Amygdala. Imminent danger or existential threat creates reflexive amygdala-driven fear behaviors from subcortical structures. Reflexive action arises from subcortical structures before identifying the threat (35). These behaviors include flight, fight, and freeze, occurring without particular order.

Stress-induced Cognitive Disorders

Stress impairs abstract thought and working memory. This confused state affects the ability to regulate thought, behavior, emotion, and flexibility of attention:

- Choke (expectations being observed).
- Impaired memory recall/enhanced procedural memory.
- Loss of abstract thought when prefrontal cortex and executive functions are impaired.
- Concrete thinking and reasoning due to loss of abstract abilities (amygdala impairs cortex).
- Rules are abstractions, therefore, challenging to recall and use.
- Failure of cognitive strategies: "*Even quite mild acute uncontrollable stress* can cause a rapid and dramatic loss of prefrontal cognitive abilities" (33).

Stress responses are from the amygdala and the neurochemical (cortisol) response to novelty, uncertainty, and uncontrollability. We must reset or change our learned approaches. Novelty, uncertainty, and uncontrollability disable abstract thought from focusing on context and action. *Without* stress responses, we would spend our spare time thinking of abstractions and theories.

Impairment of the prefrontal cortex constrains executive functions and abstract thought. Impairment of the hippocampus blocks

Table 4: Manifestations of Stress Conditions (36)

Defense	Initiation	Function	Mediator	Neurological Impairment	Manifestation
Stress	Novelty Uncertainty Uncontrollability	Block Abstractions	Amygdala	Prefrontal Cortex Executive Functions	Impaired cognition Concrete thinking Subjectively rational Objectively irrational
		Block Future Thinking Limit Memory	Cortisol	Memory Retrieval	Confusion Blunted recall Constrained memory
Fear	Proximity	Defense Escape	Ventromedial Prefrontal Cortex Periaqueductal Gray	Decision-making Flight Fight	Move to safety Offensive actions Defensive actions
Amygdala	Danger	Protection Survival	Amygdala	Subcortical Reflexive Behaviors: Freeze, Immobility Flight Fight	Anger, Frustration Plausible Avoidance Attentive Freeze Nausea Impeded Decision-making

memory retrieval except for procedural (habit or motor) memory, which is enhanced. The effect of *planned* motor activity on thought as motor cognition may explain why intentional movement can break the grip of cortisol on thinking (15, 28). Cortisol blocks memory retrieval in the prefrontal cortex and hippocampus (memory center), and the amygdala directly inhibits the prefrontal cortex.

- Novelty is processed in the right cerebral cortex, while the left cerebral cortex processes familiar perceptions.
- Uncertainty and ambiguity in decision-making occur in the ventromedial prefrontal cortex (vmPFC). The vmPFC is also involved with making decisions in uncertainty (37). See below.
- Uncontrollability or unpredictability is the stimulus for the HPA axis.

Uncontrollable stress releases cortisol to produce *stress responses*, generally related to failed memory recall. The primary memory systems affected are declarative memory for what is learned, episodic memory of experiences, and working memory for active problem-solving. Retained is procedural, or habit, memory, allowing the person to continue acting with practiced behaviors without losing time thinking and developing plans or actions.

A common belief about stress is that "during times of extreme stress, the brain takes the prefrontal cortex 'off-line' in favor of automated flight or fight responses." This consequent decrease in performance is attributed to the effects of the Yerkes-Dodson Curve (1). This curve was identified through an artifact of research design and is now considered predictable, though it is partially

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due to organizational design (14, 28). The cause is the belief in uncontrollability with stress-released cortisol block in memory retrieval in the prefrontal cortex and hippocampus (memory center) and the stress-induced amygdala directly inhibiting the prefrontal cortex.

“Now I know what you mean by [Bloom’s Affective Domain of] affective knowledge,” an emergency medicine physician once said to one of the authors [DvS] at an EMS medical meeting. The physician said he had been intubating an infant’s airway and “realized how bad I’d look if I missed it. That pressure made it more difficult to intubate. My emotion began to get in the way.” He told the author how his team had helped him and the duty he then felt toward them to place the tube successfully. The physician and author also talked about the criticisms they had heard about paramedics intubating children and how paramedics viewed the criticism since many paramedics had successfully intubated children in the past. In the EMS field, many people discuss the number of procedures necessary to maintain procedural skills; many believe that paramedics cannot reach the necessary number. The emergency medicine physician wondered how many failures in paramedic intubation may have occurred because of the pressure physicians and the system placed on EMTs (17).

Executive Functions

The brain integrates, from opposite ends, perception, hastily created plans, and motor activity. This integration is how we control our motor actions and think with motor cognition. The dorsolateral prefrontal cortex (DPFC) and the posterior parietal cortex (PPC) functionally cooperate during time-based contingencies between continuous perception and emerging motor action (38). The executive functions, acting hierarchically, coordinate temporary behavioral structures and “integrate actions with perceptions in the presence of novelty and complexity” (39).

There are specific roles for *motor attention* (impending motor action), *working memory* (sensory information for action that can be rapidly forgotten), and *inhibitory control* (interference, impulsive and reflexive behavior). These three elements produce the operational control and temporal organization of behaviors that characterize executive functions (38-40).

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The executive functions support motor attention, working memory, and inhibitory control:

- *Motor attention* prepares for impending motor action – “memory of the future” (39).
- *Working (short-term) memory* allows changing sensory stimuli to mediate perception and action toward a goal in real-time (39).
- *Inhibitory control* and selective attention protect goal-directed behavior from interference, distracting information, and impulsive or reflexive behaviors (39); inhibit emotional memories (41, 42), well-established habits, and more easily processed intuitions (43).

Working memory allows one to remember events of the last several seconds or minutes and to prepare and plan “forward” in time for prospective, near-future motor acts. Working memory has the attribute of rapidly ‘forgetting’ information as motor actions evolve. During the action, we must release memories as we continually bring new things into memory. *Working memory* mediates perception and action in real-time (40).

Cognitive flexibility refers to the ability to shift between cognitive rules or modes of thought (44). Unrestrained neurological stress responses release almost pure bottom-up control to produce self-preserving behaviors. Cortisol and the amygdala continue suppressing executive functions, and a defense cascade follows (45).

The Hippocampus

The hippocampus creates context by identifying what is different. This context may be the mechanism for the brain moving toward abstractions versus contextualizing the circumstance – interpreting the situation similarly reduces stress (no novelty) and fear (distant threat).

The anterior (ventral) hippocampus identifies the change in context, and a significant change is signaled to areas in the cortex concerned with context and to the ventromedial prefrontal cortex (vmPFC). Uncertainty and ambiguity in decision-making occur in the vmPFC, which also incorporates contextual factors into decision-making. We maintain “flight distance” for safety, behaviorally or emotionally. The flight distance is an animal’s security distance from a threat (34). Proximity measured in the hippocampus increases activity in the ventromedial prefrontal cortex (vmPFC) which connects to the amygdala to determine the motivational importance of the threat (37).

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With active behavior or attentive processes, cells in the hippocampus fire in sequential order: cells focusing behind the person fire first, and cells focusing farther ahead of the person fire later. This sequence forms an ensemble representation of spatial trajectories near the individual. The *sequence* of approach plays a more active and complex role in information processing than encoding the experience (46).

The hippocampus is part of deliberative decision-making. Hippocampal disruption shifts decision systems away from deliberative planning systems. Transient disruptions of the hippocampus impair working memory (47). Stress also impairs working memory.

Emotional Memory

During the experience of overwhelming, threatening circumstances, the individual may retain vivid memories (45) or experience memory retrieval deficits (48). In the hypervigilant state, a narrow range of stimuli may be sharply encoded (49). *Emotional memory* formation is closely linked to the amygdala and hippocampus (50), appearing to need timing with norepinephrine and cortisol release (42). During *dissociation*, on the other hand, the loss of context fragments the memory and impairs the encoding of the ongoing experience into memory. The dissociation of context and disrupted cortical integration prevent memory encoding (49).

Emotional memory is the only way an organism can learn from a single episode; what is learned is never extinguished. The amygdala processes highly arousing rewarding or aversive experiences to create persistent and vivid memories. Emotional memory is a form of episodic memory, a type of autobiographical memory from our lives. Once formed, emotional memory enhances the salience and priority of later stimuli. This system is the neurophysiology behind posttraumatic stress. *The trigger is from the past, but the response is in the present.*

A treating physician called one of the authors (DvS) by phone for advice while caring for a child with severe upper airway obstruction. After the author heard the child crying in the background, he recognized that the child was in far less danger than the team had surmised. The author used a rapid, visual respiratory exam (51) and described the use to the treating physician. The physician acknowledged that the previously administered therapy had achieved the desired effect.

The author drove to the hospital and helped the team complete the care for the child and start management. The treating physician then took the author into a private room, angry that the author had not immediately responded to the hospital; instead, the author "just talked on the phone." The author tried to explain, but the treating physician was too angry. Letting the person "empty their cup" is most effective. (It will get worse, better, or not change. If it worsens, they open up emotionally; if it gets better, they calm down and become lucid; if there is no change, it is instrumental anger. From the author's extensive experience, they do not become physical while vocal.) The physician's anger built to a crescendo, then the treating physician rapidly told the author of a personal experience in the military at a medical care facility with a critically injured sailor.

The corpsmen in assistance were worried that the sailor would die. The treating physician had called for helicopter transport, but the commanding physician at the main hospital refused, stating there was too much fog and the sailor could be cared for at the outlying facility. The treating physician remarked that helicopters had flown in worse fog and did not know why the commanding physician refused the transfer. The commanding physician would only talk on the phone.

The trigger for this anger was the author's initial action of talking by phone. The treating physician's response was to that commanding medical officer.

Fear Circuitry Behaviors

Threats that are proximal (static distance) or approaching (changing distance) will mobilize one to move toward safety or, if escape is not possible, to fight in self-defense (34). *Fear circuitry behaviors* are subjective cortical behaviors from the individual's spatial, temporal, or emotional distance from the threat (27-29). While fear reactions are a cortical response, they are triggered at the subcortical level. It is initiated below awareness and monitored for distance and direction from the threat's approach – from behind, rapidly, or leaving in order of response.

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In humans, fear circuitry behaviors generally express the emotive components with impaired functional cognition and without the motor components (15, 35).

- Flight rapidly increases the distance between the organism and the threat, with cognition focused on reaching a safe place while creating distance.
- A fight engages solely intending to break free and escape from the threat.

Flight. The individual "flees" by increasing distance from the threat. This distancing can be the motor component when the individual physically leaves the situation, such as fetching equipment that is not immediately needed. The affective component appears as avoiding, discounting, ignoring the threat, or distracting talking, perhaps by asking for more information. Verbal maneuvers include denial, dismissiveness, or depreciation of disconfirming information (52).

Social distancing acts as either a threat or as support. The close physical proximity of a threatening person elicits the same reactions as any threat. Fear responses are also transmitted through social interactions. On the other hand, social support creates a protective factor against stress, reducing the hypothalamus–pituitary–adrenal axis responsiveness to social stress (53).

Social distance, favorable or unfavorable, is subjective, but the peripersonal (i.e., near body) space is not. This location is the space where intrusion by others elicits discomfort. This space is measurable in encoding the visual receptive fields involving the ventral intraparietal area (VIP) and a polysensory zone in the precentral gyrus (54). Responses are sensitive to nearby or approaching objects (55). The VIP connects to the amygdala and the PAG for defensive and aggressive behaviors (54). The neuropeptide oxytocin partly mediates social interaction and may also regulate fear (53).

Fight. The fear attack is to push the threat away in order to flee. Separating the motor and emotional components leads to responding with anger (emotion component) without physical contact (motor component). We see this with emotional, verbal, offensive, or defensive protection.

Offensive protection prompts aggressive attacks to stop the spread of the problem. To achieve security or control, the person will use surprise, concentrated actions, fast tempo, and audacity. Blame, accusation, and personal attacks are standard methods.

Defensive protection focuses on the individual's safety, often moving to a place of psychological or physical safety (56). Demands *clearly* exceed capabilities, and risks become too great for the person to feel they can continue or survive. The person will not go near the threat or its source, whether it is abstract such as concepts or specific information, or concrete, such as the leader, an administrator, or a colleague. Because the individual will not sufficiently approach the situation, descriptions, correlations, or causations do not develop. As a result, individuals must rely on rationalizations and abstractions (for example, clichés and metaphors) to support and explain judgments, interpretations, and actions. The individual is less helpful in protecting others since they focus primarily on reducing risk to themselves. Deflection, excuses, justifications, and prophylactic self-blame are standard methods.

"Threats that are proximal (static distance) or approaching (changing distance) will mobilize one to move toward safety or, if escape is not possible, to fight in self-defense. Fear circuitry behaviors are subjective cortical behaviors from the individual's spatial, temporal, or emotional distance from the threat. While fear reactions are a cortical response, they are triggered at the subcortical level."

Anatomic Location

The distant threat within the "flight distance" for physical, emotional, mental, or temporal threat increases activity in the *ventromedial prefrontal cortex* (vmPFC) which incorporates contextual factors into decision-making in uncertain, risky, ambiguous, or context-dependent conditions (37). The vmPFC connects to the amygdala to determine the motivational importance of, or degree of, the threat. The amygdala connects onward to the *bed nucleus of the stria terminalis* (BNST) to control a repertoire of behavioral defensive states (57).

Increasing proximity switches activity from the vmPFC to the midbrain *periaqueductal gray* (PAG) nucleus, a phylogenetically older part of the midbrain. This produces the subjective representation of threat and the degree to which it is felt. The PAG controls fast reflexive behaviors (e.g., fight, flight, or freeze) and fear-induced analgesia (55, 57). The PAG also coordinates behaviors essential to survival, including threat reflexes, rapid changes to subcortical behaviors, and startle posture corrections (57). Detection by the PAG of an approaching or receding threat will functionally switch the animal's repertoire of behaviors (58).

"Social distancing acts as either a threat or as support. The close physical proximity of a threatening person elicits the same reactions as any threat. Fear responses are also transmitted through social interactions. On the other hand, social support creates a protective factor against stress, reducing the hypothalamus–pituitary–adrenal axis responsiveness to social stress."

This movement from contextual decision-making under uncertainty in the vmPFC to reflexive decision-making from the PAG makes the fight or flight of the *fear reactions* appear the same as the fight or flight from *threat reflexes*.

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The PAG has different functions in its several dorsoventral and rostrocaudal divisions. Stimulation of the dorsoventral PAG promotes passive freezing while ventral stimulation promotes escape and other active coping behaviors (57). From nose to tail, active coping strategies shift from moderate to active defense;

then aggressive defense; then strong threat display and *non-opioid*-mediated analgesia; followed by vigorous escape when the enemy is near. When escape from an enemy is impossible, passive coping strategies disengage from the environment, and behaviors shift to freezing, then moderate to strong immobility with increasing proximity. Lastly, intense freezing with *opioid*-mediated analgesia occurs (59, 60).

Amygdala-driven Fear Behaviors

People do not generally recognize that anger is an amygdala-driven reflex. The unrecognized *fight* responses include anger and frustration. One of the authors (DvS) routinely queried staff, "What would make an attending angry with you?" Answers focused on errors or poor performance. After learning about stress, fear, and threat, the answers changed – "The attending is in a fear response or threat reflex." The subordinate's response is significant; becoming more careful or working harder does not decrease fear. Asking, "How can I help?" moves cognition from the amygdala to the prefrontal cortex.

"People do not generally recognize that anger is an amygdala-driven reflex. The unrecognized fight responses include anger and frustration... But anger works. The prevalence and pervasiveness of relaxed fight responses give the impression that anger is a normal, if not necessary, behavior in an urgent or emergency environment. For example, the immediate reactions observed using the fear responses of anger and force reinforce the belief in their effectiveness. The observed effectiveness, however, is an immediate change toward homeostasis at best."

But anger works. The prevalence and pervasiveness of relaxed fight responses give the impression that anger is a normal, if not necessary, behavior in an urgent or emergency environment. For example, the immediate reactions observed using the fear responses of anger and force reinforce the belief in their effectiveness. The observed effectiveness, however, is an immediate change toward homeostasis at best while impairing allostatic strengthening.

Amygdala-driven reflexes initiate behaviors for survival. This result is an adaptation to adverse or hostile environments. Perceptions of threat will trigger reflexes that operate below the level of consciousness (61).

Amygdala-driven behaviors operate below the level of consciousness where imperiling threat reflexes predominate (2, 61). Proximal, imminent danger initiates reflexive protective behaviors while maintaining our cognitive functions, differentiating threat reflexes from stress responses or fear reactions. Though commonly referred to as "fear responses," threat reflexes include the well-known fight, flight, and freeze reflexes and tonic immobility. In humans, amygdala behaviors generally express the emotive components with functional cognition but without the motor components (15, 35).

- A fight engages to overcome the threat rather than escape the threat.
- Using cognitive abilities, flight increases the distance between the organism and the threat.
- Freeze (more accurately, "attentive freeze") is attentive or hypervigilant awareness with cessation of movement yet poised to act. It has two components: attentive awareness and poise for action. This allows information collection necessary for effective action while generating a faster response time.
- Tonic immobility, the parasympathetic nervous system, produces intense awareness with an inability to move. The initial response in many prey species is often accompanied by the evacuation of body contents to mimic carrion. More common in humans, it produces mild-to-severe nausea.

Tonic immobility. Of particular note, we have observed that tonic immobility is subtle, more commonly presenting as a "sick feeling in the pit of the stomach" or nausea. It is relieved when the threat is avoided, leading to inaction. The person maintains full awareness and consciousness (45, 62). The vagus nerve mediates many of the features of tonic immobility: bradycardia (slow heart rate), life-threatening arrhythmias, decrease in respiration, nausea and vomiting, urination, and defecation.

"For novices, nausea accompanies their first independent decision and, if unresolved, will inhibit future decision-making."

For novices, nausea accompanies their first independent decision and, if unresolved, will inhibit future decision-making. The individual does not necessarily become trapped in tonic immobility. Kozlowska et al.(45) described actions a Second World War Flying Officer would take when training pilots: he used a "firm voice devoid of fear to issue simple orders that the men had already learned and that were automatic: 'flaps,' 'raise the stick,' 'rudder.'

One of the authors (DvS) presented an invited lecture on decision-making to the Scottish Highland paramedics. The lights suddenly appeared during the presentation, and the slide projector was turned off. A gentleman announced that the lecture was over, and we were all to go home. Concerned that the lecture was too long, he asked the senior paramedics what had gone wrong. "Nothing," they said, "but could you finish your lecture early in the morning at a paramedic station?" The lecture would be recorded.

The following day, waiting at the paramedic station, the oncoming paramedic team told the author that he had become known throughout the Highlands overnight. It seemed that when a disagreement focused on a field situation, the medical director, inexperienced in the field, used anger to control the conversation. The author used neuroscience to describe what the field medics knew – anger is a sign of fear.

The night before, just after the author stated that anger is a sign of fear, the medical director stood up and walked out. The parking attendant had been sent in to stop the presentation.

Anatomic Location

The amygdala detects conflict from acute threats or stressors, receiving exteroceptive stimuli (the external environment) and interoceptive stimuli (the body's internal environment). The amygdala activates the sympathetic-adrenal-medullary (SAM) axis for the proverbial "flight-or-fight" response and the hypothalamic-pituitary-adrenal (HPA) axis for the release of peripheral adrenal hormones, including cortisol (31). The brain, reacting from bottom-up reflexive and priming processes, prepares the body for survival.

> ***"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 the 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."***

For this rapid shift to occur, the brain must decrease the influence of 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 processing initiates the adaptive cognitive shift necessary for survival.

Phenotypes of Fear

H. Stefan Bracha (2) differentiates fears having an evolutionary basis (brain-evolution-based) from fears we develop from experience (mode-of-acquisition-based). Evolution-based fears can be identified by the era they developed and their wild-type alleles, making them innate fears with which we are born. This allows us to distinguish functional stress and fear from affective disorders. That is, we can expect specific fears to be present in all of us during a crisis. We can also expect more idiosyncratic fears due to a person's family of origin and life experiences. We cannot know if someone has emotional memories or developed posttraumatic stress.

Some fears can become consolidated between innate fears and those from experiences. This "over-consolidation" can lead to the abrupt and unexpected appearance of situational cognitive distortions or disruptive behaviors. An example presented by Bracha is a clustering of phobias around blood, injections, and injuries. He posits that such a cluster consolidates a negative experience in a hospital, causing a phobia and a hardwired (innate) fear of seeing one's blood or a sharp object penetrating one's skin.

Some fear circuitry traits that had evolved have now outlived their usefulness (except in specific but uncommon circumstances). These include fear of separation, darkness, alligators, and crocodiles. Bracha divided these evolutionary fears into four eras:

- Mesozoic Era mammalian-wide evolved fear circuits
- Cenozoic Era simian-wide evolved fear circuits
- Mid and upper Paleolithic *H. sapiens*-wide evolved fear circuits
- Neolithic culture-bound-genome-specific (gene-culture co-evolution-based) fear circuits

> ***"What this means for us working with people during a crisis, the behaviors we observe have emergent, novel properties. The individual with unmodulated behaviors must be closely observed and supported during the event. They will need sense-giving and meaning-giving by the Neonatologist, or they may have a higher risk of avoidant behaviors as a means of coping post-trauma and are more likely to develop psychological distress."***

Unfortunately, pediatricians have become familiar with the homicide or death rates within a household between married relatives (such as stepchildren) and blood relatives (biological children). As described by Bracha, "*Throughout the mammalian class, intense fear of non-kin adult male conspecifics is widely documented in unweaned mammals"* (2).

These behaviors are a form of phenotype, such as Panic Disorder or Dissociative-Conversive Spectrum, and are influenced by gene dosage of wild alleles. Endophenotypes are quantifiable heritable traits that are argued to index an individual's genetic liability to develop a given disease or disorder (63, 64).

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Situational Cognitive Distortions

It is often the situation that distorts our cognition. We do not live in a constant state of stress, fear, or amygdala-driven behaviors. Maladaptive stress and fear behaviors become normalized when we do not recognize how the situation distorts our thinking. We call these *situational cognitive distortions* because, absent stress or fear, the individual operates at a high level of cognition (3, 17, 52).

- Stress – cognitive impairment
- Fear – the creation of distance, drive to a safe place
- Amygdala – existential protection

Situational cognitive distortions can develop from intrinsic sources, such as a supervisor pressuring somebody mentally, causing the impaired recall of information. This freeze response is common in the medical education method of "pimping," to ask a question that demonstrates a person does not know. It is like choking in sports. This quickly develops into ingrained responses of subordinates to the supervisor's presence while reinforcing the supervisor's belief in the poor performance of the individual.

Common cognitive distortions include (15, 35):

- 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

From our experiences and discussions with veterans from dangerous contexts, we have identified three salient situational cognitive distortions:

- Blocked recall
    - We ask an individual to recite the months of the year. Then we change the protocol to reciting the months in alphabetical order.
    - After reciting 3-4 months (and leaving out several), the individual finds it difficult to recall any month.
    - This demonstrates to the individual and witnesses the rapidity of cognitive freeze, a neurochemical. It has nothing to do with intellect or abilities.
    - We provide an escape. Doing anything physical reverses the freeze immediately.
- Attentive freeze (threat freeze)
    - The individual experiences an abrupt threat and feels the freeze but is fully attentive to the surroundings. They will misinterpret this as being "frozen from fear" or tonic immobility.
    - By pointing out that they had focused attention to detail and the mental preparation for action, they appreciate that attentive freeze is a strength.
- Tonic immobility
    - In its milder form, it appears as active refusal or avoidance to make a decision. The individual feels a "knot in the stomach" or mild nausea. In more severe cases, they may vomit.
    - They do not discuss their intestinal discomfort, thinking it is unique to them and a sign of weakness, or they interpret the sensation as caused by the attending or leader.

"The emergency physician could not pronounce death by their medical staff bylaws if a heartbeat could be obtained through treatment. A second-year pediatric resident in the second week of her PICU rotation was part of the team. Not long after she left, she returned with the child, who was now stable on medication. "

The director of an emergency department called the PICU to transfer an infant in repeated cardiac arrest. We could not place a fragile child in an ambulance with only three caregivers: a physician, a nurse, and a respiratory care practitioner. The emergency physician could not pronounce death by their medical staff bylaws if a heartbeat could be obtained through treatment. A second-year pediatric resident in the second week of her PICU rotation was part of the team. Not long after she left, she returned with the child, who was now stable on medication.

After her return, she approached one of the authors (DvS) to say, "They did the fear response you said they would do—they walked away when I came in." She added, "And I felt that freeze response in myself that you did to me last week." Asked what had happened, she said she checked the endotracheal tube *because* it was working. She elaborated that by physically checking something that was working well, she could bring herself out of the freeze response and resuscitate the infant. She achieved stable cardiac function after twenty minutes of treatment.

Was the earlier failure to achieve heart stability because of a lack of knowledge or from the influence of stress neurochemicals on the brain? An experienced emergency physician working with an experienced healthcare team responded to the stress of an infant undergoing cardiac arrest. Their response was neurochemical, situational cognitive distortions (17).

The Ecology of Fear

As a medical student and experienced fire paramedic entering the culture of medicine, one of the authors (DvS) found it odd that no one would discuss the circumstances of how an error could cause a fatal mistake, particularly for known incidents. How does one protect the patient without discussing experiences? Discussing such errors was common practice in the fire department – the year before the author arrived at his assigned firehouse, several firefighters had died from a building collapse. The incident was still a topic for discussion as a learning experience. LAFD at the time had a culture that could discuss these incidents for learning without criticizing or blaming participants.

When the Los Angeles City Fire Department experienced increased Rescue Ambulance collisions, the department sent Rescue Ambulance Drivers to the LAPD "Skid School" for training. One of the authors (DvS) attended this training. The focus was to increase the driver's capabilities. The final test was to drive fast within one's capabilities on a one-mile course, reaching speeds close to 100 mph. Then, drivers drove the course again, also for time. The second run used the siren. All students in the class passed the exam and wanted to know their times. The instructors would not give them their time – there was no set time for passing or failing. The driver failed if the driving time with the siren was faster than the time without the siren. The siren should not make someone drive faster. The instructors told the drivers, "If you are influenced by adrenaline, we don't want you."

Liability and malpractice continue to be issues that impair engagement, often framed in terms of safety or quality of care.

Without specifics and with frequent use and repetition, discussions of risk and liability become dissociated from bedside actions. The message is lost. Their influence no longer focuses on patient care, becoming generalizable fears instead. When no longer connected to specific risks, discussions of risk and liability lose relevance to patient care. However, they do gain immeasurable salience that influences the actions of healthcare providers – but not necessarily for patient care.

Administrators, regulators, and legal counsel have legitimate concerns about healthcare provider actions during uncertainty and time compression. The repetition of risks and liabilities readily develops an atmosphere of fear. Sadly, the providers who need support will scare themselves, *impairing* engagement. This process is the "ecology of fear." A different approach, described above by LAFD, is to increase capabilities, which will *enhance* engagement.

"In healthcare, we see the ecology of fear forming from the influence of error, litigation, and negligence, even in their absence."

Risk and liability can act like predators in an ecosystem. The direct killing of prey by a predator may have less influence on prey populations and even the landscape than the fear generated by the *absence* of a predator (69, 70). The ecology of fear describes predator-prey interactions in the absence of the predator (69). Not only do prey populations decrease, but the ensuing trophic cascade changes the landscape into a "landscape of fear" (71, 72). In the past two decades, fear has become a measurable element of ecology (72).

By analogy, the *fear* of failure, in the absence of failure or the threat itself, may significantly influence human behavior and culture more than actual failure (73). We can correct or recover from failure, but we cannot correct fear. Stress and fear are the individual's properties rather than the threat's properties.

In healthcare, we see the ecology of fear forming from the influence of error, litigation, and negligence, even in their absence.

- *Fear of failure* contributes to 'not acting' This is invisible and is readily assimilated into organizational knowledge (74).
- *Fear of error* contributes to behaviors that avoid actions or situations. The error can also become a faulty signal for the presence of failure (75).
- *Fear of legal action,* such as litigation, negligence, or malpractice, can become over-reliance on legal counsel with the undue influence of lawyers in providing medical care. Healthcare professionals may excessively document laboratory or radiologic studies, commonly called "legal medicine."
- *Fear of discipline*, such as for incomplete forms, leads to "euboxia," the practice of filling in blocks of information to ensure a completed form (17). Euboxia comes at the expense of an articulate description and can delay care as the individual seeks information necessary for the boxes but not medical care.

"Inadequate top-down modulation from executives, administrators, regulators, and legal counsel contributes to the ecology of fear. Repeated references to risk extend the span of control for this leadership. Such extended control, however, impairs engagement in the crises that the leaders hope to mitigate... These cognitions and behaviors can become normalized through bottom-up incorporation into the organization's culture. Because they are natural and produce swift results, they appear effective."

We can generally correct an error, but we can never correct a fear. In fact, like categorization and standardization (76), fear can be used to control people without the controller's presence. Administrators and regulators create categories and standards to avoid engaging the ill-structured problem. This permits the conversion of the ill-structured problem to the well-structured problem.

To control behavior, administrators, regulators, and, unfortunately, some leaders promulgate various fears. Such fear drives subordinates' cognitive efforts and behaviors away from the ill-structured problem. These are problems where no answer is predictably correct, an error has a function, and failure is a sign of quitting too soon.

Conclusion

The characteristics of forcing functions and abrupt crises create our ability to engage those crises.

- Stress-induced cognitive impairments "disarm" the executive functions to prevent intrusion of abstractions and future thinking while limiting various memory systems. Stress brings mental focus to the immediate circumstances.
- Fear circuitry behaviors, operating below the level of consciousness, keep us safe from threat. We can operate with safety. Distance can reduce stress, returning some of our cognitive functions.
- The amygdala operates at the subcortical level, identifying threats and initiating survival behaviors before we can recognize danger.

Without modulation, stress-induced cognitions become disorders, fear circuitry behaviors become disruptive, and amygdala-driven fear behaviors become dangerous. *Inadequate top-down modulation* from executives, administrators, regulators, and legal counsel contributes to the ecology of fear. Repeated references to risk extend the span of control for this leadership. Such extended control, however, impairs engagement in the crises that the leaders hope to mitigate. However, not only is engagement impaired at the level of local groupings but also impaired is the necessary close-in support from the full field view. Over time, there will be a widening of the operational gap between the central organizational authority and the operational line authority.

These cognitions and behaviors can become normalized through *bottom-up incorporation* into the organization's culture. Because they are natural and produce swift results, they appear effective. This normalization creates unrecognized stress responses, unrecognized fear reactions, and situational cognitive distortions. The result is impaired immediate engagement of early heralds of failure and covert, compensated system failure.

"Seeing the problem as a puzzle rather than as mysteries to investigate is simpler. Stress and fear impede the engagement of mysteries. We can use Adrian Wolfberg's concept of Full Spectrum Analysis (77) when unimpeded. We can then extend Neonatology into new areas and the mystery of the next infant's illness."

Recognition of the inherent vices of stress and threat can move individuals and organizations toward effective modulation. Gaining the ability to operate in uncertainty and time compression permits the use of greater resources, widening the spectrum of available information. A great limitation to problem-solving is our mental limits on ourselves and each other. Seeing the problem as a puzzle rather than as mysteries to investigate is simpler. Stress and fear impede the engagement of mysteries. We can use Adrian Wolfberg's concept of Full Spectrum Analysis (77) when unimpeded. We can then extend Neonatology into new areas and the mystery of the next infant's illness.

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