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High-Reliability Organizing (HRO) is Contextual

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Abstract:

HRO emerged from engagement with a flux of contingencies to make them more orderly. We cannot treat these environments as isolated systems with demarcated boundaries. Instead, the environment comprises of open, contextual systems always in flux. These sequential events are better viewed as 'state vectors' acting like arrows in time, rather than discrete, sequential events. Rational ('top down') and heuristic ('bottom up') cognitive approaches have limits when engaging these dynamic, open systems. We propose that context-focused engagement reduces the error of "engaged abstraction" and that quantum cognition contains elements used by HRO operators.

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Introduction:

When we understand the origins of HRO, we can better understand the driving forces of HRO. From WWII through the Vietnam War, the US Navy's Pacific Fleet conducted most of the US Navy's combat operations. The exigencies of combat made it imperative for everyone to identify effective actions and retain what they learned. Safety is vital even during wartime, and accidents are investigated. Safety in combat has an additional function because avoidable operational loss causes unaffordable shortages of men and planes and increases vulnerability to enemy activity. The introduction of the first *nuclear* aircraft carriers in the Pacific Fleet brought together three independent, otherwise disparate domains within a single individual: 1) aerial warfare experience with initiative, improvisation, and flexibility, 2) nuclear propulsion engineering experience with rigor, detail, and conformity to procedures; and 3) previous aircraft squadron and large ship command of complex organizations in demanding circumstances (1). HRO, codified by the UC Berkeley HRO (High-Reliability Organizing) Project, emerged from the Nimitz class nuclear aircraft carriers, US Navy's Pacific Fleet (2, 3).

In the medical world, practitioners engage with a flux of contingencies to make them more orderly and safer. Efforts to enact order sometimes succeed, sometimes fail, but most often, they produce both. Unfortunately, that mixing can threaten reliable functioning. The healthcare community has translated HRO to enact order in the flux of contingencies, support safety, and achieve reliability in the performance of healthcare (4-6).

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When operations, in the context of combat, are translated into more abstract normative statements, this can lead to nuances, fine-tuning, and subtle yet essential cues getting lost. Nuances can get restored by engagement and action. However, the context, which is a powerful component, is missed when translating HRO from a combat to a healthcare setting. Sensemaking is created from the context. Then subsequently, action emerges from this sensemaking in context. Thus, the incomplete translation of HRO will risk the loss of vital nuances in sensemaking, which are only found through the contextual engagement of the embedded, ill-structured problem (7).

Karl Weick (8) used the sinking of the El Faro, a 90-foot container ship, to describe the consequence of using abstractions to interpret contextual circumstances. The captain abstracted his experience with Alaskan winter storms to the context of a Caribbean hurricane. However, Alaskan storms demonstrate strong winds from one direction, while Caribbean hurricanes have strong winds that gradually change directions. This error resulted in him taking the ship into the eye of a Category 3 hurricane.

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Abstractions can help make the situation more understandable but also result in the loss of unique details from the original context of the circumstance. Concepts then become a definite "form" we treat as fixed and absolute rather than abstractions that are the farthest removed from our original perceptions. When we convert our perceptions into abstractions, the experience flow is interrupted, and we lose alternative insights (8). When we use abstractions to make the situation more comprehensible, we develop "engaged abstraction" – sensemaking is no longer sufficiently contextualized (9). We break our present-at-hand existence into parts. As Karl Weick states, "Actions always occur in a specific context" (personal communication).

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When we witness an event as spectators from the *outside*, we can focus on specific locations in space or time. We independently observe the flow of events and the rate of change as separable sequences. We can then also readily decontextualize events and experiences, enabling us to think with abstractions. We may prefer to call the spectator's observations 'objective evaluations.' However, there is a purpose in choosing such an external framework: we can form abstractions that are harder to disconfirm and fit easier into our understanding without changing that understanding. The selection of an *external* framework becomes a subjective selection of experience to fit our understanding. We risk developing Sanberg and Tsoukas's "engaged abstraction."

When viewed from *within* the flow of events, our observations are made with context and later become perceptions that influence our actions. Actions emerging from within the context of events become experiences (10). Abstractions quickly lose their function and become dangerous if they do not. From this *internal* framework, we respond to continuous local changes in position and pressure. We have less concern for the general flow of the event and more interest in changing its trajectory. By focusing on the flux of our *individual* segment, the "flow" that we experience the event reveals the constraints that the environment places on perception. Our understanding must fit our contextual experience.

A crisis has flux, and how the spectator or operator experiences that change influences their system information and communication. Contextual experience is unnoticeable from a fixed, external point of observation distant from events. Even within an event, our experience will differ from those around us or even working alongside us. The operator responds to local threats within the event space by creating a trajectory toward stabilization and recovery.

The academic and management science literature commonly uses the 'top-down' perspective from a fixed point outside the flux of events. The benefit is more precise information and quantitative data that produces a normal distribution for statistical analysis and probability predictions.

The operator within the flux of events, the 'bottom-up' perspective, is personally at risk during changing contexts, necessitating rapid updating of less reliable and evolving information. The internal frame relies on accurate information and communication for practical descriptions, vital characteristics when novel demands appear or rapidly increase, and unrecognized shifts in resource availability.

Operators within a crisis focus on context and what they can learn; spectators focus on what they already know.

Notions of high reliability will emphasize this difference. The high-reliability theory relies partially on how the outside view depends on codifying a framework of guiding principles. However, if those principles are seen as the essence of producing reliability, then the importance gets misplaced. Reliability is more assured when practical engagement dominates practice because this allows adjustment to the flux of circumstances. The constituents of that engagement make "higher reliability" a property of work.

This becomes the difficulty of HRO implementation – principles understood at the executive level do not support the practical engagement of disruptions. The expectation arises for operators to fit their experience into institutional understanding. Institutional expectations affect documentation, reinforcing institutional knowledge to ensure homeostatic stability, no matter how brittle.

Open Systems Create Context

We cannot treat the environment as an isolated system with demarcated boundaries. System behavior is generated by its openness, *not* a complication of openness (11). Environmental factors influence the activity and behavior of the elements and the people in this environment. Open systems are contextual.

Like the world around us, healthcare is an open system exchanging resources, energy, and information with the environment. This is like the biotic and abiotic ecological processes that interact to stabilize and sustain an ecological system. Information from the environment shapes the system's activities, while participants within the system alter the environment. This is also a form of information. This flow of information between the system and participants creates complex feedback relationships. Feedback loops can be short, long, indirect, delayed, etcetera.

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Neonatologists effectively merge the subjective into the objective – the process of contextualization. Opacity, ethical uncertainties, physiologic instability, shifting probabilities, and changing trajectories are inherent to the work of a Neonatologist. The Neonatologist becomes acquainted with the neonate's parents, family, and culture during great stress and distraction. The NICU is a microenvironment of the hospital in a healthcare system supported by other systems. This is not unlike other sciences that do not have pure objectivity: biologists, ecologists, psychologists, and sociologists.

The Logic for Contextuality

Research on human cognition is based on probabilistic models from probability theory. Quantum models of cognition are based on contextuality, how conditions of uncertainty interfere with a person's inferences and decisions (12).

Probability theory formalizes probability as a 'probability space,' specified as a measurable space with measurable subsets (a subset is an event) and a 'probability measure' between 0 and 1. Central to probability theory are random variables, probability distributions, and stochastic processes. From probability theory, we have both the law of large numbers and the central limit theorem. The Kolmogorov axioms (Andrey Kolmogorov) are the foundations of probability theory and mainstays for psychology and cognitive science.

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Observed data allowed us to combine the probability distributions of two random variables using probability theory. The data must come from the same probability space to create such a joint probability distribution. For entangled quantum systems, this operation may not be valid. Random variables from different distributions do not always have joint probability distributions. In quantum theory, the inability to combine different probability distributions into a joint probability distribution is known as *contextuality* (13).

It may seem as though the subjective character of context and contextuality would corrupt the objective nature of science. A significant source for this misconception is the inability to utilize probability theory in an open system. Kolmogorov recognized contextuality at the classical level, stating that all probability measures needed to be linked to specific contexts ((14) in (11)). Failure to consider contextuality leads to the misapplication of Kolmogorov probability theory at the classical level (11).

Some abstract principles in quantum theory are relevant to cognitive phenomena: superposition, compatibility, and complementarity.

Superposition is the sequential placement of system interactions.

In classical probability theory, the system is in a definite state with respect to possible states. When the state changes across time, it is a definite state at each moment, and the system produces a definite path. In Boolean logic, events can be combined in any order, 'A and B' equals 'B and A,' the logical conjunction is commutative.

In quantum probability theory, a system is in an indefinite (dispersed) superposition state *until a measurement is performed* on the system. All possible definite states have the potential to be actualized, but only one of them will become actual *upon measurement*. In Boolean logic, the order of combining events will change the system. 'A and B' does *not* equal 'B and A,' making the logical conjunction non-commutative.

Processes are a series of time-based steps. For continuous time as experienced, there are no gaps in the temporal order. A dense sequence always has a discrete element between any two sequential elements. In a continuous sequence, there are an infinite number of elements between any two such elements. This is for "instant-based" models. We use "interval-based" models for reasoning about events with duration [15]. The difference is whether we talk in terms of time "instants" or time "intervals." Classical logic assumes discrete elements and time measures. Logics used in HROs or quantum theory allow for partial truths (modal logics) and accept conflicting information (paraconsistent logics) (15).

This may seem a trivial distinction. Operations occur in "instant-based" time. The operator experiences continuous, smoothly changing elements but must communicate with other operators as though the elements are dense and changing as discretely different elements. Spectators observe "interval-based" time, which is also used for planning and algorithms. "Response to therapy guides further therapy as a "different" patient is created each time. The "sensed" patient, or the patient we evaluate for purposes of management, does not exist later for review. Only the "monitored" patient does; this patient is the patient reconstructed later from monitored and recorded data and caregiver notes for diagnosis, heuristics, or legal reasons. The two patients are not identical" (16).

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Our actions in an ambiguous or uncertain situation, even when we arrive or take a measurement, change the situation. The following action has a different value and response than had the action occurred first. Karl Weick (17) described superposition as a property of enactment:

> "The explorer cannot know what he is facing until he faces it and then looks back over the episode to sort out what happened, a sequence that involves retrospective sensemaking. But the act of exploring itself impacts what is being explored, which means that parts of what the explorer discovers retrospectively are consequences of his own making… Action precedes cognition and focuses cognition."

Compatibility, whether two questions can be answered simultaneously or sequentially.

The questions are compatible if two questions can be answered simultaneously or if the order does not matter. In classical probability models, we can describe all events within a single, compatible collection of events. If the two questions must be answered sequentially, and the order matters, the questions are incompatible.

Principle of complementarity, some questions are incompatible

(the effect of sequence)

Incompatible questions provide different perspectives of an event, perspectives we need to understand the world (13). The Heisenberg Uncertainty Principle is a product of the principle of complementarity. We can be certain about the particle's position or momentum, but not both simultaneously.

This is relevant for us to know a person's understanding of two events, such as their understanding of the beliefs or experiences of two different people or processing two different perspectives of the same matter. We must switch between points of view, and the points of view may not be compatible. Presenting two perspectives or points of view can imply incompatibility; the person cannot process both perspectives simultaneously. Superposition means one cannot decide a matter from more than one perspective – to choose from one perspective; you are making your cognitive state dispersed (making indefinite) for the other perspective (13).

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Inherent Vice

Compatibility and complementarity explain the dictum of fire rescue ambulance personnel who trained one of the authors: "What helps us now can hurt us later; what hurts us now can help us later."

Compatibility and complementarity help us understand the inherent vice of stress and fear. The activation sequence of the locus coeruleus versus the hypothalamus-pituitary-adrenal axis can affect dominance during a stress response of norepinephrine or cortisol. The sequence for the ability to escape or gain control of the situation compared to the presentation of the position (context) of the threat can determine flight versus fight fear responses (18).

We borrow the insurance term "inherent vice" to describe how the desired qualities of a commodity can damage the commodity. For example, stress disables the executive functions for rapid adaptive response to novel, uncertain, or uncontrollable situations. Stress also impairs cognition and memory recall, confounding efforts to develop a solution.

Events: States or Vectors

In quantum probability theory, events are treated as vector spaces rather than subsets of a universal set. Within the circumstances, an element or person is not a subset of a larger set. Instead, they are elements as vectors with potential directions. We do not know the direction, and the person does not know until they move or act. This better fits our experience in abrupt crises: things do not go as we expect, and people do not necessarily behave as we expect.

A state vector acts like an arrow in time, replacing probability values used in classical logic (13). Concepts change continuously under the influence of context. The change is 'the change of state of the concept.' Concepts, then, can be modeled as a quantum entities influenced by the contexts of measurement (19). HRO is the dynamic, physical enactment of the contextual. It is not a state variable to achieve,

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Decisions within Context

Academic studies of decision-making fall into two distinct approaches, a decontextualized rational approach and a heuristic approach using 'bounded rationality' that recognizes the contextual limits of human cognition (20, 21). Operators in dangerous contexts find that these two approaches neither describe nor prescribe how operators make decisions in dangerous contexts (22-27). 'Quantum cognition,' derived from quantum theory, adopted mathematical approaches developed to address contextual influences encountered in quantum physics (11, 13).

Rational approaches comprising 'top-down' deductive approaches will incorporate subjective probability and expected utility. Models assume people are rational actors whose decisions meet an expected utility. Fundamental axioms to derive inferences are independent of context (28). Rational approaches to decision-making use Bayes Theorem and are found in game theory and decision theory. Scientific rationality and classical logic work well with what Herbert Simon calls the well-structured problem (29) but fail in the VUCA-2T environment or when experiencing liminality (15) [Table 1].

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Heuristic approaches are bottom-up inductive processes that incorporate contextuality for Simon's ill-structured problem. Simon acknowledged the limits of human cognition with his concept of

'bounded rationality.' Heuristics, rather than algorithms, would overcome the limitations posed by both the problem and cognition (20, 29-31). Heuristic approaches support operations in the VUCA-2T environment [Table 1].

Table 1. VUCA-2T (3)

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

Quantum cognition accepts the limits of human cognition and bounded rationality with a heuristic approach. In common with the rational approach are inferences from a defined probability theory derived from basic axioms (11, 13), described in "The Logic of Contextuality" above.

Superposition

In the superposition state, there is no single trajectory or algorithm for a decision, leaving the individual conflicted until the moment of decision (12). Irving Janis and Leon Mann identified the effects of such conflict on decision-making (32) [Table 2]. Cognitive decision-making models assume that we can immediately know the antecedent state of mind before the inquiry. In quantum cognition, the act of deciding *creates* the cognitive state. This is like Niko Tinbergen's approach to animal behavior – we do not investigate until we see the behavior, and antecedents cannot be identified. Quantum cognition would investigate the 'function' of a decision like Tinbergen investigated the 'function' of behavior (see "Contextuality and the Function of Behavior," below). Deciding can also create the emotional state of fear or gastric distress (tonic immobility), strongly influencing social interactions and collaborative decision-making (33).

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Table 2: Conflicted Decision-Making (32)

Decision Strategy	Characteristics
Vigilance	"A thorough information search, unbiased assimilation of new information and other qualities of high-quality decision-making" Awareness of serious risks for *no* protective action taken and when protective actions *are* taken Compare the risk of acting and the risk of doing nothing.
Hypervigilance	A nonselective search for information and a rapid, cursory evaluation of data Only consider limited alternatives; do not review the decisions Thought processes are simplistic and easily disrupted. If an action is not fruitful, then develop a new action plan, continuing this cycle in response to local successes and failures
Unconflicted inertia	A decision raises little emotional arousal Maintain the status quo – no decision process, no decision made ["no decision" *is* a decision]
Unconflicted change	After considering other courses of action, choose an alternative that offers no serious risks
Defensive avoidance	Belief there are no good alternatives Give up the search Minimize threat cues Develop "fatalistic beliefs that support a precariously optimistic outcome."

Inquiry can also create a cognitive state when the individual's state is ambiguous. Asking if the person is afraid creates fear ("Should I be?") (13). This is like workers in dangerous contexts; while they can feel fear, they cannot show fear (3).

The answer to a question causes one to respond differently because the question and answer create a new context. One behavior of leadership follows "The questions the leader asks and the answers the leader accepts ((34), 404-405). Questions can be directed to move people, identify discrepancies, or appreciate complexity and ambiguity. Subordinates can develop alternative explanations for events and circumstances.

> William J. Corr, Captain, Los Angeles City Fire Department, would ask firefighters to describe or explain what they were doing. He would compliment them on their skill, expertise, and ingenuity. Over time he began to talk to the firefighters, not to offer suggestions but to ask if they had considered anything else since they'd last spoken. Within a few months, the culture of the fire station had changed.
>
> —Daved van Stralen

Self-Organization is Contextual

In an open system, fluctuations and noise frequencies became contextually dependent. Consequently, context affects which measurements can be observed and what values can be obtained

(11). Interactions in an open system can induce change in the state of the involved processes, if not the process itself. Process algebra, based on Alfred North Whitehead's process theory (35), is a framework for processes that become a sequence of generated events ("actual occasions"). There is a coherent temporal structure, but the generated events in the sequence have a transient existence. Information plays a fundamental role in the unfolding of reality, and the meaning of that information gives coherence to events. Reality emerges out of a series of actual occasions (11).

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Local, nonlinear feedback develops order and stabilizes systems through self-organization. Positive feedback contributes to growth and structure, while negative feedback restricts growth. Through self-organization, order comes out of chaos (36), but nonlinear interactions degrade our ability to predict trajectories. Self-organization, then, is contextual.

External environmental fluctuations can correlate on different time and space scales, forming processes with unstable frequencies (37). Internal fluctuations, like self-organization and multiple degrees of freedom, can generate a nonequilibrium dynamical system that regains the lost stability (38). Because red and pink noise ["Context Influences Noise" below] do not form a Gaussian curve, collecting more data does not produce a better norm or stochastic model. Instead, more data increases the variance of the system (39).

In self-organizing systems, structure emerges through nonlinear kinetics. Such dynamic systems require continual flux of energy and matter in an open system, as noted above. The continuous flux of energy supports reactions far away from the equilibrium state. These are termed dissipative structures from their continuous dissipation of energy. Patterns then arise from energy dissipation into the environment (40).

Context Influences the Color of Noise

Random fluctuations of energy without a predominant energy frequency and uncorrelated in time form 'white noise' with a Gaussian distribution. However, feedback, or autocorrelation, increases the power spectrum in the lower frequencies. This creates a long period of 'reddened' noise frequencies discussed below. The Gaussian distribution of white noise is the basis for *objective* classical science and Newtonian physics. Reddened noise creates a power distribution contextual in time and space, introducing complexity and *subjectivity* into science (Table 3).

The order of sequence of interactions between frequencies influences their summation, "incompatibility" in quantum terms. The principle of complementarity describes this incompatibility and the uncertainty principles that derive from them. An accurate or precise prediction of a forcing function is not possible.

In a red noise environment or during a pink noise event, using beliefs derived from probability theory contributes to mistranslations of scientific principles while corrupting the necessary flow of information. The noise process is independent of timescale or magnitude. We need not characterize normal environmental variation differently from catastrophes (39).

The long periods of red noise frequencies carry greater energy, becoming a 'forcing function' that forces a system or population to respond. "External forcing by environmental noise alters the qualitative nature of the dynamics" (37), driving environmental influences into the organization and destabilizing the organization's internal environment. In systems dominated by lower frequencies, that is, increased redness, contextual and ecological processes predominate.

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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	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 3. Patterns and Characteristics of Noise (41)

Forcing functions experienced by the individual illuminate the stress response functions and reveal weaknesses in leadership and the social fabric of the organization or culture. Novelty, uncertainty, and uncontrollability, elements that are inherent to red noise, cause stress. (43, 44).

- *Novelty* comes from the emergence of new properties during the nonlinear interactions of self-organization.
- *Uncertainty* is an inherent principle of linear, time-variant systems, a product of the stochastic frequencies in red noise. (Heisenberg's Uncertainty Principle is an example from quantum mechanics.)
- *Unpredictability* develops from stochastic frequencies and the rate of change in the logistic equation that can develop into deterministic chaos (45).

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Contextuality as Phronesis

This quandary of subjective wisdom versus objective knowledge was well known to the Greeks. Aristotle distinguished wisdom from the knowledge within the context – the particulars of a situation. Virtue emphasizes acting for the community values necessary for the common good rather than working in self-interest.

In Aristotle's words, *phronesis* (prudence) is an intellectual virtue or characteristic that is "bound up with action, accompanied by reason, and concerned with things good and bad for a human being" (46). Those with prudent judgment consider the good of the community, which makes this one of Aristotle's four cardinal virtues (the others are justice, temperance, and fortitude). The three elements of phronesis are:

- The person (as an actor who possesses character)
- The particular (situation and context)
- Values (a vision of the good of the community, phronesis is a virtue)

Phronesis is acquired by both practice and observation: practice creates the experience, while observation of elders who model this virtue leads to phronesis. The Neonatologist continuously acquires and models phronesis.

"Providence of foresight" is the source for our word "prudence"; the Romans translated *phronesis* as "prudence." Phronesis is now more commonly translated as "practical wisdom."

Contextuality is Irreversible

Feedback loops in self-organizing processes can amplify or dampen long periods in red or pink noise frequencies, affecting, but not preventing, the presentation of forcing functions. A dissipative structure emerges from local, nonlinear reactions (contextuality) supported by the flow of energy (entropy). These dissipative structures are irreversible without adding some form of energy from outside the system. *Contextuality is irreversible*.

"To understand the dynamics of complex systems confronting us, we need a conceptual model that *embraces fundamental irreversible change.* This requires nothing less than a major shift in our interpretation of physical reality," William Sulis, McMaster University, Ontario, Canada (11) [emphasis from the authors]. Karl Weick, while reviewing the HRO Series published in *Neonatology Today*, observed, "The common notion of enactment is wrongly indifferent to materiality. You add that in as it should be."

Each interaction in the system induces a change in the involved process, if not the process itself. These transitions may be transiently irreversible, but the irreversibility of transitions ensures a non-commutative operation (11). Actions that influence the process, no matter how minor, can thus have sustained effects on the system. For decision-making, on the other hand, such irreversible transitions ensure that the consequences of decisions by individuals persist, enabling a collective transition to form.

The transition is not only to a new state or process but to a new probability distribution. Therefore, these systems cannot be represented by a single probability distribution. Irreversibility also means the systems are history-dependent and different histories will have different probabilities for subsequent behaviors. The resulting autocorrelation reddens the noise frequency for that system.

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Context Is from the Hippocampus

Context is hierarchical and critical for episodic memory storage and retrieval. The cognitive map in the hippocampus is the physiological basis for the context (47). Spatial and episodic contexts are formed in the hippocampus as maps, providing representations of context to the brain and tracking changes over time. Recognition of a novel context may lead to exploration, while a familiar context may elicit a past experience in that context. Discrepant or disrupted predictions formed from past experience in the context could lead to a new or modified context representation (48, 49). Different maps for a physical area can be represented if the behavioral or sensory information differs between encounters. An episodic context can change from spatial representation to temporal (chunks of time) defined by the behavioral goal (49).

The hippocampus seems to have four computational functions (49):

- Recognize return to a familiar context and where one is within that context
- Provide a map associating internal (self-motion, dead reck-

oning) and external (sensory) cues
- Map a search to a plan, deliberate, and identify novel paths and connections
- Provide a resource for consolidation

With active behavior or attentive processes, cells in the hippocampus fire in sequential order: cells with place fields behind the animal fire first and cells with place fields farther ahead of the animal fire later. This forms an ensemble representation of spatial trajectories near the animal. Sequences play a more active and complex role in information processing than encoding experience (50).

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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 (49). Stress also impairs working memory.

The anterior (ventral) hippocampus identifies a change in context, and a significant change is signaled to areas in the cortex concerned with context and the ventromedial prefrontal cortex (vmPFC). Uncertainty and ambiguity in decision-making occur in the vmPFC, incorporating contextual factors into this process. We maintain "flight distance" for safety, behaviorally or emotionally. The flight distance is an animal's security distance from a threat (51). Proximity measured in the hippocampus increases activity in the ventromedial prefrontal cortex (vmPFC), which connects to the amygdala for the determination of the motivational importance of the threat (52).

Contextuality and the Function of Behavior

People and organizations must defend against hostile environments and adverse situations. Outside the flux of events, management science addresses adverse situations through risk and risk management strategies. The HRO operates within the flux of events to engage the situation through capability and the suppression of fear (3, 18).

Fixed constitutive defenses, such as spines or shells for animals or a well-developed hierarchy for an organization, make sense when risks are consistently high or defensive costs are low. Proactive defenses such as rules and protocols are most effective when risks are predictable and controllable (53). The HRO, however, operates where risks vary by location and time, and defenses carry costs. Reactive defenses are more effective and reliable with these increasingly unpredictable or uncontrollable risks (53).

"Every animal has to cope in numerous ways with a hostile, at least uncooperative environment," Nobel laureate Niko Tinbergen. Behavior is the most immediately adaptive method for surviving hostile environments (54).

The spectator, however, does not notice the behavior until it happens, and the spectator doesn't know the individual's mind. Observing behaviors only when they come to attention confounds cause-and-effect reasoning – the event as the arbitrary cause in the flow of time and *the observed behavior as the effect*. The spectator looks backward in time from the behavior to seek the cause. The spectator cannot know the antecedents of the behavior nor the cognitive-affective processes of the individual (54).

Tinbergen (54) treated behaviors as a process, tracing the ever-changing effects of the behavior *forward* in time – *the observed behavior as the cause*, not the effect. Does the observed behavior promote better achievement and survival? Describing how a behavior achieves better survival is to describe the *function* of the behavior. That is, observe the effect of behavior to identify its function. Raymond Novaco changed his focus on studying anger from the *cause* of anger to the *function* of anger after Tinbergen's reasoning (personal communication, DvS).

Behavior is more than a physical act. We couple perception and action, adjusting our actions to changing situations and learning through physical actions (55). Motor cognition, combined with somatic and cognitive knowledge, enhances thinking while acting (17). We use motor cognition when we are actively engaged in an uncertain situation.

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Contextuality and the Ecology of Fear

A predator has greater influence through its absence than its presence; this is the ecology of fear (56). Not only do prey populations decrease, but the ensuing trophic cascade changes the landscape to become a "landscape of fear" (57). The focus of management science on risk and the management of risk rather than increased capabilities and the suppression of fear contributes to the organizational ecology of fear (58). Defense patterns differ if the risk is unpredictable, uncontrollable, variable, and the defense costs are high (53).

Vigilance in the absence of the predator, a defense cost, sustains the stress response with chronically elevated glucocorticoid levels and reduced reproduction (59, 60). Inducible antipredator responses allow selecting antipredator behaviors with variable expression, increasing behaviors for elevated risks and decreasing their expression as the threat abates (53).

Stress. Novelty, uncertainty, and uncontrollability, in the domain of executive functions, cause stress responses (43, 44). Uncontrollability causes minor stress to impair executive functions (61).

Novelty. In any new situation, we can find something familiar; then, we start at that point. We can use metaphors for description and analogies for analogical reasoning. Metaphors carry meaning and assist interpretation when the person using the metaphor has to experience the word or phrase. Analogies have greater applicability to support interpretation and reasoning when the comparison has plausibility, high similarities, and correspondences between domains. Without analogical strength, the metaphors and analo-

gies become thought-terminating cliches (62). We cannot describe or argue against a metaphor or cliché.

Uncertainty. Collecting more data and information to reduce variance is counterproductive in a red noise environment. On the contrary, more information increases variance and uncertainty.

Controllability. The sense of control comes from how we choose and interpret our actions. When people used pencils for examinations, one of the authors (DvS) asked the residents why they brought five sharp pencils to the exam when one dull pencil would suffice. The degree of stress experienced by consulting physicians in an ICU room could be observed by how often they turned the display knob on a mechanical ventilator. They would observe the chest, turn the knob, read the numbers, observe the test, and repeat. What they saw on the ventilator was not a new setting but different displays.

Predictability. Inference to know if therapy will succeed or the course of a disease commonly follows scientific logic and probability statistics. Modal and paraconsistent logics replace scientific logic (15, 63). We cannot develop probabilities because we do not have a Gaussian distribution in red noise environments.

Fear. Proximity in time or space of a threat or an approaching threat. We use Joseph LeDoux and Daniel Pine's (64) description of "fear" as a conscious, subjective feeling generated in *cortical regions* of the brain. Therefore, fear is amenable to conscious interpretation, and consequently, the individual can modulate what we call "fear reactions."

Fear reactions are conscious sensations experienced when exposed to an imminent threat (64, 65). The amygdala sends signals to the brain's unconscious (subcortical) and conscious (prefrontal cortex) regions, accounting for the uncontrolled fear responses and the feeling of fear. The emotional response of fear is to diminish danger (66), creating the drive to avoid or escape, generally focusing on self-interest, self-protection, or the protection of others.

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Response to Thinking and Acting

The human brain will release corticotropin-releasing factor (CRF), which goes to the hypothalamic-pituitary-adrenal axis (HPA). The HPA terminates ongoing activity, suppresses 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.

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.

Norepinephrine, an amino acid hormone, has binding sites on the membrane of specific cells and rapid, specific actions (50 milliseconds). Steroid hormones are fat soluble, so they cross the cell membrane into the cytoplasm and affect cell function with less specificity and a more delayed response – slower, organ-specific (5 minutes).

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Lack of Contextual Information

During interviews with participants following a terrorist shooting, the authors identified misunderstandings due to the lack of contextual information (67).

Unexpected Helicopter Transport

A trauma center received two patients by helicopter. They had not been notified of the patients. Some individuals in the administration of the trauma center and EMS agency believed the helicopter was ordered to fly to a non-trauma hospital.

The context: The scene transportation manager took advantage of a pause in the flow of ambulances Triage A. He rapidly selected two patients for helicopter transport to move some patients to trauma centers away from the two local trauma centers and to transport two patients rather than wait for another ambulance. One patient began to deteriorate at altitude. The treating medic requested the dispatcher to notify the trauma center, but the dispatcher was preoccupied with activities surrounding the shooting.

Wandering Evacuees

Medics at the triage site observed people walking away from the buildings and crossing a major street. Complaints came in about the unplanned creation of a second triage site while the triage medics were trying to manage arriving victims.

The context: A call came for an ambulance and field supervisor to respond to a home north of the triage site. Even though the call was heard in the field, no one responded. It appeared the call was to respond to a nearby abandoned house. Law enforcement officers had selected the abandoned house for a secondary triage site to collect possible injured people evacuating from a nearby office building. The abandoned house had a metal fence useful for protection from a possible sniper, and the site could contain people from nearby buildings, keeping the main triage site clear.

Less Serious Patients Transported First

An ambulance crew was prepared to transport a seriously wounded patient shot in the chest. Instead, they were given a less critical patient with multiple wounds in the extremities.

The context: A patient with a chest wound was in the ambulance receiving area. As the ambulance arrived, the patient showed signs of developing pneumothorax. Ambulances were backed up. The treating medic did not want to waste time, so he sent the

patient with multiple gunshot wounds who was less sick. This allowed him to stabilize the patient with the chest wound by completing the thoracentesis.

Under-triage Shooting Victims

Nurses at a community hospital heavily criticized medics for transporting shooting victims to a community emergency department rather than a trauma center. These criticisms continued, interfering with the completion of the medic's paperwork.

The context. All area trauma centers were receiving critically injured victims. It was explained to the nurses with some effort that a major shooting had occurred. Trauma centers should not be inundated with minor patients simply because of the type of trauma.

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Ambulance Self-dispatch

Ambulances from a private ambulance service arrived at a fire station near the triage area—the self-dispatched of several ambulances to the scene confused within the system.

The context. The regional EMS authority contacted the ambulance service, requesting two ambulance strike teams to respond to the site.

Case Studies

The following stories illustrate the effect of disregarding context. The actors are all successful; their decision-making is typical. What is different is the lack of context in their problem-solving.

The El Faro (8)

The captain of the container ship El Faro had 15 years of experience sailing through arctic winter storms between Tacoma, Washington, and Anchorage, Alaska. As captain of the El Faro in the Caribbean, he sailed the ship into a Category 3 hurricane. The wind, waves, and list of the ship were, the captain would repeat, a typical winter day in Alaska. The ship turned over and sank.

The shipping route off Alaska was close to a shoreline that buffered winds. The winds of arctic storms blow north to south. The wind direction is circular in a hurricane. Winds blowing against the port side (left) confused the captain.

The captain misattributes the ship's list to the wind hitting the large sail of the ship. Thirty minutes later, the captain and crew realize the list is due to flooding.

The captain never called them a "hurricane." Instead, the storm was a "system," "low," "disturbance," or "storm."

By describing this as a 'typical winter day in Alaska,' the captain was looking for a similar situation. The hippocampus creates context by identifying what is different. This may be the mechanism for the brain moving toward abstractions versus contextualizing the circumstance – interpreting the situation similarly reduces stress (no novelty) and fear (distance from threat).

Interpreting the situation, like his experience in Alaska, lifts events out of the environment to connect them to abstract concepts. The captain's substitution of other words for "hurricane" furthered his shift in thought. The supposition of a "typical" storm substituted an abstract conceptual order for the current perceptual order of the storm. Concepts in this new conceptual order became converted into discontinuous "facts." The captain developed "engaged abstraction" (9).

Mount Everest (68). After 30 years of attempts, climbers failed to reach the summit of Mount Everest. In the 1920s, George Finch, a mountaineer, and scientist with engineering skills developed portable oxygen equipment and advocated better sleep and diet (69). Finch was excluded from the 1924 expedition and had been denied membership to the London Alpine Club because of conflicting personalities. His ideas did not match the high-altitude science at the time; science developed in pressure chambers for aeronautics (69, 70).

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 (71). In 1953, Sir Edmund Hillary and Tenzing Norgay reached the summit of Everest, smiled, removed their oxygen set, and took photos (70).

Cholera. The scientific theory of cholera pathology was the poison of the sodium pump by cholera toxin. This disabled the active transport of glucose in the intestinal mucosa. In South Asia, for hundreds of years, treatments for cholera included fluids with salt and a form of sugar. Robert A. Phillips (72), a medical researcher, gained extensive clinical experience with cholera in South Asia during the 1950s and '60s. He led a team that, by 1970, overturned that theory of cholera pathology. A solution consisting of sugar, salts, and water now saves countless lives of severely dehydrated adults, children, and infants.

Assisted ventilation. Physicians through the 19th Century considered mouth-to-mouth resuscitation a futile method to save lives. "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" (73). The physician writing those words resuscitated several newborn babies, starting in 1814.

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Mechanical ventilation causes extreme distress in patients unless the patient is sedated. Otherwise, the ventilator causes ventilator-patient asynchrony in the breathing patient. One of the authors (DvS), serving on a fire rescue ambulance, had administered mouth-to-mouth breathing in the field to an infant, adolescent, and

adult. We used that experience to teach bag-valve-mask (BVM) resuscitation for breathing patients, a technique used in a pediatric subacute care facility and some elite army special operations forces. When used for ventilator-dependent children, they smile and laugh, some for the first time (74).

For children with cognitive disabilities, unfamiliar faces or touch cause them to withdraw mentally and emotionally. This state of "hypoactive delirium" is a reversible decrease in mental state. Healthcare and public safety professionals routinely interpret this as a severely blunted mental state, if not a vegetative state, though these children smile in response to family and familiar healthcare providers. The likely cause is the change in social context processed by the hippocampus as a significant contextual change. The hippocampus becomes disabled for memory retrieval, except motor memory, while signaling to the ventromedial prefrontal cortex (vmPFC) about uncertainty or the proximity of a threat within the safety distance. Healthcare professionals outside the context of familiarity do not understand the bond formed by the child who can smile, while families lose some of their trust in healthcare professionals. It is not uncommon for families to report that healthcare professionals tell the parents that the child cannot smile. Instead, the Duchenne emotional smile involving the eyes is a reflex or grimace; the child does not feel happy or pleasure—this is from a simple change in context.

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Military combat. Academicians criticized a study of soldiers in the operational area (75) because problems in its design and execution would limit any attempt to conclude it. The authors did not indicate that the quotes used were statistically representative. The study's findings would challenge the conventional wisdom about military unit cohesion. The authors found that, contrary to the consensus findings of the vast literature, the distinction between social and task cohesion is irrelevant in the operational area.

The authors of the critiqued publication had deployed into an active war zone. Soldiers were assigned to the authors for force protection. However, the first duty of the soldiers in the operational area was to defend the area by engaging the enemy rather than standing by the authors.

> "Is [it] scientifically appropriate to assume that the extensive work done in peaceful settings will necessarily generalize to combat?"
>
> "Research involving human participants conducted in safe, peaceful settings will not necessarily generalize to combat; combat findings may differ from those developed elsewhere."
>
> Thomas A. Kolditz (76)

Implementation of HRO, Patient-Centered Care

Referring to an article about HRO in a medical setting, a patient safety officer wrote, "The article seemed descriptive rather than numbers driven. Unless there is some specific data, it will be met with skeptical responses" from members of the quality improvement committee.

Classical logic and Kolmogorov probability theory are deeply embedded in medical science. The familiarity and trust that develop influence the beliefs of healthcare professionals and their understanding of how they think. The risk is reliance on abstract concepts, even extracting abstract concepts from operating concepts. As Weick describes the captain of the El Faro: The captain substituted an abstract conceptual order for the current perceptual order of the storm. Concepts in this new conceptual order became converted into discontinuous "facts." The captain developed "engaged abstraction."

The authors have implemented HRO into their various programs, but it was through appreciation of contextual details and decision-making as reciprocal feedback. This drives operations deeper into the situation.

The lack of contextualization in HRO implementation impairs operations and washes out the function of HRO. The organization does not develop the capability to withstand environmental forcing functions, let alone develop adaptive allostatic growth.

As described in our disaster series, bedside staff repeatedly resolved daunting circumstances without a plan or outside direction. In each disaster setting, self-organization against the environment created improvisation, and self-organization with colleagues made teams. Success emerged from their focus on context, influenced by their acceptance that each of them was a participant.

Directing care to our patients too quickly becomes a 'substituted abstract conceptual order' for evaluation and management. Adjusting care to the patient's circumstances becomes 'patient-centered care.' Perhaps we could consider a quantum approach of continuous change and different perspectives. We could also examine the realization that uncertainty is the state in which we operate rather than the result of ineffective operations. We work within the patient's context rather than a medical context.

In the 1970s, one of the authors (DvS) served on a fire rescue ambulance that responded with two medics but no fire companies or law enforcement officers. Approaching the scene meant entering the patient's territory, whether that was the home, vehicle, office, or vacant field. The patient did not adapt to us. Instead, we adapted to the patient, which meant their language, culture, family and friends, and local furniture and belongings. You cannot tell people to leave when it is their grandparent's bedroom.

This gave a different tenor of care compared to a medical setting and revealed the power of role theory. Patients and their families are intruders into our abode in the medical setting. This is good as they more readily take on the role of patient. In their home, they forget this and continue their role as human beings. The author learned through experiencing failures and successes that we treat the family, friends, and home, regardless of patient privacy. That is not to say personal details are shared, but that the patient and parents benefit if they can learn how to explain their changed circumstances with varying levels of prudence.

"That is not to say personal details are shared, but that the patient and parents benefit if they can learn how to explain their changed circumstances with varying levels of prudence."

Patient-centered care, like all medical care, has the danger of becoming "engaged abstraction" when we want it to be "engaged context."

"Consequently, stress and fear responses may become naturalized in our behavioral responses. We then engage the changing contextual order, but with the error of "engaged abstraction." Accepting uncertainty and flux and understanding that our presence alone changes the situation can reduce the emergence of stress and fear responses."

Conclusion:

HRO emerges when our perceptual order is contextual. Context develops when environmental changes come to our attention through the hippocampus. The hippocampus is linked to brain regions that respond to uncertainty and fear. Consequently, stress and fear responses may become naturalized in our behavioral responses. We then engage the changing contextual order, but with the error of "engaged abstraction." Accepting uncertainty and flux and understanding that our presence alone changes the situation can reduce the emergence of stress and fear responses. But more critical is the understanding that their history does not predetermine the trajectory of events, the act of measuring changes events, and asking questions and the answers we accept can be sufficient to move in a better direction

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