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Operational Logics and Inference During [1/f or f -1] Noise Events: High-Reliability Operations (HRO)

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Abstract:

To prepare for and operate in stochastic environments, we study and even master academic models. The environmental stochastic Noise separates the world of practice from scientific theory. Oscillating and fluctuating processes create frequencies of power, the color of Noise, and unpredictability. These environments also contain the determinants of stress, putting individuals at risk of the peculiar Logic of Stress and the ecology of fear. We effectively engage these environments by logic, a logic of practice shared by those who crossed the threshold with us - not classical logic, however. Modal logics conform to changing events and support flexible thinking. Paraconsistent logics support inferences from contradictions. In topology, the central concept is continuity and how the elements preserve a notion of nearness by a continuous function. They maintain connectedness during deformation without tearing apart to create a new boundary.

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Introduction

We "must act when we cannot foresee consequences; we must plan when we cannot know; we must organize when we cannot control," Todd R. La Porte (1).

"No plan survives the first shot." "No plan survives the first contact with the enemy." "Every plan is a good one until the first shot is fired." We hear these phrases, resignations to the futility of cherished, though undependable, plans. Then why make such futile plans? As stated by La Porte, *we must act*. But act into what? "The fog of war"? Another phrase like the weather – talked about yet not acted upon. The fog of war is the uncertainty and confusion of any red noise forcing function – the system, through individuals, must respond even when "we cannot know…we cannot control."

We *can* project thought into the stochastic environment. We *can* act into uncertainty. We can operate in that fog by generating new information through logically acting and inferring new information. By appreciating the limits of classical logic, we can identify logic to our actions, the logic of practice.

To prepare for and operate in stochastic environments, we study and even master academic models. Logic is how we can reliably use these models with available information to make useful, valid inferences. However, information in these environments is imperfect and in flux, opening a gap between practice and theory. Using scientific models to predict what would happen when entering these environments can kill inaccurate models (2).

"Everything around us, and within us, from the micro to macro, has oscillating behaviors. These oscillations may become synchronous, aggregating into waveforms that can develop into collective behavior (3). Feedback or an external force can readily desynchronize the oscillations and waves into aperiodic fluctuations, the variable, random, stochastic 'noise' forming our environment."

Everything around us, and within us, from the micro to macro, has oscillating behaviors. These oscillations may become synchronous, aggregating into waveforms that can develop into collective behavior (3). Feedback or an external force can readily desynchronize the oscillations and waves into aperiodic fluctuations, the variable, random, stochastic 'noise' forming our environment. This is the actual, 'real' world, the world studied by scientists, academicians, and management scholars, whether in the field or the laboratory. The Gaussian distribution disintegrates from these noisy fluctuations, impairing correlations between the environment and laboratory or office.

When we separate and remove signals (cycles with predictability that have meaning) from Noise (the residual variability that causes unpredictability), we can distinguish environmental stochastic noise patterns from their probability distributions and the influence by various frequencies – white brown, pink, and red Noise.

We develop concepts, models, and theories to understand and predict aggregating, collective behavior that has been influenced by environmental stochastic Noise. Classical logic underlies the development of scientific theories (4). Scientific rationality provides the framework of organizational and management theories (5). Classical logic and scientific rationality are founded on deductive reasoning (facts guarantee the conclusion), statements either true or false (bivalence), and discrete entities having distinct properties (law of the excluded middle). Environmental stochastic Noise separates the world of practice from scientific theory. It separates the formal knowledge produced by management scholars from the applied knowledge needed by practitioners.

The Color of Noise and Predictability

Oscillating and fluctuating processes create frequencies of power. In some environments, the spectrum has an equal distribution of all frequencies with constraints on the power. This is a 'white noise environment' with a frequency value f^{0}, named after the white Noise in acoustical systems. The frequencies and power can all be random as in Brownian motion; hence, ' brown noise environments' with frequency value f^{2}. The frequencies of these two environments are related through the calculus integral function discussed below. Half the integral of white Noise is pink Noise with frequency value f^{-1} with characteristic 'flickers' of power. Environments with low-frequency (or long-period) cycles are a 'red noise environment' having frequency values around that of pink Noise. We will discuss how this affects logic and the inferences we can make.

"Without the dominance of any frequency, events are random and independent of past events (6, 7). This does not mean that surprises will not occur. Novel properties can emerge from the stochastic resonance that creates environmental Noise (8)."

White Noise has a flat spectrum uniformly spread across all frequencies ($1/f^{0}$, a constant). Without the dominance of any frequency, events are random and independent of past events (6, 7). This does not mean that surprises will not occur. Novel properties can emerge from the stochastic resonance that creates environmental Noise (8).

White Noise has the characteristic that the values will converge by summing the low frequencies at random (integration by the calculus of the power). If we sum the *high* frequencies at random, the values will *diverge*. When we sum all random frequencies over longer time intervals, the values will converge to an average or *mean value*. The instantaneous value, however, will be undefined (9).

White noise frequencies, $1/f^{0}$ (a constant), therefore generate a normal distribution with zero mean, constant variance, and is uncorrelated in time (in a time sequence, the value at time t is random and independent of the value at time s). 'Gaussian' white Noise has a normal distribution of mean 0 and standard deviation 1. This makes possible statistical analysis and probability calculation and the development of reliable models and theories.

'Brown' Noise (after Brownian motion) is random Noise generated by keeping a running or cumulative sum of power differences in increments, constantly adding up the power. This summing up makes brown Noise the calculus *integral* of white Noise and white Noise; therefore, the calculus *differential* of brown Noise. Since the flat spectrum of white Noise is $1/f^{0}$, then brown Noise has a spectrum of $1/f^{2}$.

When summed (integrated) toward *zero frequency* and over longer timescales, the value *diverges* from its initial value. Summing frequencies that approach *infinity* gives *converging* values. Combining all the frequencies as for white Noise (which converges to a mean value, described above), the diverging low frequencies and converging high frequencies results in *no* mean value. Brown noise, therefore, generates a random distribution rather than a Gaussian distribution. Over time, this random walk function wanders farther away.

Pink Noise (also called fractal, flicker, 1/*f*, or f^{-1} noise) is half the integral of white Noise. Pink Noise is the power function halfway between white Noise's predictability and the randomness of brown Noise. We can observe 'flickers' of power (abrupt increases in magnitude) (9, 10) at 'half' the integral of white noise processes. Flicker noise sums (calculus integration) *diverge toward zero or infinite frequencies*. Without a long-term mean or defined value at an instantaneous time, pink Noise does not form a Gaussian curve. Because these divergences are logarithmic, extending time intervals in a time series may not capture the flicker (9). Rare events are more severe and sudden in the pink noise environment, as forcing functions (7), forming a power distribution.

[The name flicker noise came from John B. Johnson's initial measurements of the white noise spectrum. He measured an unexplained flicker at low frequencies halfway between white and brown Noise (10).]

Red Noise is dominated by low-frequency (or long-period) cycles producing an increased probability of long runs of above or below average conditions. Low-frequency events (reddened spectrum) have an inordinate influence on a system because prolonged decay continues dissipating energy and environmental disruption (11, 12).

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

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Whenever a system results from its past, there is feedback or correlation between past and present. Feedback from the system onto the system is autocorrelation and shifts a system from white Noise and the Gaussian distribution to red or pink Noise and power distribution. It is forcing functions to become ubiquitous, not entirely random except by timing. The forcing function emerges from known processes within normal variation, differing from only as a matter of time scale and magnitude.

As described above, low-frequency events are forcing functions that the system must respond to. While possibly counterintuitive, this also describes human behavior – our past experiences influence our current behavior, and we constantly interact with those around us. ALL human behaviors are autocorrelated. ANY system with *human behavior is a red noise environment that will generate forcing functions into the system.*

We may have a hard time accepting that random environmental Noise has the power to force the system to respond. This is especially true when the human behaviors are *internal* to the system: leaders, supervisors, and line staff. We believe that everything that happens must have a cause(s) that can be identified, and for that, we can prepare. Stochastic resonance brings things to our notice, things we would not usually detect (8). Environmental stochastic Noise brings things together for interactions we would not normally expect. Stochastic Noise, then, generates the unexpected from the expected.

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Feedback processes generate stochastic resonance that creates the red noise environment with the loss of Gaussian distributions. However, precise, tight coupled scientific theories, models, and concepts do not necessarily provide the necessary accuracy for deadly contexts (2, 13). Red Noise creates the dangerous gap that forms between theory and practice (5, 14), discrete concepts and continuous perceptions (15, 16), and the academician and operator (13, 17). Engagement of feedback and stochastic resonance in the red noise environment distinguishes operations from logistics.

Environmental stochastic Noise challenges our knowledge, undermines our experience, and refutes closely held beliefs, models, and theories. In the red noise environment, we have a logic of practice that differs from the laboratory or office – one that paradoxically applies to the well-controlled lab or office environment and for red Noise forcing functions and abrupt pink noise catastrophes. We use inductive reasoning and heuristics (18), loop decision making (19), and practical common-sense problem solving (20). In this paper, we discuss modal, paraconsistent, and topological logics.

The Logic of Stress

We must rapidly infer new information when the environment is in flux. All disturbances of various sizes are red Noise forcing functions and abrupt pink noise catastrophes, normal environmental variations experienced at different time scales (7). The properties that emerge are likely novel to individuals unfamiliar with the event, introducing a greater level of uncertainty. Trajectories become unpredictable and seemingly uncontrollable.

Stress interferes with making logical inferences. Novelty, uncertainty, unpredictability, and uncontrollability are the determinants of stress responses (21, 22). Uncontrollability alone causes minor stress to impair the brain's executive functions (23), restricting abstract thought and suppressing action. Abstract words generate thinking while concrete, active words facilitate action (24). It is action, though, coupled with the perception that forms *motor cognition*, allowing us to adjust our actions to changing situations (25). The effect of *intentional* motor activity on thought as motor cognition may explain why intentional movement can break the grip of cortisol on abstract thinking.

This is the paradox of stress: inhibited abstract thinking with concrete motor cognition. We can recall our actions but not the logical inferences or conscious intentions that supported those actions. Conscious intention occurs *after* preparatory brain activity in the frontal and parietal brain areas (26), and intention in motor cognition is not complete until the motor function ends (26).

Logical inferences during stress events make sense to the operator at the time yet appear illogical to spectators and are often difficult to explain later. The authors have commonly observed concrete thinking that the individual later explained as actually being more complex abstract thought. More serious is the effect of fear reactions and threat reflexes while making logical inferences.

Interpretation of the stressor as a threat brings forward the conscious yet subjective *fear reactions* and subcortical, objective *threat reflexes* (27, 28). Separating the emotional and motor components of stress, fear, and threat elucidates the effect of stress on logical inferences in the VUCA-2T environment [see Table 1] caused by forcing functions. Because even showing fear impairs performance, those operating in dangerous contexts suppress the showing of fear reactions (personal experience and observation of the authors; (29-31). They also modulate threat reflexes because of the effect on cognition and performance (32).

Volatility	The rapid, abrupt change 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	Limitation acquiring information, deciding or acting before consequential changes

Table 1. VUCA-2T (33)

Fear Reactions

We maintain distance for safety. An encroaching threat elicits the fear reaction to increasing distance by moving to a place of psychological or physical safety (34) and, if that fails, fighting to escape (35). The distant threat increases activity in the ventromedial prefrontal cortex (vmPFC), the brain structure necessary for decision-making in uncertain, risky, ambiguous, or context-dependent conditions (36). The vmPFC incorporates contextual factors into decision-making. The subjective representation of threat, and the degree to which it is felt, is processed in the phylogenetically older midbrain structure, the periaqueductal gray (PAG) nucleus. The PAG coordinates behaviors essential to survival controls, such as fast reflexive behaviors (e.g., fight, flight, or freeze) (37, 38).

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 to be the same as the fight or flight from *threat reflexes*. What it describes, though, is the functional flow of response to a developing danger: apprehension leads to avoidance (flight), then becomes engagement (self-defensive fight). Fear reactions (PAG) develop from distance-based assessments as a functional approach, while *threat reflexes* (amygdala) come from active danger.

It becomes clear why those who work in dangerous contexts will suppress the subjective feeling of fear. The logical inferences that one would describe making during conscious, subjective fear responses develop deeper within the brain than conscious thought. Fear-*flight* causes people to avoid the threat in some way. Fear-

fight poses a more significant problem as the individual will focus on self-preservation by defensive protection or taking offensive protection through prompt aggressive attacks to stop the spread of the problem.

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Defensive protection keeps the threat at a distance. 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. Distance interferes with forming accurate descriptions, correlations, or causations. Individuals, instead, rely on rationalizations and abstractions (for example, clichés and metaphors) to support and explain judgments, interpretations, and actions. The individual is less helpful to protect others since the person becomes focused primarily to reduce risk to themselves. Deflection, excuses, justifications, and prophylactic self-blame are standard methods (39).

The limited accuracy of observation and inferences directed toward self-preservation follow idiosyncratic rules specific to an individual. Others will learn these methods through modeling as they appear prudent and rational at the moment. As a method for logical inference, they are more likely to lead to failure to engage the situation, failure by not acting. We enact our operations restraints and may enact our fear. Failure from not acting is invisible and becomes part of the organization's knowledge (40), forming the invisible ecology of fear (41).

Threat Reflexes

Threat reflexes are subcortical actions due to *attack*, the *imminence of a threat.* We cannot control the threat reflexes as a reaction, but we can inhibit sustained threat reflexes and control consequent behaviors (32). Threat reflexes initiate behaviors for survival and adaptation to adverse or hostile environments. Perceptions of threat trigger reflexes that operate below the level of consciousness (42). Threat reflexes do not generate information by logical inference but will intrude into cognitive efforts to infer new information.

The fight is manifested by anger, including the instrumental use of anger for gain unrelated to the threat. The flight takes the form of avoidance and distraction. Freeze as attentive freeze supports observation. The body is tense and poised to act; the mind is watchful, collecting information. Attentive freeze is associated with faster subsequent cue-signaled responses (43).

Emotional memory rapidly initiates a behavior from a trigger event through the amygdala (44, 45). Emotional memory contributes to the logical inference that can be effective from an experienced veteran but destructive when associated with a traumatizing event at a subcortical level.

While mentoring military or public safety professionals regarding post-traumatic stress, one author (DvS) would describe their sudden anxiety during a medical emergency (but not where the individual is exposed to danger). When they walk into a patient's room, their brain identifies objects by past, present, and future. The vase with flowers: who gave it, how did it get there, and why in that spot; is the vase interfering with activity; what can happen to the vase, will it fall, what can the vase be used for (as a weapon, for protection). Rather than fighting these images from the compression of time as past-present-future meant survival in a dangerous context, the individual can gain insight into the situation and the patient.

Fear as Faulty Inference

As with fear responses, logical inference from threat reactions is more likely a justification for behavior rather than the inference for new information. The resulting, unrecognized concrete thinking restricts if not intrudes into, the abstract, decontextualized processes of classical logic.

What confounds the translation of classical logic into reddened noise environments is the necessity to generate the information that is needed as the situation changes, cognitive impairments from maladaptive stress responses, the autocorrelation of time sequences (feedback), multiple valences developing from oscillations, fluctuations, and indications for when and how to act. The logic of practice translates to experience in dangerous contexts for routine operations. With the logic of practice, we need not see everything as a danger.

The Logic of Practice

We engage and enact in uncertain or ambiguous situations, not by decision theory, not by rationality, and not by sensemaking. It is, by logic, a logic of practice shared by those who crossed the threshold with us.

Academicians study the logic of practice from outside the flux and trajectory of events. Cognition and behaviors become normalized without the necessary access to inner mental states that may have been impaired by stress and threat. What is missed is stress and threat manifested as contingently linked behaviors (5, 17, 46). Detached observation and identification of abstract properties, necessary for scientific objectivity, conceal the situational reasoning and intent of the operator (5, 47, 48). Individuals' internal logic of operations becomes unrecognized and inaccessible (49).

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Within the NICU, the environment can become unpredictable from time compression and abrupt changes in structure. The Neonatologist must work with imperfect information in flux—the internal logic of events changes. Threats impair the mind, which, if unmodulated, can quickly become unrecognized and even normalized (32).

Karl Weick (50) described how these "cosmology episodes" collapse sensemaking and leadership. This occurred even with seasoned wildland firefighters during the 1949 Mann Gulch Fire when they mistook a large fire for an ordinary fire; then, they were overtaken by a firestorm. Such abrupt breaches in the environment involve the entire group or organization. In structured, predictable environments, what is rational and logical becomes harmful during a cosmology episode. Actions or events may appear irrational solely because we do not recognize the system's internal logic. We likely continue using classical, scientific logic even as the system's internal logic changes.

Boyd's response (51) to a disruption of observed reality parallels Weick's sensemaking perspective that operators create what they focus on through repeated cycles. For Weick's sensemaking, the operator distinguishes cues within an ambiguous event to use for enactment toward a resolution that restores the disrupted activity (52, 53).

This illustrates three problems with scientific rationality (5):

- Underestimating the meaningful totality into which practitioners are immersed,
- Ignoring situational uniqueness characteristic of the tasks practitioners do, and
- Abstracting away from time as experienced by practitioners.

Modal Logic

When the Neonatologist enters the room, staff and family see the individual *designated* as the Neonatologist. In logic systems, if that specific Neonatologist can be interchanged with any Neonatologist, we are only seeking a Neonatologist, then "Neonatologist" is considered an *extension*. Logic systems that only consider *the designation of things* are extensional. Mathematics is an *extensional* logic system.

To the people in the room, "Neonatologist" has different *meanings*. For example, the same Neonatologist could be a teacher, the attending Neonatologist, or a supervisor. Meanings are truth values independent of the form, as the different meanings of "Neonatologist." Meanings are called *intention*s, and logical systems that deal with meanings are *intensional* logics. Meaning is the form, or mode, of a thing. Thus, a *modal logic* evaluates the mode or qualification of truth: the different ways things are true.

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Extension refers to the truth value entirely deriving from its form. For example, "Neonatologist" refers to the same attributes of all actors acting as "Neonatologist." These are extensional logics, and the *substitutivity principle* is valid, which is invalid *intensional* logics because the truth values are determined by something other than its form.

"Neonatologist" is interchangeable in classical logic, measured only as a quantity. Modal logics allow qualifications for "Neonatologist" such as "necessarily" and "possibly." In the 20th Century, modal logics developed to work with time, knowledge, belief, belief revision, and moral obligation (54).

These other logics allow values we need if we are to understand the VUCA-2T (Table 1, above) environments, the indeterminate problem (i.e., time compression, uncertainty, and threat), and ill-structured or embedded problem [references]. In informal logic,

1. multiple adaptive answers are possible;
2. many-valued and partially valued logics are used;
3. more than one truth, and partially true values all exist; and
4. the universe is *not* knowable.

We present modal and inconsistent logics as systems that benefit high reliability-seeking operations. Rational thought and preserving truth through logical operations may provide the best security in dangerous circumstances. However, mild uncontrollable stress impairs cognition and flexible thinking (23), corrupting rational thought while imperfect information in actively changing states corrupts classical logic operations. In addition, classical logic tells us what things are, the ontology, and not what we can or should do. Modal logics conform to changing events and support flexible thinking. Paraconsistent logics support inferences from contradictions.

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The limits to scientific logic can be addressed by the modal logics: the different ways, or modes, that things are true. We must learn how to use these logics to infer reliable information from imperfect information, understand our changing beliefs in a dynamic world with uncertain information, appreciate how time changes the truths and information we work with, and comprehend how situations create different, but logical, duties and obligations.

The rigid restraints of classical logic impair usage for uncertainty and inconsistency, particularly the law of the excluded middle. We can evaluate a premise by its appearance or form, or we can use partial operators. That is, we limit the action of the operator. Modal logic classifies propositions as *contingently* true or false and allows claims about what is necessary, possible, contingent, essential, and accidental. Modal logic is the logic of "modalities," *modes* (means) of truth, by using a variety of operators dependent on the domain of the logic (55) (Table 2).

Logic	Domain	Operators
Modal	Qualify the truth of a judgment	"necessarily," "possibly"
Epistemic	Knowledge and belief	"it is known that" "*x* knows that" "*x* believes that"
Doxastic	Belief revision (add information) Updating (world has changed)	"*x* holds after contraction / revision / expansion"
Deontic	Moral expression, duty	"ought to be" "obligatory," "permitted," "forbidden."
Temporal	Future, past Linear & branching-time	"it will be / it was" "it will be / it will always be"
Paraconsistent	Partial truth	"necessarily" rendered as "pragmatic validity." "possibility" rendered as "pragmatic truth."

Table 2. Modal Logics

Epistemic logic (Greek *episteme*, knowledge; the *certainty* of sentences) concerns the justification and rationality of knowledge and belief. Epistemic models help us understand how operators perceive the actual world. The person may have belief as conviction, that everything they believe is true, or they may only believe what is objectively true, that is, a belief independent of their subjectivity. There are small but conceptually important differences between these two frames of view. (Epistemology has two aspects: the definition of knowledge and its logical inferences. The two logical inferences are epistemic knowledge logic and doxastic belief logic.)

Knowledge of the situation depends on the frame of reference (17, 56): the subjective internal, the perfect (objective) external, and the imperfect external points of view.

<u>The subjective internal view</u>

The person involved in the situation builds from a mental model representing how the world is perceived. This model must include the beliefs of others and the beliefs that others have about the person, however wrong they are. Therefore, these beliefs could be wrong, and the envisaged models could be wrong. The individual maintains this level of self-awareness during a crisis.

<u>The perfect (objective) external view</u>

The person is an omniscient, uninvolved observer with perfect knowledge of the situation and has access to the minds of the people involved. The models are envisaged as true to reality. This is the presumptive view of planners and can be found in executives, administrators, and managers.

<u>The imperfect external view</u>.

The person is outside of the situation but does not have perfect knowledge. Any models envisaged could be wrong. This view drives the search for information and initiates HRO.

During the complexity of events, we assume that our actions have a very narrow effect and that most things will not change. The assumption of "no change," similar to inertia, is called "causal inertia" in artificial intelligence and forms the "Frame Problem" (57). What makes this a problem are the variables that don't appear to be involved with the action but are partially relevant or contingent information that can influence events. The Frame Problem formalizes this inertial reasoning (58).

"*Dynamic epistemic logic*" is a logical framework dealing with knowledge and information change and planning for partial observability and non-determinism (56, 59). These events can change the real properties of the actual world. It describes knowledge and how actions change knowledge (epistemic) and facts (ontic) (59). While dynamic epistemic logic provides a logical framework to reason about the outcomes of a series of actions, this reasoning will always be situational. Thus, it has a focus on situations involving multiple agents/actors and how their knowledge changes when the situation changes. Each agent will generate a set of possible worlds that are compatible with an agent's knowledge and those that are not. This can be limiting as inexperienced agents comment, such as "How common is this?" "It can't be done, it's not possible" "What will *they* do?" "How can *they* help?"

Modal operators for shared knowledge include:

- *General knowledge* – everybody in the group knows
- *Common knowledge* – everybody knows, and everybody knows that everybody knows
- *Distributed knowledge* – if participants pooled their knowledge, they would know what holds true, knowledge becomes *distributed*

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The visibility of information is difficult in dynamic events because facts are not accessible, or they change. In dynamic epistemic logic, *public announcements* present information to everyone without factual changes occurring. Actions are *fully observable* (*public*), *partially observable*, or *non-observable*. Observability can be private or by the group. Operators may know *something* has happened but not precisely what.

> The PICU interfacility transport program expanded rapidly in the first three years. Referral emergency departments, unfamiliar with the process, insisted on rapid departure for critically ill or injured children. The author (DvS) advised the team to operate in similar conditions to how the fire rescue ambulance operated. Family, friends, or bystanders of all socio-economic groups were confused about the need for on-scene medical treatment. Methods of intimidation included voice, stance, and threats, including the display of weapons. Fire medics would kneel by the patient while facing the more vigorous bystander to maintain strict neutrality on the scene and decelerate the aggression. All actions were clearly shown, if not mildly exaggerated, and thought processes and actions were clearly "described" to the other medic. The author suggested such an approach and the PICU mantra to "never criticize." He explained that the ED staff would ob-

serve and listen from a distance. Their action would reassure and educate staff and demonstrate there would be no delay in transport. Within weeks, ED staff began walking by the patient and would stop and watch. After a few months, ED staff began asking questions. At six months, the transport supervisor began receiving service compliments. The transport teams used epistemic logic to overcome the partial observability problem and reduce uncertainty.

Partial observability contributes to uncertainty. For the single operator, uncertainty also comes from incomplete knowledge of initial conditions and indeterminate course of events. With multiple operators, the acts of other operators give rise to additional uncertainty.

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Each possible world is an alternative to the actual world for epistemic modal logic. An individual operator cannot distinguish which possible world will become actual. Dynamic epistemic logic can offer the ability to plan in these nondeterministic, partially observable, multi-agent domains (60).

In the subjective internal view, the operator will not know the state of the actual world when the plan is initiated, but the operator will know the state of the world once the plan is executed. Whereas conventional planning assumes or disregards belief and knowledge of the operators, dynamic epistemic logic incorporates belief and knowledge of multiple operators into the logic system. Planning for operators' knowledge (and iterated knowledge) allows for more complex planning domains than plans that are concerned with simple facts about the world (60).

Part of this richness comes from the epistemic logical branching of plans. Plans cannot guarantee to achieve goals in all contingencies, and branching increases the power of the plan. Branching models can represent how the operator perceives the actual event, whose own epistemic model contains knowledge and ignorance. The branching of planning trees can expand by adding nodes or contracts as nodes are solved (59).

Forcing functions that emerge from normal processes are likely to be first noticed by those sensitive to the subtle appearance of the function or when the least experienced person begins to feel the effects. Epistemic models help us understand how individuals perceive an unexpected actual world in flux. HRO leaders appreciate the limitations of their imperfect external view, which then drives their search for information and efforts to generate new information. Reliance on branching plans that can expand by adding or contracting nodes increases their effectiveness during a forcing function's flux.

Doxastic logic (Greek *Doxa*, "belief"), a form of epistemic logic, concerns the logic of belief of participants. Doxastic logic provides reasons about belief rather than knowledge. The difference is that a belief is probably, though not necessarily, true. When we are not careful, we may collapse knowledge and belief into the same system as conviction in epistemic logic. Our beliefs become refractory to disconfirming evidence and contribute to motivated reasoning. In the worst case, such logic strengthens cognitive dissonance. Doxastic operators capture belief change, as "belief revisions" or "belief updates," when they receive conflicting information or encounter a discrepancy or disruption.

- A *belief update* refers to accounting for a change in the situation and acquiring new, more reliable information; this requires us to change our inaccurate old beliefs to more accurate, new ones.
- *Belief revision* occurs when we identify the old information as less reliable and use new, more reliable information to revise our older beliefs; we keep the new belief as close as possible to the old belief while accepting the newer, more accurate information.

Forcing functions in the reddened noise environment increases the gap between our place in the actual world and the models and theories we customarily use. We may have to act before acquiring information at the abrupt presentation of a pink noise catastrophe. Collecting more information simply increases the variance of our knowledge about the situation. Belief and attitudes become our primary operational methods. We rely on belief when we operate in an environment in flux and imperfect information. One response is to hold close to certain beliefs, *motivated reasoning* (61). The individual then scrutinizes information that conflicts with those beliefs and too readily accepts data that supports the belief. Because of our epistemic imperfect external view, we do not have access to the individual's beliefs and must infer their interpretation of new, conflicting information.

Belief updating and revision can help in these situations. We find updating and revision useful when those with authority have created a steep authority gradient that impairs information flow. Also, more timid individuals are more willing to speak up if they are "updating" information.

Deontic logic (Greek *Deon*, "that which is binding," "duty," "ought") guarantees the conditional obligations to act. It provides reasons about duty or obligation and drives action from states. Every proposition exists in one of three mutually exclusive states in this logic: necessary, contingent, or impossible. Things that are possible are either necessary or contingent. Things that are not necessary are either contingent or impossible (62).

Classical logic is static. Because something "is" does not mean it drives an action—that is, we "must" or "ought to" act on the information. This is the *is-ought* quandary of logic; its static nature does not connect a premise to action. "Deontic logic," however, takes us from "is" to "ought to"—that is, if an event occurs, then an action may be either *obligated* or *not permitted*. Deontic logic is

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the logic of norms or accepted standards.

Spectators may comment on an individual's choice of actions or question efforts that place a person in danger while helping others. This makes sense for those operating in the white noise environment with a Gaussian distribution. We collect sufficient information to support action from a pre-selected set of actions. In a reddened environment, collecting more information clouds our selections, stress responses impair our cognition, and fear reactions lead to ineffective actions no matter how internally logical they seem.

We can identify " tipping points " when we will or can act by discussing our duty and what we ought to do, adjusting for time and the flux of events, can identify "tipping points" when we will or can act. These discussions occur outside the static structure of most logic systems.

Temporal logic reasons how time qualifies statements and propositions with two basic operators, future and past. The asymmetry of time describes how the past is fixed, yet the future is branching and open to influence and change. A deterministic view of time requires the use of linear time for the future (63).

In terms of logic, time is discrete, occurring as intervals, or time is continuous, flowing onward as instants. Scientifically, we assume continuous instants for scientific logic, computer programs, processes, protocols, and algorithms. For categorization and data collection, we take time sequences as discrete intervals. However, any real-world operation, scientific or otherwise, has a duration that occurs within intervals. These intervals can overlap or be embedded within other events, run parallel with other independent or interdependent events, jump to other events, or depend on the initiation or completion of different events. (Intervals are used in artificial intelligence and computer science.)

"Logic can also be modified for concepts of time. For example, X is true at all times, while Y is true only sometimes. While the past is fixed and already determined, logical processes can account for the branching of time in the future. "Temporal logic" addresses problems of causality and mechanism, continuous change, planning actions, concurrent or discontinuous events, and the persistence of a fact rather than the truth of a fact."

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Temporal logic is vital for any logic system operating in red or pink noise environments. The time-series changes from white Noise to red or pink Noise. White Noise has discrete time intervals independent of the next interval in the series. A time sequence builds on the previous time interval, a type of feedback. The events at any one time will correlate with events in its past, the definition of autocorrelation, and the development of stochastic resonance.

Stochastic interactions between different environmental noise frequencies create stochastic outcomes in the unpredictable development of sepsis or retinopathy of prematurity. Branching time in temporal logic creates the necessity for the branching plans found in epistemic logic. In the logic of practice, we simultaneously act to increase the probability of the preferred end state while also reducing the probability of the unwanted end state. This often leads to simultaneous plans to act on both outcomes.

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Paraconsistent and Paracomplete Logic Systems

Forcing functions and catastrophes from red or pink noise release energy from the environment into our well-designed systems. Information entropy corrupts information. The give and take of interacting systems, increasing feedback, rapid oscillating processes, the forcing functions' frequency, and the Gaussian distributions' loss disintegrate the utility of inferences from classical logic. Events of lesser time scales and smaller magnitudes do the same. We will experience contradictions and the need to infer across quantitative and qualitative data collected from heterogeneous systems in a multitude of states.

Rejection of inconsistencies and contradictions creates risk in dangerous contexts (13). Describing reliance on laboratory research to support Mount Everest climbing expeditions, Vanessa Heggie (2) wrote, "Predicting what would happen to the first human beings to climb that high was, therefore, a matter of life or death – here inaccurate models could kill. Consequently, high-altitude respiratory physiology has prioritized not the laboratory, but the field."

"The reflection that apparent contradictions are everywhere around us and that treating them as anomalies may not be the best way to go" (64). We easily collect contradictory data, accumulate inconsistent information, and find the increasing information also increases the variance (7, 65, 66). We invalidate and change our conclusions and derived solutions processes not permitted in monotonic classical logic (67, 68). "Handling contradictory data is one of the most complex and important problems in reasoning under uncertainty" (66). These are the paraconsistent logics. Formalized modes of *nonmonotonic reasoning* give "rules of conjecture" rather than "rules of inference." Conclusions appropriate in one set of assumptions can be disconfirmed by the addition of new assumptions (69).

Reddened noise environments give us partial (incomplete) and excessive (contradictory) information. "A logic is called paraconsistent if it 'tolerates contradictions' and paracomplete if it does not 'enforce completeness/exhaustiveness'" (70). Paraconsistent and paracomplete logics meet the needs for rapidly changing, conflicting information and adjusting solutions. This is the operator, working contextually "bottom-up" from within the trajectory, inside events, feeling the pressure of elements. Thus, paraconsistent logics do not have the "principle of explosion." If we accept a contradiction in classical logic, then everything follows – the explosion. Paraconsistent logics allow us to make logical inferences with contradictions. Paracomplete logics do not have the "law of excluded middle" (either the proposition is true or false), allowing the use of gradations and shared qualities.

Paraconsistent and paracomplete logic systems allow us to work with partial truths, called initially 'pragmatic truth,' connecting it with the pragmatism of William James, John Dewey, and Charles Sanders Pierce. Operators for truth value (Table 2, above) are renderings of modal "necessarily" and "possibility" as "pragmatic validity" and "pragmatic truth," respectively. We can differentiate between acceptance and belief, with acceptance defined as the belief that the theory is partially true and belief defined as the correspondence to the truth. If we assume "acceptance," we can act *as if it were true* for further elaboration, development, and investigation (71).

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Contributing to a bias toward classical, monotonic logic is the frame of reference common to planners, executives, administrators, and managers. From their external, fixed reference point, they observe the flow of events and identify rates of change, but it is a decontextualized view. This is the spectator, top-down, outside the events, free from the direct influence of events, and able to differentiate concepts through observation. Classical logic more readily infers solutions from the more static, aggregated information.

Paraconsistent and paracomplete logic systems can support our navigation through this environment if we maintain guarded respect for the limits of classical logic (4). 'Para' was initially referred to as 'quasi' or 'similar to' but now seems accepted as a different meaning, 'beyond' (72). Classical logic avoids paradoxes and explosion into triviality by restricting sets with the law of excluded middle. Weakening classifications by weakening the excluded middle allows more detailed distinctions and nuanced inferences. We can weaken the logic system for the possibility of non-trivial inconsistency (73). Paraconsistency logic weakens formulations of logical inference with limitations to the choice of variables (71).

Paraconsistent Logics

Consistent logic systems (*consistency*) contain no contradictions (The Law of Noncontradiction) and contain at least one situation when all formulas are valid. *Inconsistency,* the acceptance of contradictions, permits a formal system to derive *every* statement, rendering such a logic system meaningless or trivial. Logic terms for this are *explosion*, anything that can follow from a contradiction, and *triviality* because it has little importance since *any* proposition can be inferred.

> An explosion is a problem of accepting contradictions, a false proposition implies any proposition, and any proposition implies a true proposition.

Paraconsistent logics are consequence relations that are not explosive. They do not allow any contradiction in a controlled way, treating inconsistencies as informative (72). Paraconsistency permits us to use inconsistent beliefs and enter inconsistency ethically. For example, medical specialists will develop their findings from their knowledge and experience using the same information and relying on the same logic system. They may reach different, inconsistent diagnoses.

Paracomplete Logic

When we probe back, seeking greater accuracy and identifying subtlety, we find differences between our continuous perceptions and discrete concepts (16). Because we change concepts to fit our observations, our observations of reality are incomplete.

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Gödel proved a system's consistency could not be demonstrated within the system. To determine the consistency, we must use another system beyond the system where we are operating (51). William Harvey (74) observed, "the best fertilizer for medicine is the progress of other and quite different sciences."

In complete logic systems, every property or statement (true or false) can be derived from *within* the system. Systems, however, cannot be complete. For example, from Kurt Gödel's The Second Incompleteness Theorem (75), through arithmetic itself, the consistency of arithmetic cannot be proved. Because of incompleteness (76):

- an element cannot be completely classified
- incomplete or partial information
- the excluded middle is not enforced

Paraconsistent and paracomplete logics differ by the application of non-contradiction and the excluded middle (77, 78) (Table 3).

- Paraconsistent logics – non-contradiction *does not* apply. Therefore, the explosion does not hold, while the excluded middle *does* apply.
- Paracomplete logics – non-contradiction *does* apply,

Logic System	Non-contradiction	Logic Explosion	Excluded Middle	Usage	Truth Values
Paraconsistent	Not applicable	None	Possible	Contradictory data	Over-define (restrictive)
Paracomplete	Applicable	Possible	None	Incomplete data	Unknown

Table 3. Paraconsistent, Paracomplete Logics

while excluded middle *does not* apply.

Belief Revision.

People have inconsistent beliefs. The most consequential sources of inconsistencies are motivated reasoning and cognitive dissonance. Paraconsistent logic drives inquiry to correlate and revise belief to the context instead of motivated reasoning and cognitive dissonance. We cannot eliminate all inconsistencies (72).

Sectioning Data Base.

People create consistent subsets in their "belief database," then remove the sections they feel are inconsistent or have lower degrees of acceptability. There is a risk of losing information. (65).

Many-Valued Logics.

Classical logic allows truth values of "true" or "false." Paraconsistent logics can aggregate conflicting information by adding a third, "indeterminate," or using a four-value logic with "both" or "neither." Modal logic can incorporate multiple values. Rather than value as a function, values can operate as relations; the proposition relates to true, false, or neither (72).

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Discussive (or *discursive*) *logic*

A form of deference to expertise, each person shares information they possess, true according to the individual even if inconsistent with that of others. During the discourse, the whole of the assertions become consistent (72).

Adaptive, Nonmonotonic Logics.

The inferences from these logics change as information becomes available and premises expand the external dynamic. The internal dynamic describes withdrawing the inference rule should we encounter a contradiction (72).

Relevant Logics / Topology.

The conclusion must be relevant or connected to the premises (72). In topology, a boundary can make the premise inconsistent depending on its relation to other elements (79). On the other hand, contextual isolation of premises from "failure of the object of understanding to cohere with readily available unitary context" (80). If from simplicity, then complexification by developing information may bring understanding.

Topology

Network topology is a discrete, object-oriented model that involves objects, nodes, edges, and connections. The topology leads to network system properties such as connectivity, directedness, closeness, betweenness, degree, characteristic path length, small worlds, and giant components (81, 82). In topology, the central concept is continuity and how the elements preserve a notion of nearness by a continuous function. They maintain connectedness during deformation without tearing apart to create a new boundary. Topology replaces precise characterizations with a topological differentiable state representing possible variable states and possible worlds (83, 84). The topological space of connection and relation does not localize an object in the Euclidean space of points and measures.

Note that in a topological network, the strength of relations between nodes has a more significant influence than the distance between nodes as in a Euclidean network. Graph representations of network topologies include line, ring, mesh, star, tree, bus, and the fully connected mesh topology.

Logic as a topology

'Category theory' is a certain way physicists use categories. A category has 'objects' or 'forms' representing things and 'morphisms' representing ways to go between things. In logic, objects are propositions, and morphisms are logical proofs. The morphism of proof accomplishes the connection between two forms as propositions (hypothesis and conclusion). Topological categories (forms) are 'manifolds,' Their morphisms are 'cobordisms,' the evolution passing to the continuum (73, 85).

In this sense, logic acts as a topology in a topological space.

Topology as a logic

Topology does not have a point and fixed (relative or comparative) distance metric as in Euclidean geometry. Instead, a single binary operator can compare distances between sets and a unary operator that distinguishes between limits (maximum and minimum; least, necessarily the least, not necessarily the least) of those distances (86) (Table 4). Sets can be open or closed or between the two. An open set is like a table chart without the frame lines. When we cut and paste, we are not aware of the contents of each cell. A closed set has the lines. We can consider these sets as possible worlds.

"A person's connections to experiences, facts, and people significant in their lives may be deformed but never torn. They will operate and self-organize as a topology. The organization that plans based on rigid Euclidean structures will fail when individuals self-organize in a topological space with stronger topological connections."

We can view human relations as a topological space for logical inference during a forcing function. As a social system, two actors are *adjacent* if they can interact immediately, even if by influence alone. The set of all adjacent actors is the neighborhood of the event. A person's connections to experiences, facts, and people significant in their lives may be deformed but never torn. They will operate and self-organize as a topology. The organization that plans based on rigid Euclidean structures will fail when individuals self-organize in a topological space with stronger topological connections.

Homeomorphism in topology is a continuous mapping or function that preserves the topological shape. Lines between two points do not intersect but represent possible worlds that change continuously. The horizontal axis interprets the modal operator while the vertical axis forms a possible world. Modal logics support reasoning and inference for relative distances as relative with limits rather than the metrics of Euclidean space. The homeomorphism of knowledge can become deformed by a forcing function but not torn.

Measure	Operator
Homeomorphism	Interior, border, frontier
Value	Maximum/minimum value of uncertainty There exists *x* such that *x* is the least There exists *x* such that *x* is necessarily the least
Distance function	"no greater than." "Closer" "not closer."

Table 4. Topology Operators

The logic of the Color of Noise

Stochastic resonance, forcing functions, and catastrophe create the environment from white, red, and pink Noise. A 'cosmology' event collapses our sensemaking and classical logic fails. We cannot rely on models that are unproven in these environments.

Colored noise environments are autocorrelated segments in time series that can branch. Oscillations between demands and capabilities create bivalence, even multi-valences. Fluctuations and change create new premises and the consequent necessity to change or find new solutions, possibly with the same premises. Static, classical logic gives us a solution, but not whether we have an obligation to act toward that solution. Some logics correlate to these demands from stochastic resonance and the color of Noise.

"When a frequency becomes autocorrelated by segments, it develops stochastic resonance. Time segments are no longer independent but can change the environment or branch into different possible worlds. Human behavior is always autocorrelated. Deductive processes and classical logic do not permit changing a solution or deduction once it is reached."

Time Series.

When a frequency becomes autocorrelated by segments, it develops stochastic resonance. Time segments are no longer independent but can change the environment or branch into different possible worlds. Human behavior is always autocorrelated. Deductive processes and classical logic do not permit changing a solution or deduction once it is reached. Temporal logic gives inferences when time becomes a factor in the environment, such as branching-time or the need to update or revise the premises we are using.

Oscillating Processes.

Even the most straightforward environmental process oscillates between resources and constraints. Within a forcing function, actions can rapidly shift from helping to hurting and back again, a bit riskier than assuming one can 'titrate to effect.' Information can be true or false or could become neither unknown nor contingent.

Fluctuation.

"Handling contradictory data is one of the most complex and important problems in reasoning under uncertainty" (66). Paraconsistent logics allow contradiction without any solution, thus treating inconsistencies as informative. Paracomplete logics allow us to work with entities undergoing continuous change; there is no need to assume "A" or "not-A." Nonmonotonic logics allow us to change our solutions as events evolve.

Duty to act

The moral duty to act and engage in threat comes from deontic logic. Public safety organizations must act in situations that civilians can avoid. Deontic logic provides inference rules for the obligation to act and when we must not act.

Conclusion

Reddened Noise brings forcing functions and crises. Classical logic does not serve us well with the consequent uncertainty and unpredictability. Our logic of practice can be idiosyncratic or derive from the logic of stress. Modal logics, the different ways things can be true, support inference in these situations and can drive action. Paraconsistent logic supports the revision of solutions as we develop new information. Paraconsistent logics also support inference in an environment of flux, contradictions, and inconsistencies. Topological logics reveal how we work with elements that have more significant influence than their physical absence suggests.

You solve these problems by entering their environment. It is *environmental* stochastic Noise, and you become part of that environment; you become the stochastic Noise around the problem to influence it as any noise would. Our connections to experiences, facts, and people may be deformed, but they are never torn.

References:

1. *La Porte TR. Complexity and uncertainty: Challenge to action. In: La Porte TR, editor. Organized social complexity: Challenge to politics and policy. Princeton, NJ: Princeton University Press; 1975. p. 332-56.*
2. *Heggie V. Experimental physiology, Everest and oxygen: from the ghastly kitchens to the gasping lung. The British Journal for the History of Science. 2013;46(1):123-47. doi: 10.1017/s0007087412000775.*
3. *Garfinkel A. The Slime Mold Dictyostelium as a Model of Self-Organization in Social Situations. In: Yates FE, editor. Self-organizing systems: The emergence of order. New York, NY: Springer Science & Business Media; 2012. p. 181-212.*
4. *van Stralen D, Mercer TA. High-Reliability Organizing (HRO) and Abrupt Change from COVID 19: Failure of Scientific Rationality and Classical Logic. Neonatology Today. 2021;16(6): 97-109. doi: https://doi.org/10.51362/neonatology.today/2021616697109*
5. *Sandberg J, Tsoukas H. Grasping the logic of practice: Theorizing through practical rationality. Academy of management review. 2011;36(2):338-60.*
6. *Steele JH. A comparison of terrestrial and marine ecological systems. Nature. 1985;313(6001):355-8.*

7. Halley JM. Ecology, evolution and 1f-noise. Trends in ecology & evolution. 1996;11(1):33-7.
8. McDonnell MD, Abbott D. What is stochastic resonance? Definitions, misconceptions, debates, and its relevance to biology. PLoS computational biology. 2009;5(5):e1000348.
9. Press WH. Flicker noises in astronomy and elsewhere. Comments on Astrophysics. 1978;7:103-19.
10. Johnson JB. The Schottky effect in low frequency circuits. Physical review. 1925;26(1):71-85. doi: 10.1103/PhysRev.26.71.
11. Kaitala V, Ylikarjula J, Ranta E, Lundberg P. Population dynamics and the colour of environmental Noise. Proceedings of the Royal Society of London Series B: Biological Sciences. 1997;264(1384):943-8.
12. Vasseur DA, Yodzis P. The Color of Environmental Noise. Ecology. 2004;85(4):1146-52.
13. van Stralen D, Mercer TA. High Altitude Climbing, High Reliability, COVID-19, and the Power of Observation. Neonatology Today. 2021;16(1):68-79. doi: 10.51362/neonatology.today/20211616879.
14. Zundel M, Kokkalis P. Theorizing as engaged practice. Organization Studies. 2010;31(9-10):1209-27.
15. Schulman PR. General attributes of safe organisations. BMJ Quality & Safety. 2004;13(suppl 2):ii39-ii44.
16. Weick KE. Organizing for Transient Reliability: The Production of Dynamic Non-Events. Journal of Contingencies and Crisis Management. 2011;19(1):21-7. doi: 10.1111/j.1468-5973.2010.00627.x.
17. van Stralen D. Pragmatic High-Reliability Organization (HRO) During Pandemic COVID-19. Neonatology Today. 2020;15(4):3-9.
18. van Stralen D, Mercer TA. Inductive Processes, Heuristics, and Biases Modulated by High-Reliability Organizing (HRO) for COVID-19 and Disasters. Neonatology Today. 2021;16(9):104-12. doi: 10.51362/neonatology.today/20219169104112.
19. van Stralen D, Mercer TA. High-Reliability Organizing (HRO), Decision Making, the OODA Loop, and COVID-19. Neonatology Today. 2021;16(8):86-96.
20. van Stralen D, Mercer TA. Common Sense High Reliability Organizing (HRO) in the Response to COVID-19. Neonatology Today. 2021;16(7):90-102. doi: 10.51362/neonatology.today/2021716790102.
21. Mason JW. A review of psychoendocrine research on the pituitary-adrenal cortical system. Psychosomatic medicine. 1968;30(5):576-607.
22. Gagnon SA, Wagner AD. Acute stress and episodic memory retrieval: neurobiological mechanisms and behavioral consequences. Annals of the New York Academy of Sciences. 2016;1369(1):55-75.
23. Arnsten AF. Stress signalling pathways that impair prefrontal cortex structure and function. Nat Rev Neurosci. 2009;10(6):410-22. Epub 2009/05/21. doi: 10.1038/nrn2648. PubMed PMID: 19455173; PubMed Central PMCID: PMCPMC2907136.
24. Harpaintner M, Sim EJ, Trumpp NM, Ulrich M, Kiefer M. The grounding of abstract concepts in the motor and visual system: An fMRI study. Cortex. 2020;124:1-22. Epub 2019/12/11. doi: 10.1016/j.cortex.2019.10.014. PubMed PMID: 31821905.
25. van Stralen D, Mercer T. High Reliability Organizing (HRO) is the Extension of Neonatology during Pandemic COVID-19. Neonatology Today. 2021;16(5):97-109. doi: 10.51362/neonatology.today/2021516597109.
26. Haggard P. Conscious intention and motor cognition. Trends Cogn Sci. 2005;9(6):290-5. Epub 2005/06/01. doi: 10.1016/j.tics.2005.04.012. PubMed PMID: 15925808.
27. LeDoux JE, Pine DS. Using Neuroscience to Help Understand Fear and Anxiety: A Two-System Framework. Am J Psychiatry. 2016;173(11):1083-93. Epub 2016/11/02. doi: 10.1176/appi.ajp.2016.16030353. PubMed PMID: 27609244.
28. Panksepp J, Fuchs T, Iacobucci P. The basic neuroscience of emotional experiences in mammals: The case of subcortical FEAR circuitry and implications for clinical anxiety. Applied Animal Behaviour Science. 2011;129(1):1-17.
29. Hicks AM. Learning to Watch Out. Journal of Contemporary Ethnography. 2012;41(6):636-67. doi: 10.1177/0891241612452139.
30. Fitzpatrick JS. Underground mining: a case study of an occupational subculture of danger [Dissertation]. Columbus, OH: The Ohio State University; 1974.
31. Haas J. A study of high steel ironworkers' reactions to fear and danger. Sociology of work and occupations. 1977;4(2):147-70.
32. van Stralen D, Mercer TA. Pragmatic High-Reliability Organizations (HRO) Modulate the Functions of Stress and Fear Behaviors During Pandemic COVID-19: The Stress-Fear-Threat Cascade. Neonatology Today. 2020;15(10):126-34. doi: 10.51362/neonatology.today/2020101510126134.
33. van Stralen D, Mercer TA. High-Reliability Organizing (HRO) in the COVID-19 Liminal Zone: Characteristics of Workers and Local Leaders. Neonatology Today. 2021;16(4):90-101. doi: 10.51362/neonatology.today/2021416490101.
34. Oatley K, Johnson-Laird PN. Cognitive approaches to emotions. Trends Cogn Sci. 2014;18(3):134-40. Epub 2014/01/07. doi: 10.1016/j.tics.2013.12.004. PubMed PMID: 24389368.
35. Hediger H. Wild animals in captivity. London, UK: Butterworths Scientific Publications; 1950.
36. Fellows LK, Farah MJ. The role of ventromedial prefrontal cortex in decision making: judgment under uncertainty or judgment per se? Cereb Cortex. 2007;17(11):2669-74. Epub 2007/01/30. doi: 10.1093/cercor/bhl176. PubMed PMID: 17259643.
37. Graziano MS, Cooke DF. Parieto-frontal interactions, personal space, and defensive behavior. Neuropsychologia. 2006;44(6):845-59. Epub 2005/11/10. doi: 10.1016/j.neuropsychologia.2005.09.009. PubMed PMID: 16277998.
38. Mobbs D, Petrovic P, Marchant JL, Hassabis D, Weiskopf N, Seymour B, et al. When fear is near: threat imminence elicits prefrontal-periaqueductal gray shifts in humans. Science. 2007;317(5841):1079-83. Epub 2007/08/25. doi: 10.1126/science.1144298. PubMed PMID: 17717184; PubMed Central PMCID: PMCPMC2648508.
39. van Stralen D, Mercer TA. Pandemic COVID-19, the High-Reliability Organization (HRO), and the Ecology of Fear. Neonatology Today. 2020;15(12):129-38. doi: 10.51362/neonatology.today/2020121512129138.
40. Weick KE. Enactment and Organizing. The Social Psychology of Organizing. Second ed. New York, NY: McGraw-Hill, Inc.; 1979. p. 147-69.

41. Clinchy M, Sheriff MJ, Zanette LY. Predator-induced stress and the ecology of fear. Functional Ecology. 2013;27(1):56-65.
42. LeDoux JE. Coming to terms with fear. Proc Natl Acad Sci U S A. 2014;111(8):2871-8. Epub 2014/02/07. doi: 10.1073/pnas.1400335111. PubMed PMID: 24501122; PubMed Central PMCID: PMCPMC3939902.
43. Roelofs K. Freeze for action: neurobiological mechanisms in animal and human freezing. Philosophical Transactions of the Royal Society B: Biological Sciences. 2017;372(1718):20160206.
44. LeDoux JE. Emotion circuits in the brain. Annual review of neuroscience. 2000;23(1):155-84.
45. Joëls M, Fernandez G, Roozendaal B. Stress and emotional memory: a matter of timing. Trends in cognitive sciences. 2011;15(6):280-8.
46. van Stralen D, Mercer TA. During Pandemic COVID-19, the High-Reliability Organization (HRO) Identifies Maladaptive Stress Behaviors: The Stress-Fear-Threat Cascade. Neonatology Today. 2020;15(11):113-24. doi: 10.51362/neonatology.today/2020111511113124.
47. Dreyfus HL. What could be more intelligible than everyday intelligibility? Reinterpreting division I of Being and Time in the light of division II. Bulletin of Science, Technology & Society. 2004;24(3):265-74.
48. Benner P. From Novice to Expert: Excellence and Power in Clinical Nursing Practice. Menlo Park, CA: Addison-Wesley; 1984.
49. van Stralen D, Inozu B, Byrum S. High Reliability for a Highly Unreliable World: Preparing for Code Blue through Daily Operations in Healthcare. North Charleston, SC: CreatSpace Publishing; 2017.
50. Weick KE. The collapse of sensemaking in organizations: The Mann Gulch disaster. Administrative science quarterly. 1993;38(4):628-52.
51. Boyd J. Destruction and creation. Fort Leavenworth, KS: US Army Comand and General Staff College, 1976.
52. Sandberg J, Tsoukas H. Making sense of the sensemaking perspective: Its constituents, limitations, and opportunities for further development. Journal of Organizational Behavior. 2015;36(S1):S6-S32. doi: 10.1002/job.1937.
53. Weick KE. Sensemaking in organizations. Dickens G, editor. Thousand Oaks, CA: Sage; 1995.
54. Ballarin R. Modern Origins of Modal Logic. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy. Fall 2021 Edition ed: Metaphysics Research Lab, Stanford University; 2012.
55. Garson J. Modal Logic. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy: Metaphysics Research Lab, Stanford University; 2021.
56. Aucher G. An Internal Version of Epistemic Logic. Studia Logica. 2010;94(1):1-22. doi: 10.1007/s11225-010-9227-9.
57. Thomason R. Logic and Artificial Intelligence. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy Summer 2020 Edition ed: Metaphysics Research Lab, Stanford University; 2020.
58. McCarthy J, Hayes PJ. Some Philosophical Problems from the Standpoint of Artificial Intelligence. In: Meltzer B, Michie D, editors. Machine Intelligence 4. Edinburgh, Scotland: Edinburgh University Press; 1969. p. 463--502.
59. Andersen MB, Bolander T, Jensen MH. Conditional Epistemic Planning. In: del Cerro LF, Herzig A, Mengin J, editors. Logics in Artificial Intelligence. Lecture Notes in Computer Science. Heidelberg, Germany: Springer; 2012. p. 94-106.
60. Bolander T, Andersen MB. Epistemic planning for single- and multi-agent systems. Journal of Applied Non-Classical Logics. 2012;21(1):9-34. doi: 10.3166/jancl.21.9-34.
61. Kunda Z. The case for motivated reasoning. Psychological bulletin. 1990;108(3):480.
62. McNamara P, Putte FVD. Deontic Logic. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy: Metaphysics Research Lab, Stanford University; 2021.
63. Goranko V, Rumberg A. Temporal Logic. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy: Metaphysics Research Lab, Stanford University; 2020.
64. Rudnicki K. The psychological aspects of paraconsistency. Synthese. 2021. doi: 10.1007/s11229-020-02983-8.
65. Hunter A. Paraconsistent logics. Reasoning with Actual and Potential Contradictions: Springer; 1998. p. 11-36.
66. Arieli O, Avron A, Zamansky A. Ideal paraconsistent logics. Studia Logica. 2011;99(1):31-60.
67. McCarthy J. Artificial intelligence, logic and formalizing common sense. In: R.H. T, editor. Philosophical logic and artificial intelligence. Berlin, Germany: Springer, Dordrecht; 1989. p. 161-90.
68. Minsky M. A framework for representing knowledge. In: Winston PH, editor. The Psychology of Computer Vision. New York, NY: 211-277; 1975.
69. McCarthy J. Some expert systems need common sense. Ann N Y Acad Sci. 1984;426:129-37. Epub 1984/01/01. doi: 10.1111/j.1749-6632.1984.tb16516.x. PubMed PMID: 6391331.
70. Fuenmayor D. Topological semantics for paraconsistent and paracomplete logics in Isabelle/HOL. arXiv preprint arXiv:210404284. 2021.
71. da Costa NC, Krause D, Bueno O. Paraconsistent logics and paraconsistency. In: Jacquette D, editor. Philosophy of logic. Handbook of the Philosophy of Science. Amsterdam, The Netherlands: Elsevier; 2007. p. 791-911.
72. Priest G, Tanaka K, Weber Z. Paraconsistent logic. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy Summer 2018 Edition ed: Metaphysics Research Lab, Stanford University; 2018.
73. Baez J, Stay M. Physics, topology, logic and computation: a Rosetta Stone. New structures for physics: Springer; 2010. p. 95-172.
74. Kevles B. Pioneering Physician Is Vividly Recalled: DIARY OF WILLIAM HARVEY: The Imaginary Journal of the Physician Who Revolutionized Medicine by Jean Hamburger. Los Angeles Times 1992 October 27, 1992;Sect. Book Review.
75. Raatikainen P. Gödel's Incompleteness Theorems. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy: Metaphysics Research Lab, Stanford University; 2021.
76. Ciucci D, Dubois D. Three-valued logics, uncertainty management and rough sets. In: Peters JF, Skowron A, editors. Transactions on Rough Sets XVII. Lecture Notes in Computer Science. Berlin, Germany: Springer-Verlag; 2014. p. 1-32.
77. Carnielli W, Rodrigues A. On epistemic and ontological interpretations of intuitionistic and paraconsistent paradigms. Logic Journal of the IGPL. 2021;29(4):569-84.
78. Brenner JE. Logic in reality. Netherlands: Springer Nether-

lands; 2008.
79. *Mortensen C. Inconsistent Mathematics. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy Fall 2017 Edition ed: Metaphysics Research Lab, Stanford University; 2017.*
80. *Gunga S, Embeywa HE, Amukowa W. Understanding as a Concept in Education: Conceptions and Alternative Interpretations. Journal of Educational and Social Research. 2014;4(1):339-.*
81. *Proulx SR, Promislow DE, Phillips PC. Network thinking in ecology and evolution. Trends Ecol Evol. 2005;20(6):345-53. Epub 2006/05/17. doi: 10.1016/j.tree.2005.04.004. PubMed PMID: 16701391.*
82. *Prager SD, Reiners WA. Historical and emerging practices in ecological topology. ecological complexity. 2009;6(2):160-71.*
83. *Mol A, Law J. Regions, networks and fluids: Anaemia and social topology. Soc Stud Sci. 1994;24(4):641-71. Epub 1994/11/01. doi: 10.1177/030631279402400402. PubMed PMID: 11639423.*
84. *Asher N, Vieu L, editors. Toward a geometry of common sense: A semantics and a complete axiomatization of mereotopology. IJCAI (1); 1995: Citeseer.*
85. *Coecke B, Paquette EO. Categories for the practising physicist. In: Coecke B, editor. New structures for physics. 813. Oxford, UK: Springer; 2011. p. 173-286.*
86. *Sheremet M, Wolter F, Zakharyaschev M. A modal logic framework for reasoning about comparative distances and topology. Annals of Pure and Applied Logic. 2010;161(4):534-59.*

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