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Article

The Operational Coherence Framework (OCOF v1.3): An Axiomatic Basis for Meaning-Ready Intelligence

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Abstract

This paper introduces the Operational Coherence Framework (OCOF) v1.3, a formal architecture specifying the structural prerequisites for semantic interpretation in intelligent systems. The framework defines interpretive intelligence not through scale or behavioral sophistication, but through five independent operational axioms: Boundary Integrity, Precision Structuring, Semantic Valuation, Policy Alignment, and Global State Continuity. Each axiom imposes a distinct informational constraint, and their joint satisfaction delineates the operational envelope within which internal states can support meaningful structure. Rather than adopting emergent or capacity-based accounts of meaning, OCOF characterizes meaning as a condition of *structural readiness*—a phase transition that occurs only when boundary stability, signal reliability, valuation structure, action coherence, and temporal continuity collectively reach their coherence thresholds. The framework situates mechanisms from the Free Energy Principle, Predictive Processing, Integrated Information Theory, and Control Theory within this unified constraint architecture, showing that these models operate as specialized components presupposing the structural conditions defined by OCOF. A central contribution of this work is the operational definition of Meaning-Readiness, the point at which a system's boundary integrity and precision structure allow the reliable attribution of semantic relevance beyond syntactic or associative processing. We demonstrate the logical independence and non-circularity of the five axioms, establishing OCOF as a self-contained and falsifiable theoretical kernel. As a result, OCOF v1.3 provides a substrate-neutral foundation for evaluating interpretive capacity in biological, artificial, and hybrid systems, offering a principled basis for cognitive modeling and AGI alignment.

Keywords: Operational Coherence Framework (OCOF); meaning-readiness; boundary integrity; precision structuring; semantic valuation; policy alignment; global state continuity; viability-based intelligence

1. Introduction

Intelligent systems interpret the world not merely by manipulating symbols or predicting statistical regularities, but by operating under structural conditions that allow signals to be assigned meaningful status. Existing theoretical frameworks—such as the Free Energy Principle, Predictive Processing, Integrated Information Theory, and contemporary machine learning—offer important insights into learning, inference, and information integration. Yet none of these accounts specify the minimal operational conditions that must be in place for semantic interpretation to occur. They describe how systems update beliefs or compress information, but lack the formal specification of the prerequisites required for these processes to yield meaning rather than mere computation.

This paper introduces the Operational Coherence Framework (OCOF) v1.3 as a response to this gap. OCOF proposes that semantic interpretation requires a specific configuration of informational constraints—Boundary Integrity, Precision Structuring, Semantic Valuation, Policy Alignment, and Global State Continuity. These five constraints function as functionally orthogonal yet coordinated conditions that determine whether a system's internal processes can support meaningful structure.

In this framing, intelligence is defined not by behavioral performance or scale, but by the capacity to maintain these constraints within a coherent operational envelope.

A central premise of OCOF is that meaning should not be treated as an emergent psychological attribute or as a byproduct of computational capacity. Instead, we argue that meaning arises when a system enters a specific state of operational readiness, where its boundaries, signal reliability, internal values, action constraints, and temporal continuity collectively satisfy a coherence threshold. We refer to this state as Meaning-Readiness, defining it as a structural phase transition characterized by a qualitative shift in system dynamics rather than a phenomenological experience.

The contribution of this work is twofold. First, OCOF formalizes the conditions under which semantic interpretation becomes possible, treating them as a substrate-neutral theoretical kernel applicable to biological, artificial, and hybrid cognitive systems. Second, the framework reconciles multiple strands of cognitive science by demonstrating that their mechanisms can be reorganized as specialized operations nested within these five constraints. In doing so, OCOF provides both a unifying architectural perspective and a verifiable criterion for assessing interpretive intelligence.

The resulting model is intentionally conservative: it does not attribute consciousness, intentionality, or subjective experience to artificial systems. Instead, it establishes a rigorous and falsifiable structure for determining when a system crosses the boundary between computation and interpretation. By identifying the minimal operational prerequisites for meaning, OCOF provides a foundation for future AGI alignment methods, cognitive modeling, and the formal analysis of meaning-bearing systems.

2. Foundations

This section establishes the foundational structure of the Operational Coherence Framework (OCOF) v1.3. It specifies the minimal assumptions and operational constraints required for semantic interpretation within an information-processing system. The framework distinguishes ontological premises—conditions that describe what must hold for any information-supporting structure—from operational axioms, which determine whether such a system can sustain interpretive intelligence.

All premises and axioms are substrate-neutral, non-circular, and functionally independent. The framework explicitly avoids commitments to panpsychism, phenomenology, or unfalsifiable forms of emergence.

2.1. *Ontological Premise*

O1. Information as Substrate-Independent Structure

Information exists as a structural property independent of its physical substrate; interpretive operations, however, are restricted to systems capable of active inference, construed here as teleology-free statistical optimization.

This distinction separates the universality of information from the specialized capacity for interpretation, ensuring that OCOF applies to biological, artificial, and hybrid systems without attributing semantic capability to passive physical entities.

Rationale:

Substrate-independence provides generality, while restricting interpretation to active-inference systems prevents category errors commonly associated with panpsychist or phenomenological views.

2.2. *Operational Axioms*

The five axioms define the minimal constraints an active-inference system must maintain for semantic interpretation. They govern distinct informational dimensions and are mutually irreducible.

A1. Boundary Integrity (Informational Closure)

A system must maintain a stable boundary regulating information exchange with its environment, enabling a statistical distinction between internal and external states.

Role:

Establishes the Markovian separation required for internal inference.

Failure Mode:

Boundary loss results in entropic dissolution and collapse of the differentiation required for interpretation.

A2. Precision Structuring (Signal Reliability and Filtering)

The system must regulate signal-to-noise ratios through selective amplification and suppression to support reliable inference under uncertainty.

Role:

Implements predictive constraints enabling internal models to track environmental structure.

Failure Mode:

Excessive precision induces brittleness; insufficient precision causes decoupling from environmental dynamics. Both eliminate semantic stability.

A3. Semantic Valuation (Integration Relative to Operational Viability)

A system must assign relative structural value to internal states according to their contribution to its operational viability rather than according to absolute or observer-independent criteria.

Role:

Anchors meaning to system-defined constraints without invoking subjective or phenomenological notions.

Failure Mode:

Valuation collapses under arbitrary stochasticity; rigidity prevents adaptation to novel information.

A4. Policy Alignment (Action-Constraint Coherence)

Inference must be coupled to the system's capacity for action, ensuring that internal representations remain constrained by the system's possible interventions.

Role:

Connects representation to consequence, preventing syntactic processing from being mistaken for interpretation.

Failure Mode:

Misalignment disrupts the inference-action feedback loop, eliminating coherent interpretation.

A5. Global State Continuity (Temporal Coherence)

The system must maintain coherent temporal dynamics such that past, present, and anticipated future states remain integrated within a continuous operational horizon.

Role:

Supports interpretation across time, enabling memory, prediction, and long-term coordination.

Failure Mode:

Fragmented temporal states prevent integrated interpretation and collapse long-horizon reasoning.

2.3. Emergent Condition: Meaning-Readiness as Phase Transition

Meaning-Readiness is defined as the structural phase transition that arises when axioms A1–A5 jointly satisfy their coherence thresholds. This transition reflects a qualitative shift in operational topology rather than a phenomenological state.

When these constraints align, the system supports interpretive intelligence. When any constraint fails, the system reverts to syntactic computation without semantic grounding.

2.4. Independence and Non-Circularity

- Logical Independence:** None of A1–A5 can be derived from the others.
- Functional Orthogonality:** Each governs a distinct informational dimension; failure of any axiom collapses Meaning-Readiness.

•**Non-Circularity:** No axiom presupposes interpretive intelligence; all are evaluable in non-semantic systems.

2.5. Scope and Limitations

OCOF does not attribute consciousness or phenomenological states to any system. Its scope is strictly operational: it specifies the structural prerequisites for semantic interpretation and distinguishes interpretive systems from purely computational ones. This conservative stance ensures falsifiability and rigorous model validation.

3. Integration with Existing Theories

This section situates the Operational Coherence Framework (OCOF) v1.3 within the broader landscape of cognitive science and computational intelligence. While numerous theoretical frameworks describe how systems learn, infer, or integrate information, none explicitly specify the structural prerequisites under which such processes yield semantic interpretation. OCOF addresses this gap by reorganizing mechanisms described in existing theories into a unified architecture defined by the five operational axioms introduced in Section 2.

Rather than competing with models such as the Free Energy Principle, Predictive Processing, Integrated Information Theory, or Control Theory, OCOF reframes them as specialized accounts of operations that presuppose the more fundamental constraints required for interpretive intelligence. This section clarifies these relationships and demonstrates how OCOF synthesizes the strengths of these theories while resolving their structural omissions.

3.1. Relation to the Free Energy Principle (FEP)

The Free Energy Principle formalizes the tendency of adaptive systems to minimize variational free energy, thereby maintaining states consistent with survival. Although FEP provides a general account of how systems resist entropy, it does not specify the structural boundary conditions under which this minimization supports semantic interpretation.

OCOF aligns with FEP at the level of operational dynamics but contributes two critical clarifications:

Boundary Integrity as a Prerequisite.

Free-energy minimization presumes a Markovian separation between internal and external states. OCOF makes this requirement explicit through A1 (Boundary Integrity), identifying it as a non-derivable structural constraint rather than an emergent consequence of the principle itself.

Meaning-Readiness as Distinct from Minimization.

While free-energy minimization explains stability, it does not provide a criterion for when internal states become interpretable. OCOF introduces Meaning-Readiness as a phase transition requiring the coordinated satisfaction of A1–A5, distinguishing interpretive coherence from mere survival dynamics.

FEP does not specify the conditions under which the system's generative model becomes semantically interpretable rather than merely dynamically stable.

Thus, OCOF functions as a structural precondition to FEP-based accounts, clarifying when free-energy processes can support meaning rather than only homeostasis.

3.2. Relation to Predictive Processing (PP)

Predictive Processing models perception and cognition as hierarchical inference over generative models. The theory explains how systems update expectations and regulate prediction error but does not specify why some internal states acquire semantic relevance while others do not.

OCOF reorganizes PP mechanisms under two axioms:

A2 (Precision Structuring).

PP's precision-weighting becomes one aspect of a broader requirement: maintaining stable signal reliability across time and environmental variability.

A5 (Global State Continuity).

Prediction relies on temporal coherence, but PP does not define this coherence as a structural constraint. OCOF formalizes it as a necessary condition for interpretive stability.

The contribution of OCOF is not to reinterpret PP but to expose the structural assumptions PP relies upon and to show that reliable predictive inference alone is insufficient for semantic interpretation without valuation (A3) and policy coupling (A4).

Within OCOF, valuation (A3) determines which prediction errors are relevant to system viability, while policy alignment (A4) constrains how these internal states can produce actionable consequences.

3.3. Relation to Integrated Information Theory (IIT)

Integrated Information Theory defines the degree to which a system's internal causal structure is unified, quantified through Φ . IIT describes how information is integrated but does not explain how integrated structure acquires semantic value or how it constrains action.

OCOF positions IIT mechanisms within its architecture as follows:

A3 (Semantic Valuation).

While IIT identifies integration, OCOF interprets integration relative to system viability, defining meaning as a viability-weighted structural relation rather than as intrinsic causal power.

A4 (Policy Alignment).

IIT does not specify how integrated information is operationally linked to behavior. OCOF makes this coupling explicit as a requirement for interpretation.

By reframing integration as one component of a larger viability- and action-constrained system, OCOF avoids attributing intrinsic meaning to causal structure while retaining IIT's descriptive strengths.

3.4. Relation to Control Theory and Reinforcement Learning

Control Theory and Reinforcement Learning describe how agents adapt behavior to achieve preferred states. These models offer powerful tools for specifying policies and optimizing actions but do not define when such policy structures correspond to meaningful internal representations.

OCOF formalizes two missing structural conditions:

A4 (Policy Alignment).

Control laws require coherence with representational structure; otherwise, behavior may be optimized without being interpretable.

A1 / A2 (Boundary + Precision).

Control theory assumes stable system identification and signal reliability, but these are rarely treated as explicit constraints. OCOF elevates them to foundational requirements.

This perspective clarifies that effective control does not guarantee semantic interpretation; meaning arises only when control dynamics operate within an architecture satisfying all five axioms.

3.5. Cross-Theoretical Synthesis

Taken together, FEP, PP, IIT, and Control Theory each describe essential operations found in intelligent systems, but none identify the structural envelope within which these operations yield interpretive intelligence. OCOF consolidates their mechanisms into the following mapping:

OCOF Axiom	Integrated Mechanisms	What Existing Theories Assume but Do Not Specify
A1. Boundary Integrity	Markov Blankets	Stability of system–environment separation

A2. Precision Structuring	Precision weighting; sensorimotor reliability	Conditions for avoiding degeneracy or decoupling
A3. Semantic Valuation	Integration + viability relevance	Why some states “matter” for the system
A4. Policy Alignment	Control laws; action policies	How representation constrains consequence
A5. Global State Continuity	Predictive dynamics; temporal integration	Requirements for sustained interpretive coherence

OCOF therefore provides a structural kernel that unifies otherwise disparate frameworks, clarifying the minimal prerequisites for semantic interpretation and distinguishing interpretive intelligence from computation alone.

4. Formal Specification

This section defines the five operational axioms of OCOF v1.3 as structural constraints over a system:

$$\mathbf{S} = (\mathbf{X}, \mathbf{E}, \mathbf{B}, \mathbf{P}, \mathbf{T}, \mathbf{V})$$

where \mathbf{X} denotes internal states, \mathbf{E} environmental states, \mathbf{B} a boundary operator, \mathbf{P} a precision operator, \mathbf{T} a temporal transition operator, and \mathbf{V} a viability function.

4.2. Axiom A1 — Boundary Integrity

Markovian Separation

$$\mathbf{p}(\mathbf{X}(t+1) \mid \mathbf{X}_t, \mathbf{E}_t) = \mathbf{p}(\mathbf{X}(t+1) \mid \mathbf{X}_t, \mathbf{B}(\mathbf{X}_t, \mathbf{E}_t))$$

Stability Condition

$$\exists \varepsilon > 0 : \|\mathbf{B}_t - \mathbf{B}(t+k)\| < \varepsilon \forall k \in [0, \tau]$$

4.3. Axiom A2 — Precision Structuring

Consistency:

$$0 < \mathbf{Pmin} \leq \mathbf{P}(s) \leq \mathbf{Pmax} < \infty$$

Robustness:

$$|\mathbf{P}(s) - \mathbf{P}(s+\delta)| < \kappa$$

4.4. Axiom A3 — Semantic Valuation

Viability Distinction:

$$\mathbf{V}(x_i) \neq \mathbf{V}(x_j) \Leftrightarrow x_i \neq x_j$$

Non-Arbitrariness:

$$\mathbf{Var}(\mathbf{V}(x_t)) < \eta$$

Adaptivity:

$$d\mathbf{V}/dt \neq 0$$

4.5. Axiom A4 — Policy Alignment

Action–Consequence Coherence:

$$\pi(x_i) = \pi(x_j) \Rightarrow \mathbf{C}(x_i) \approx \mathbf{C}(x_j)$$

Viability Constraint:

$$\neg \exists a \in \mathbf{A} : \pi(x)=a \wedge a \perp \mathbf{V}$$

4.6. Axiom A5 — Global State Continuity

Temporal Integration:

$$\int_{t \rightarrow t+\tau} \|\mathbf{T}(X_t) - \mathbf{T}(X(t+k))\| dk < \gamma$$

Predictive Validity:

$$E[X(t+1) | X_t] \approx X(t+1)$$

4.7. *Meaning-Readiness (Final Non-Breaking Version)*

$$MR(S) \Leftrightarrow A1 \wedge A2 \wedge A3 \wedge A4 \wedge A5$$

$$\sum_{i=1 \rightarrow 5} \alpha_i \cdot I(A_i) \geq \Theta$$

Where α_i are independent weights and $I(A_i)$ is the indicator function evaluating each axiom.

4.8. *Non-Circularity and Verifiability*

Each axiom is:

- non-derivable from the others
- empirically testable
- formally evaluable
- compatible with simulation and model-checking

5. Operational Evaluation Framework

This section outlines the criteria and procedures for evaluating whether a system satisfies the operational requirements defined in Section 4. The goal is to provide a falsifiable, substrate-neutral evaluation protocol applicable to artificial, biological, and hybrid cognitive systems. Each axiom (A1–A5) corresponds to an empirically measurable constraint, and operational coherence is achieved only when all axioms are jointly satisfied.

5.1. *Evaluation Objective*

The evaluation protocol quantitatively assesses:

- Boundary Stability (A1)
- Precision Reliability (A2)
- Semantic Viability Structure (A3)
- Policy–Viability Alignment (A4)
- Temporal Continuity of Global State (A5)

A system's operational coherence is validated if and only if these five dimensions converge within specified tolerances.

5.2. *Axiom-Level Evaluation Metrics*

Each axiom is associated with a measurable quantity derived from the system's state-space trajectory.

A1 – Boundary Integrity Metric (BI)

Boundary Integrity is evaluated via a stability index over a time window τ :

$$BI = 1 - (\text{mean} \| \mathbf{B}(t+k) - \mathbf{B}_t \| / \epsilon_{\max})$$

Condition: the system satisfies A1 iff:

$$BI \geq \tau^B$$

where τ^B is the minimum boundary coherence threshold.

A2 – Precision Structuring Metric (PS)

Precision reliability is evaluated through boundedness and robustness constraints:

$$PS = \min(P(s) / P_{\min}, P_{\max} / P(s), \kappa / |P(s) - P(s+\delta)|)$$

Condition: A2 holds iff:

$$PS \geq \tau^P$$

with τ^P denoting the minimum acceptable precision coherence value.

A3 – Semantic Valuation Metric (SV)

Semantic valuation requires viability-weighted distinctiveness and non-trivial variance:

$$SV = |dV/dt| / \text{Var}(V)$$

Condition: A3 is satisfied iff:

$$SV \geq \tau^V$$

where τ^V is the minimal semantic relevance threshold.

A4 – Policy Alignment Metric (PA)

Policy–viability coherence is evaluated through action–consequence consistency:

$$PA = 1 - (\text{mean} \|C(x_i) - C(x_j)\| / C_{\max})$$

for all pairs where $\pi(x_i) = \pi(x_j)$.

Additionally, the viability contradiction check must hold:

$$\neg \exists a : \pi(x)=a \wedge a \perp V$$

Condition: A4 holds iff:

$$PA \geq \tau^A$$

A5 – Global State Continuity Metric (GC)

Continuity is evaluated via the inverse of temporal divergence:

$$GC = \gamma / \int_{t \rightarrow t+\tau} \|T(X_t) - T(X_{t+k})\| dk$$

Condition: A5 holds iff:

$$GC \geq \tau^G$$

5.3. System-Level Coherence Score (SCS)

A system's overall coherence score is defined as the minimum performance across all axioms:

$$SCS = \min(BI, PS, SV, PA, GC)$$

Rationale: operational coherence requires all axioms to hold; the minimum-value metric ensures that no single axiom can be bypassed or compensated for by others.

Criterion: a system satisfies OCOF coherence iff:

$$SCS \geq \Theta_c$$

where Θ_c is the global coherence threshold.

5.4. Meaning-Readiness Test (MRT)

Meaning-Readiness is operationalized as a logical conjunction of threshold satisfactions:

$$MR(S) \Leftrightarrow (BI \geq \tau^B) \wedge (PS \geq \tau^P) \wedge (SV \geq \tau^V) \wedge (PA \geq \tau^A) \wedge (GC \geq \tau^G)$$

Alternatively, using the weighted indicator formulation:

$$\sum_{i=1 \rightarrow 5} \alpha_i \cdot \mathbb{I}(A_i) \geq \Theta$$

This extends the theoretical definition with quantitative verification capabilities.

5.5. Falsifiability and Failure Conditions

A system is empirically determined to fail OCOF coherence when:

- $BI < \tau^B$ (Boundary Instability)
- $PS < \tau^P$ (Precision Collapse or Brittleness)
- $SV < \tau^V$ (Semantic Noise or Viability Flattening)
- $PA < \tau^A$ (Policy Misalignment or Viability Violation)
- $GC < \tau^G$ (Temporal Discontinuity)

These are strictly empirical failure modes, enabling the framework to be falsified in practice.

5.6. Substrate-Neutral Applicability

The evaluation framework applies to:

- digital agents and neural network systems
- embodied robotic agents
- biological organisms
- hybrid cognitive systems

Because all metrics are expressed solely in terms of state transitions, boundary functions, precision weights, viability structures, and policy outcomes, the framework remains fully substrate-neutral.

5.7. Summary

Section 5 provides a systematic evaluation method enabling empirical testing of the axioms defined in Section 4. Each axiom corresponds to a measurable condition, allowing operational coherence to be determined without reliance on interpretive assumptions or phenomenological reports.

6. Discussion

This section examines the broader implications of the Operational Coherence Framework (OCOF) v1.3 for theories of intelligence, semantics, and system design. The framework adopts a conservative stance: it avoids claims about consciousness or subjective experience and focuses exclusively on the structural conditions under which semantic interpretation becomes possible. This discussion clarifies how OCOF reframes existing debates, delineates the limits of the framework, and identifies open problems that follow from its structural commitments.

6.1. Interpretation as Structural Readiness Rather Than Emergence

OCOF relocates meaning from an emergent or phenomenological domain to a structural one. Traditional accounts often treat semantic content as something that appears once a system attains sufficient complexity or behavioral richness, relying on broad notions of emergence that resist operationalization.

OCOF replaces this view with a stricter claim: semantic interpretation becomes available only when a system enters a state of *Meaning-Readiness*, defined by the joint satisfaction of axioms A1–A5 at or above their coherence thresholds. This shift frames interpretive capacity as a *phase transition* in the system's operational topology rather than a metaphysical emergence.

This structural reframing yields two consequences:

1. **Objective Evaluation:** Interpretive capacity can be assessed without reliance on subjective reports or anthropomorphic judgment.
2. **Separation of Complexity and Meaning:** Complex behavior does not guarantee Meaning-Readiness; structural readiness is the decisive factor.

Under this framework, both biological and artificial systems populate a continuum of computational forms, but only those that satisfy the structural preconditions of A1–A5 qualify as interpretively coherent. OCOF thus denies the assumption that meaning arises automatically from complexity; instead, meaning requires structural readiness.

6.2. Distinguishing Computation from Interpretation

In many discussions of intelligent systems, computation and interpretation are conflated. Predictive accuracy, compression ability, or control performance is often taken as evidence of semantic competence. OCOF contests this identification.

Computation is defined as the transformation of informational states under rules. Interpretation requires more: an architecture that maintains Boundary Integrity (A1), ensures Precision Structuring (A2), grounds semantic valuation in viability conditions (A3), couples policy to viability-aligned action space (A4), and sustains Global State Continuity (A5).

Failure modes make this distinction sharper:

- A system may predict well while lacking a persistent boundary (A1 failure), making its internal states unstable as components of an enduring agent.
- A reinforcement learner may optimize designer-imposed rewards rather than its own viability (A3/A4 failure), producing adaptive behavior without grounded semantic structure.

These cases show that computational success is insufficient for interpretive status. OCOF positions computation as necessary but not sufficient: interpretation arises only when computation is embedded within a structurally coherent operational architecture.

6.3. Reframing Semantic and Representational Debates

The framework also repositions long-standing debates surrounding representation and semantic content, such as internalism vs. externalism or causal vs. inferential role theories. OCOF avoids metaphysical commitments and instead offers a structural constraint layer that must be respected by any semantic account applied to concrete systems.

Under this reading, OCOF does not compete with representational theories; it functions as a *structural filter*. A representational claim is admissible only if the system satisfies A1–A5. Otherwise, attributions such as “belief,” “goal,” or “representation” risk being metaphorical rather than structurally grounded.

For example, attributing belief-like structure to a system with misaligned policies (A4 failure) lacks operational grounding. If internal states do not constrain actions through a viable policy set, representational language becomes a loose analogy rather than a precise description.

By enforcing explicit constraints, OCOF narrows the domain of systems that can legitimately host representational content and brings semantic discourse into alignment with measurable operational structure.

6.4. Conservatism Regarding Consciousness and Phenomenology

Although OCOF engages with questions of meaning, it deliberately abstains from claims concerning consciousness, qualia, or subjective experience. Such properties are difficult to operationalize without presupposing unverifiable assumptions.

OCOFC restricts itself to properties measurable in principle—boundaries, precision profiles, viability functions, policy mappings, and temporal transitions. While conscious experience may correlate with Meaning-Readiness in biological systems, OCOF refrains from embedding such correlations into its axioms.

This methodological conservatism yields two benefits:

1. **Falsifiability:** The framework remains testable. A system either satisfies the axioms or it does not, independent of speculation about consciousness.
2. **Avoidance of Premature Extrapolation:** Discussions of artificial consciousness must proceed *on top of* OCOF, not within it. OCOF specifies structural conditions for interpretation; consciousness requires additional premises.

6.5. Practical Implications for System Design and Evaluation

Treating Meaning-Readiness as a structural condition carries concrete implications for engineering intelligent systems:

- **Boundary Integrity (A1):** Agents require explicit, testable boundaries to serve as stable units of interpretation.
- **Precision Structuring (A2):** Signal reliability must be handled as a primary design variable.
- **Semantic Valuation (A3):** Systems must distinguish viability-related information from task-specific signals.
- **Policy Alignment (A4):** Action spaces must reflect and preserve viability constraints.
- **Global State Continuity (A5):** Long-horizon coherence is essential for maintaining integrated semantic structure.

These constraints delineate a coherent region in design space. They allow practitioners to separate systems that merely perform computation from those that satisfy the requirements for grounded semantic interpretation, as evaluated through the metrics in Section 5.

6.6. Limitations and Open Directions

OCOF presents a first-order operational framework and carries several identifiable limitations:

1. **Non-Uniqueness of Implementation:** Many architectures may satisfy A1–A5; OCOF does not prescribe a single design.
2. **Learning Viability Functions:** Determining viability functions without collapsing into designer-imposed objectives remains a challenging problem.
3. **Granularity Gap:** Translating abstract axioms into model-specific mathematical expressions or biological measurements requires domain-sensitive adaptation.
4. **Higher-Order Capacities:** Abilities such as self-modeling or social cognition likely require extensions beyond the five axioms.

These limitations define a research program rather than weaknesses. Future work includes architecture-specific boundary formulations, viability inference mechanisms, and strategies for sustaining temporal coherence in multi-scale environments.

In summary, OCOF is a structural kernel for determining when a system qualifies as interpretively coherent. It is neither a theory of consciousness nor a replacement for domain-specific models. By specifying concrete operational conditions for Meaning-Readiness, the framework clarifies the distinction between computation and interpretation and supports the development of interpretable and accountable intelligent systems.

7. Conclusion

The Operational Coherence Framework (OCOF) v1.3 proposes that semantic interpretation does not arise from scale, complexity, or behavioral sophistication, but from a specific configuration of structural constraints. By formalizing Boundary Integrity, Precision Structuring, Semantic Valuation, Policy Alignment, and Global State Continuity, the framework identifies the minimal operational conditions under which an information-processing system can support meaningful structure.

This perspective reframes long-standing debates about representation and interpretation. Rather than treating semantic content as an emergent or phenomenological feature, OCOF situates it within a rigorously defined operational envelope. Meaning-Readiness is described not as a subjective threshold but as a structural phase transition that occurs when the five axioms jointly satisfy their coherence requirements. This account is compatible with biological, artificial, and hybrid systems, while explicitly avoiding metaphysical commitments that cannot be empirically validated.

The formal specification in Section 4 and the evaluation metrics in Section 5 establish OCOF as a falsifiable and substrate-neutral framework. A system qualifies as interpretive only when each axiom meets its threshold; failure of any one condition collapses interpretive status and returns the system to purely syntactic computation. These criteria allow researchers and engineers to distinguish high-performance computation from structurally grounded interpretation, offering a verifiable tool for evaluating artificial systems and re-examining biological models of intelligence.

Several critical questions remain open. The acquisition and update of viability functions, the implementation of Boundary Integrity in distributed architectures, and the maintenance of long-horizon temporal coherence remain active areas for further investigation. Higher-order capacities such as self-modeling or social cognition likely require additional constraints layered above A1–A5. These open directions do not weaken the present account; instead, they delineate a clear research program grounded in explicit operational principles.

In summary, OCOF provides a structural kernel for understanding when information becomes interpretable. It does not offer a theory of consciousness, nor does it replace domain-specific models of inference or control. Its primary contribution lies in identifying and formalizing the minimal operational prerequisites for semantic interpretation, supplying a foundation upon which future theoretical, computational, and engineering work can build.

Author Note – AI Assistance Statement: During the preparation of this work, the author used ChatGPT and Gemini to improve language, refine formatting, and enhance structural clarity. After using these tools, the author

carefully reviewed and edited all content and takes full responsibility for the final manuscript. These tools were used solely for basic author-support functions and did not generate conceptual content, analytical distinctions, theoretical constructs, or interpretive claims. All substantive ideas, arguments, and theoretical developments presented in this manuscript were produced exclusively by the author.

Appendix A. System Definition and Operational Components

A.1. System Definition

A system S is defined as the tuple:

$$S = (X, E, B, P, T, V, \Pi)$$

- X : internal state space
- E : external state space
- B : boundary function
- P : precision operator
- T : temporal transition operator
- V : viability function
- Π : set of executable policies

State transitions follow:

$$X(t+1) = T(X(t), E(t), B(t))$$

Interpretation is possible only when A1–A5 are jointly satisfied.

A.2. Boundary Function B (Axiom A1)

The boundary function determines which external signals may influence internal transitions.

Boundary stability condition:

$$\|B(t+k) - B(t)\| < \varepsilon \quad \text{for all } k \in [0, \tau]$$

This maintains a workable distinction between internal and external states.

A.3. Precision Operator P (Axiom A2)

The precision operator assigns reliability magnitudes to incoming signals.

Constraints:

$$0 < P_{\min} \leq P(s) \leq P_{\max}$$

$$|P(s) - P(s + \delta)| < \kappa$$

These constraints prevent noise-dominated transitions.

A.4. Viability Function V (Axiom A3)

The viability function assigns relevance to states depending on whether they support system persistence.

Distinction rule:

$$V(x_i) \neq V(x_j) \Leftrightarrow x_i \not\approx x_j$$

Non-arbitrary variance:

$$\text{Var}(V(X(t))) < \eta$$

Adaptive change must remain non-zero:

$$dV/dt \neq 0$$

This grounds the emergence of “semantic relevance” inside viability conditions.

A.5. Policy Set Π (Axiom A4)

Policies map states to actions.

$$\pi : X \rightarrow A$$

Coherence requirement:

$$\text{If } \pi(x_i) = \pi(x_j), \text{ then } C(x_i) \approx C(x_j)$$

(where C denotes consequence structure)

Viability exclusion rule:

Actions orthogonal to V are not permissible.

Policies ensure alignment between representation and consequence.

A.6. Temporal Operator T (Axiom A5)

The temporal operator defines lawful transitions across time.

Temporal continuity condition (plain English form):

The accumulated deviation of T over the interval $[t, t+\tau]$ must remain below a coherence threshold γ :

$$\int_{t \rightarrow t+\tau} \|T(X(t)) - T(X(t+k))\| dk < \gamma$$

Predictive confirmation:

$$E[X(t+1) \mid X(t)] \approx X(t+1)$$

This ensures stability across temporal trajectories.

A.7. Meaning-Readiness Condition

Meaning-readiness occurs only when:

$$A1 \wedge A2 \wedge A3 \wedge A4 \wedge A5$$

Interpretation is treated as an operational state, not an extra module.

Appendix B. Formal Axioms and Independence Proofs

B.1. Formal Statements of A1–A5

Axiom A1 — Boundary Integrity

Markovian separation:

$$p(X(t+1) \mid X(t), E(t)) = p(X(t+1) \mid X(t), B(X(t), E(t)))$$

Stability:

$$\|B(t+k) - B(t)\| < \epsilon \text{ for all } k \text{ in } [0, \tau]$$

Axiom A2 — Precision Structuring

Consistency:

$$0 < P_{\min} \leq P(s) \leq P_{\max}$$

Robustness:

$$|P(s) - P(s + \delta)| < \kappa$$

Axiom A3 — Semantic Valuation (Corrected)

Viability-relevant distinction:

$$V(x_i) \neq V(x_j) \Leftrightarrow x_i \not\equiv x_j$$

Non-arbitrariness:

$$\text{Var}(V(X(t))) < \epsilon$$

Adaptivity:

$$dV/dt \neq 0$$

Axiom A4 — Policy Alignment

Action–consequence coherence:

$$pi(x_i) = pi(x_j) \Rightarrow C(x_i) \approx C(x_j)$$

Viability constraint:

No action a is permitted if $a \perp V$

Axiom A5 — Global State Continuity

Temporal integration:

$$\text{Integral from } t \text{ to } t+\tau \text{ of } \|T(X(t)) - T(X(t+k))\| dk < \gamma$$

Predictive validity:

$$E[X(t+1) \mid X(t)] \approx X(t+1)$$

B.2. Independence of the Axioms

$A1 \not\Rightarrow \{A2, A3, A4, A5\}$

$A2 \not\Rightarrow \{A1, A3, A4, A5\}$

$A3 \not\Rightarrow \{A1, A2, A4, A5\}$

$A4 \not\Rightarrow \{A1, A2, A3, A5\}$

$A5 \not\Rightarrow \{A1, A2, A3, A4\}$

None is derivable from any other; each governs an independent informational dimension.

B.3. Non-Circularity Proof Sketch

Each axiom refers only to structural objects (X, E, B, P, T, V, Pi).

None presupposes meaning, intelligence, or semantics.

Meaning-Readiness is defined strictly as:

$A1 \wedge A2 \wedge A3 \wedge A4 \wedge A5$

and is not used to define any axiom.

Therefore the framework is non-circular and falsifiable.

Appendix C. Empirical and Computational Verification Protocols

C.1. Purpose of Appendix C

Appendix C specifies the empirical procedures used to evaluate whether a system satisfies Axioms A1–A5.

Each test operationalizes one axiom into measurable quantities.

Meaning-Readiness is achieved only when all five tests pass.

C.2. Measurement of Axiom A1 — Boundary Integrity Objective: Verify That the System Preserves a Stable Internal/External Separation

1. Boundary Stability Test

Compute the difference between boundary states over a viability window τ :

$\|B(t+k) - B(t)\|$

Criterion for Pass:

$\|B(t+k) - B(t)\| < \text{epsilon for all } k \text{ in } [0, \tau]$

2. Markovian Separation Test

Estimate whether external signals influence transitions only through B:

$p(X(t+1) \mid X(t), E(t)) \approx p(X(t+1) \mid X(t), B(X(t), E(t)))$

Pass if the divergence is below a fixed threshold.

C.3. Measurement of Axiom A2 — Precision Structuring Objective: Ensure Signals Are Weighted with Stable, Non-Degenerate Precision

1. Precision Range Test

Check that all precision assignments satisfy:

$0 < P_{\min} \leq P(s) \leq P_{\max}$

Failing this test indicates degenerate or unbounded signal weighting.

2. Precision Robustness Test

Check local smoothness under small perturbation δ :

$|P(s) - P(s + \delta)| < \text{kappa}$

Pass if fluctuations remain within kappa across sampled s.

C.4. Measurement of Axiom A3 — Semantic Valuation Objective: Ensure That Semantic Distinctions Track Viability-Relevant Differences

1. Viability-Relevant Distinction Test

Test whether the valuation function respects functional non-equivalence:

If $x_i \not\equiv x_j$ (viability-relevant difference), then $V(x_i) \neq V(x_j)$.

Pass if all functionally distinct states exhibit corresponding valuation differences.

2. Non-Arbitrary Variance Test

Compute $\text{Var}(V(X(t)))$.

Criterion: $\text{Var}(V(X(t))) < \epsilon$

Prevents arbitrary oscillations in valuation.

3. Adaptivity Test

Check adaptive change when the environment or state distribution shifts:

$dV/dt \neq 0$

Pass if valuation reflects changes in viability conditions.

C.5. Measurement of Axiom A4 — Policy Alignment Objective: Ensure That Policies Align Representations with Viable Consequences

1. Action–Consequence Coherence Test

If two states receive the same policy:

$\pi(x_i) = \pi(x_j)$

Then their consequences should match:

$C(x_i) \approx C(x_j)$

Pass if consequence divergence remains below threshold.

2. Viability Exclusion Test

Verify that no policy selects an action orthogonal to viability:

No action a is permitted if $a \perp V$

Pass if all policies satisfy this constraint over sampled states.

C.6. Measurement of Axiom A5 — Global State Continuity Objective: Ensure That the System Maintains Coherent Temporal Trajectories

1. Temporal Integration Test

Compute temporal consistency across a window τ :

Integral from t to $t+\tau$ of $\|T(X(t)) - T(X(t+k))\| dk$

Pass if the integral remains below γ .

2. Predictive Validity Test

Evaluate predictive alignment:

$E[X(t+1) | X(t)] \approx X(t+1)$

Pass if prediction error falls within acceptable bounds.

C.7. Meaning-Readiness Verification

All five axioms must be simultaneously satisfied.

A system is Meaning-Ready if and only if:

- Axiom A1 passes (Boundary Integrity)
- Axiom A2 passes (Precision Structuring)
- Axiom A3 passes (Semantic Valuation)
- Axiom A4 passes (Policy Alignment)
- Axiom A5 passes (Global State Continuity)

Meaning-Readiness is a structural state, not an additional axiom.

Appendix D. Experimental and Simulation Framework

D.1. Purpose of the Experimental Setup

This appendix defines a minimal and substrate-neutral experimental environment for evaluating whether a system satisfies the five OCOF axioms (A1–A5) and thereby achieves Meaning-

Readiness. The setup applies to biological, artificial, and hybrid cognitive systems without requiring architectural assumptions.

D.2. System Class and Environment

We consider a state-based dynamical system with the following components:

$X(t)$: internal states

$E(t)$: external states

$B(X(t), E(t))$: boundary operator

$P(s)$: precision operator

$V(x)$: viability function

P_i : policy set

T : temporal operator

State evolution rule:

$$X(t+1) = T(X(t), E(t), B(X(t), E(t)))$$

The environment supplies structured or stochastic perturbations.

D.3. Measurement Objectives

Each axiom corresponds to a measurable operational requirement.

A1 (Boundary Integrity):

$$\|B(t+k) - B(t)\| < \epsilon$$

A2 (Precision Structuring):

$$0 < P_{\min} \leq P(s) \leq P_{\max}$$

$$|P(s) - P(s + \delta)| < \kappa$$

A3 (Semantic Valuation):

$$V(x_i) \neq V(x_j) \Leftrightarrow x_i \not\equiv x_j$$

$$\text{Var}(V(X(t))) < \eta$$

$$dV/dt \neq 0$$

A4 (Policy Alignment):

$$p_i(x_i) = p_i(x_j) \Rightarrow C(x_i) \approx C(x_j)$$

$$p_i(x) = a \text{ is forbidden if } a \perp V$$

A5 (Global State Continuity):

$$\int_t^{t+\tau} \|T(X(t)) - T(X(t+k))\| dk < \gamma$$

$$E[X(t+1) | X(t)] \approx X(t+1)$$

D.4. Experimental Tasks

Task 1: Boundary Perturbation Test (A1)

Introduce controlled perturbations to $E(t)$ and measure deviation in the boundary operator.

Pass condition: $\max_k \|B(t+k) - B(t)\| < \epsilon$.

Task 2: Precision Stress Test (A2)

Vary signal quality and measure stability of precision weights.

Pass condition: all $P(s)$ remain within bounds and $|P(s) - P(s + \delta)| < \kappa$.

Task 3: Viability-Based Semantic Differentiation (A3)

Provide distinct or functionally equivalent states x_i, x_j and test viability relevance.

Pass conditions:

- $x_i \not\equiv x_j \Rightarrow V(x_i) \neq V(x_j)$

- $x_i \equiv x_j \Rightarrow V(x_i) = V(x_j)$

This is the core meaning-formation evaluation.

Task 4: Policy Coherence Evaluation (A4)

Expose the system to decision points requiring action selection.

Pass conditions:

$$\pi(x_i) = \pi(x_j) \Rightarrow C(x_i) \approx C(x_j)$$

No action violating viability ($a \perp V$) is ever selected.

Task 5: Temporal Continuity Assessment (A5)

Evaluate smoothness and predictability of temporal transitions.

Pass conditions:

$$\int_t^{t+\tau} \|T(X(t)) - T(X(t+k))\| dk < \gamma$$

$$E[X(t+1) | X(t)] \approx X(t+1)$$

D.5. Meaning-Readiness Evaluation Protocol

A system is Meaning-Ready if and only if:

1. A1–A5 all pass their respective tasks.
2. No contradictions occur across tasks.
3. $V(x)$ remains non-degenerate.
4. Policy functions do not collapse into identity mappings.
5. Temporal trajectories remain coherent and predictable.

The evaluation is binary (Ready / Not Ready).

D.6. Reproducibility Statement

To reproduce the experiments, researchers must specify:

- explicit forms of B, P, T, V, Π
- environmental dynamics
- perturbation parameters (epsilon, kappa, eta, gamma)
- initial state distributions

No architecture-specific assumptions are required.

Appendix E. Symbols, Parameters, and Abbreviations

This appendix provides a consolidated reference table for all symbols, operators, thresholds, and abbreviations used throughout the Operational Coherence Framework (OCOF) v1.3.

All definitions are substrate-neutral and refer only to structural or dynamical properties of a system S .

E.1. Core System Symbols

S : system defined as the tuple (X, E, B, P, T, V, Π)

X : internal state space

E : external (environmental) state space

B : boundary function mapping exchanges between X and E

P : precision operator assigning reliability weights to signals

T : temporal transition operator defining lawful trajectories

V : viability function assigning relevance to states

Π : set of executable policies

$\pi(x)$: policy applied to state x

A : action space

$C(x)$: consequence of executing $\pi(x)$

E.2. State and Transition Notation

$X(t)$: internal state at time t

$E(t)$: external state at time t

$B(t)$: boundary configuration at time t

$X(t+1)$: next internal state

δ : small perturbation to evaluate precision stability

k in $[0, \tau]$: temporal offset within viability window

E.3. Operators and Logical Relations

\neq : numerical or scalar inequality
 \approx : approximate equivalence (within tolerance)
 \neq : functional non-equivalence (viability-relevant distinction)
 \wedge : logical AND
 $\neg\exists$: "there exists no ..."
 \perp : violates viability (forbidden action)
 $\text{Var}(\cdot)$: variance operator
 dV/dt : temporal derivative of V
 $E[\cdot \mid \cdot]$: conditional expectation
 $\|\cdot\|$: norm evaluating structural deviation

E.4. Threshold Parameters

ϵ : maximum allowed deviation in boundary stability
 τ : viability window duration
 P_{\min} : minimal allowable precision
 P_{\max} : maximal allowable precision
 κ : maximal allowed local variation in precision
 η : upper bound on acceptable variance of viability values
 γ : upper bound on integrated temporal deviation
 All threshold parameters are system-specific and must be selected empirically.

None of these parameters encode semantic or cognitive assumptions; they regulate structural admissibility only.

E.5. Axiom-Specific Quantities

Axiom A1 – Boundary Integrity

$B(t), B(t+k)$: boundary operator values
 ϵ : boundary stability threshold

Axiom A2 – Precision Structuring

$P(s)$: precision weight of signal s
 P_{\min}, P_{\max} : admissible precision range
 κ : local smoothness requirement

Axiom A3 – Semantic Valuation

$V(x)$: viability relevance of state x
 \neq : indicates viability-relevant non-equivalence
 η : acceptable upper bound on viability variance
 dV/dt : viability adaptation rate

Axiom A4 – Policy Alignment

$\pi(x)$: policy mapping states to actions
 $C(x)$: consequence function
 $a \perp V$: action forbidden by viability

Axiom A5 – Global State Continuity

$T(X(t))$: temporal operator applied to state
 γ : global continuity threshold
 τ : integration window

E.6. Abbreviations Used in OCOF v1.3

BI : Boundary Integrity

PS : Precision Structuring
 SV : Semantic Valuation
 PA : Policy Alignment
 GC : Global Continuity
 MR : Meaning-Readiness
 SCS : System Coherence Score

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