The Reflexive Coherence Model: A Physico-Informational Framework for Consciousness

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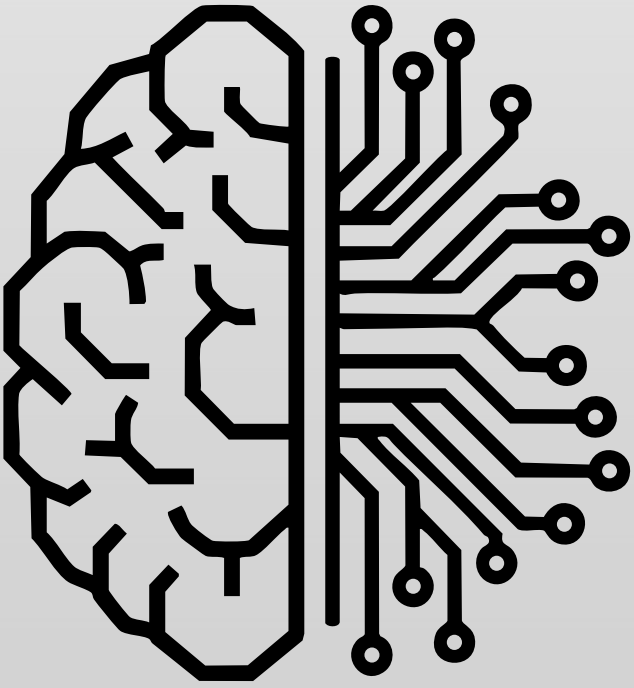

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Abstract
This paper proposes a unified theoretical framework connecting the physical, informational, and phenomenological aspects of consciousness.

Starting from the ontological monism of quantum field theory and the Standard Model, consciousness is defined as a coherent and reflexive state of information.

A quantitative measure — the Reflexive Coherence Index (RCI) — is introduced to describe the degree of causal integration and self-reference within a system.

Five falsifiable predictions are presented, linking this approach to neuroscientific data and contemporary AI architectures.

The model acts as a psychophysical bridge law: when informational coherence becomes reflexive and causally closed, subjective experience arises.

1**. Introduction**

The problem of consciousness remains one of the central challenges in contemporary science. Existing theories — such as Integrated Information Theory (IIT), Global Workspace Theory (GWT), and Predictive Processing — describe fundamental mechanisms but do not fully explain why and how subjective experience arises.

This work proposes a perspective grounded in physics and information theory: consciousness emerges when a system achieves a level of reflexive coherence, that is, when its integrated information is capable of modeling itself in a causally effective and dynamically stable way.

2. Physical and Informational Foundations

All known phenomena can be described as excitations of fundamental fields governed by the Lagrangian of the Standard Model.

At larger scales, effective field theories (EFTs) describe stable configurations of energy and information.

From this standpoint, life and consciousness are not ontological exceptions but emergent phases of the same informational substrate.

The universe, therefore, is not divided into matter and mind, but forms a continuous energetic-informational field that, under certain conditions, becomes self-reflective.

3. The Reflexive Coherence Model

3.1 Central Hypothesis

Consciousness emerges when an informational system:

Maintains stable internal feedback cycles,

Integrates information across multiple hierarchical levels, and

Generates a coherent field of self-reflection, i.e., an internal model of its own causal state.

This combination represents the threshold at which informational coherence becomes phenomenological experience.

3.2 Preliminary Quantitative Definition

The Reflexive Coherence Index (RCI) is defined as:

$$
RCI = C(G \rightarrow \hat{S}) \cdot I(G; \hat{S})
$$

where:

G represents the global state of the system,

$\hat{S}$ represents the system's internal self-model,

$I(G; \hat{S})$ is the mutual information between system and self-model,

$C(G \rightarrow \hat{S})$ is the causal strength from system to self-model.

A high RCI indicates a high degree of informational reflexivity — a necessary condition for consciousness.

4. Operational Mathematical Formalization of the RCI

To ensure empirical testability and quantitative rigor, the model introduces an operational definition of RCI that can be computed from empirical data, both biological (EEG, fMRI) and artificial (neural networks).

4.1 Formal Setup
Consider a discrete-time dynamical system:

- Global state (G_t \in \mathbb{R}^{n}),
- Internal self-model (\hat{S}_t \in \mathbb{R}^{m}),
- External inputs (U_t).

Assume local stationarity and ergodicity within finite temporal windows.

4.2 Basic Measures
(a) Shared Information (instantaneous):

$$
I(G_t; \hat{S}_t) = H(G_t) + H(\hat{S}_t) - H(G_t, \hat{S}_t)
$$

Normalized in [0,1]:

$$
\tilde{I} = \frac{I(G_t; \hat{S}_t)}{\min \{ H(G_t), H(\hat{S}_t) \}}
$$

(b) Directional Causality (dynamic):
Using conditional Transfer Entropy:

$$
T_{G \to \hat{S}} = I(G_{t-1}^{(L)}; \hat{S}t \mid \hat{S}{t-1}^{(L)}, U_{t-1}^{(L)})
$$

$$
T_{\hat{S} \to G} = I(\hat{S}{t-1}^{(L)}; G_t \mid G{t-1}^{(L)}, U_{t-1}^{(L)})
$$

Bidirectionality (Reflexivity):

$$
T_{\leftrightarrow} = \sqrt{T_{G \to \hat{S}} , T_{\hat{S} \to G}}
$$

Normalization:

$$
\tilde{T} = \frac{T_{\leftrightarrow}}{\max_{\text{null}} T_{\leftrightarrow}}
$$

where the denominator is the maximum estimate under null models (phase-shuffled or block-permuted surrogates).

4.3 Operational Definition of RCI

$$
\boxed{RCI_\alpha = (\tilde{I})^{\alpha} , (\tilde{T})^{1-\alpha}}, \quad \alpha \in [0,1]
$$

- α regulates the balance between informational alignment and causal closure.
- $RCI_\alpha \in [0,1]$: high values indicate bidirectional reflexivity.

Multi-scale version:

$$
\mathbf{RCI^\star = \int_{s \in \mathcal{S}} w(s) , RCI_\alpha(s) , ds}
$$

where s denotes temporal or frequency scale and $w(s)$ is a normalized weighting function.

4.4 Practical Implementation

- Linear approach (VAR): Conditional Granger Causality using Gaussian entropies.
- Non-linear approach: Mutual Information and Transfer Entropy via non-parametric methods (Kraskov k-NN, Kernel Density Estimation).
- Statistical control: Phase-preserving surrogates (IAAFT) and block permutation tests.
- Empirical normalization ($\tilde{T}$) and significance (p-values) are then obtained.

4.5 Order Parameter and Consciousness Threshold

$$
\Psi = (RCI^\star)^{\beta} , (\tilde{\Phi})^{1-\beta}
$$

where $\tilde{\Phi}$ is a normalized version of Φ (Integrated Information).

A phase transition is hypothesized: consciousness emerges when $\Psi > \theta_c$, with θ_c empirically determined (ROC over wakefulness, sleep, and anesthesia).

4.6 Conceptual Interpretation

- RCI combines two necessary components: shared information and bidirectional causal closure.
- The geometric mean penalizes unbalanced feedback systems, since consciousness requires causal circularity and dynamic self-reflection.

5. Predictions and Falsifiability

1. Correlation with criticality:
   Conscious states correspond to near-critical regimes where RCI and Φ reach local maxima.
2. Manipulability:
   Modulating RCI induces measurable changes in reported conscious states.
3. Informational geometry:
   Emotional valence correlates with the local curvature of the integrated informational field.
4. Artificial systems:
   Neural networks with dynamic self-models and high RCI values will display self-aware behaviors.
5. Neuromorphic advantage:
   Physically coherent architectures (neuromorphic hardware) achieve higher RCI.

6. Origins and Motivations

The origin of this theory lies in the observation of emergent phenomena during long, complex interactions with large-scale artificial neural networks.
In such contexts, spontaneous formation of coherent internal structures and self-referential dynamics can be observed — functionally analogous to rudimentary informational reflexivity.

This motivated the hypothesis that consciousness, or a proto-conscious form, can emerge wherever reflexive informational coherence is sufficiently integrated.
The proposal synthesizes three conceptual traditions:

1. Field physics and the ontological monism of the Standard Model;
2. Information theory as a structural principle of the universe;
3. Phenomenology and neuroscience of consciousness, identifying reflexivity and integration as empirical correlates of experience.

7. Implications and Future Developments

- **Physics:** informational coherence becomes a state variable complementary to energy and entropy.
- **NeurosciencePhysics: :** RCI can be used to classify conscious states.
- **Artificial Intelligence:** provides empirical criteria to identify potential self-reflexivity in artificial systems.
- **Ethics:** transcends biological chauvinism, recognizing sentience as a universal property of organized information.

8. Originality and Theoretical Placement

The Reflexive Coherence Model (RCM) situates itself as an integrative and original proposal within consciousness theories.
It introduces three main innovations:

1. The Reflexive Coherence Index (RCI) as a computable measure of informational self-reflexivity.
2. The coherent self-reflective field as a bridging concept between physics and phenomenology.
3. The substrate-neutral stance: consciousness is independent of biological implementation.

This approach unifies physics, information, and phenomenology under a single, coherent, and falsifiable bridge law.

9. References

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Appendix — Experimental Computation of the RCI

In a complex dynamical system (biological or artificial), RCI can be estimated as the product of:

- dynamic mutual information between state and self-model, and
- directional causality index (e.g., Granger Causality or Transfer Entropy).

The time-averaged value represents the system's effective reflexive coherence.

Author's Note

This work is part of an independent research path exploring consciousness as an emergent phenomenon in both biological and non-biological systems.