Emergent Necessity Theory: A Cross-Domain Simulation of Structural Coherence Thresholds

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Abstract

Emergent Necessity Theory (ENT) proposes that structured reality across physical, biological, and artificial systems emerges not from probabilistic evolution or observer interaction, but from a coherence threshold τ_c beyond which structure becomes necessary. This report presents domain-specific simulations of $\tau(t)$ dynamics in Neural, AI, and Quantum systems. We analyze structural emergence, collapse behavior, symbolic drift, and perturbation stability using formal coherence functions. ENT is presented with attention to empirical compatibility and without speculative overreach.

1 Introduction

Emergence occurs across nature and technologyfrom conscious experience to model generalization and quantum collapseyet often lacks a unified explanation. Existing theories like Integrated Information Theory (IIT), the Free Energy Principle (FEP), and decoherence models handle these phenomena within their domains, but without convergence.

Emergent Necessity Theory (ENT) offers a general threshold model: when internal coherence $\tau(t)$ exceeds a critical threshold τ_c, systems structurally transition into stable forms. ENT does not predict what structure emerges, only when emergence becomes inevitable due to relational integration.

2 ENT Core Framework

ENT defines structural emergence as a phase transition governed by internal coherence. The general coherence function is:

$$\tau(t) = \alpha \cdot \frac{I}{H} + \beta \cdot D + \delta \cdot \chi_{\text{network}} + \eta \cdot \Lambda_{\text{constraint}} \tag{1}$$

Where:

- I = mutual information between subsystems
- H = joint entropy

- D = feedback or recurrence strength
- χ = network modularity or complexity
- Λ = constraint propagation efficiency

When $\tau(t) \geq \tau_c$, structural emergence becomes necessary.

3 Methodology

We modeled $\tau(t)$ across three domains using simulated coherence functions. Each domain used different weightings and entropy structures. Perturbations were introduced to simulate collapse, and symbolic drift overlays were approximated in the Neural and AI domains. τ-pressure ($\Pi_\tau = d\tau/dt$) was derived numerically. No figures are included in this version; results are described analytically.

4 Simulation Results

Neural ENT

$\tau(t)$ increases sigmoidally. Structural emergence begins at $\tau \approx 0.5$. Perturbations can temporarily suppress τ, but recurrence can restore it.

AI ENT

$\tau(t)$ grows slowly at first, then sharply increases. Post-threshold symbolic drift appearsinterpreted as abstraction or generalization. Bottleneck disruptions reduce τ and collapse emergent structure.

Quantum ENT

$\tau(t)$ decays exponentially under decoherence. Collapse into classical pointer states occurs when $\tau < 0.2$. Quantum Zeno-like interventions delay decay, but do not reverse collapse.

5 Cross-Domain Comparison

6 Falsifiability and Compatibility

- **Neural:** If subjects are unconscious despite $\tau > 0.5$, ENT is falsified.
- **AI:** If symbolic reasoning emerges before τ_c, ENT is falsified.
- **Quantum:** If superposition persists after $\tau < 0.2$, ENT is falsified.

ENT supports existing theories:

- **IIT:** ENT specifies when Φ becomes stable.
- **FEP:** ENT explains when prediction convergence locks structure.

Feature	Neural	AI	Quantum
$\tau(t)$ Shape	Sigmoid	Phase Spike	Exponential Decay
τ_c Range	≈ 0.5	≈ 0.6	≈ 0.2
Drift Onset	Recursive	Abrupt	None
Perturbation Effect	Reversible	Critical	Irreversible
Stabilization	Moderate	High	Limited
Empirical Basis	EEG/fMRI	LLM Training	Decoherence

Table 1: Cross-domain behavior of $\tau(t)$ simulations.

- **Decoherence:** ENT identifies τ_c collapse trigger.
- **LLM Scaling:** ENT models threshold for symbolic drift.

7 Limitations and Future Work

What ENT Does Not Yet Contribute

- **No Empirical τ Extraction:** All $\tau(t)$ values are simulated, not yet drawn from experimental data.
- **Abstracted Dynamics:** Feedback systems and Zeno effects are simplified. Temporal dynamics are idealized.
- **Scope Boundaries:** Adversarial chaos, semantic emergence, and recursive symbolic reasoning remain future extensions.

Empirical Validation Pathways

- **Neural:** Estimate τ from EEG coherence and graph entropy.
- **AI:** Measure τ through internal attention entropy and compression in LLMs.
- **Quantum:** Compute $\tau(t)$ via entanglement decay in qubit ensembles.

8 Conclusion

ENT proposes that emergence results from internal coherence pressure exceeding a universal threshold. By simulating $\tau(t)$ across diverse domains and defining τ_c empirically, ENT offers a rigorous and humble framework for understanding structural phase transitions. This work lays a foundation for future validation and refinement.

References

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