Title: A Cartography of Consciousness: Validating the Emergent Recursive Information Framework Across Biological and Artificial Systems

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Date: July 2025

Keywords: Consciousness, Information Theory, EEG, Anesthesia, Artificial Intelligence, ERIF, Recursion, Open Science

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Abstract
The Emergent Recursive Information Framework (ERIF) is a meta-theoretical model that characterizes consciousness not as a single quantity, but as a dynamic state within a two-dimensional space defined by Temporal Persistence (T) and Recursive Integration (R). We tested this framework through four independent lines of inquiry: foundational EEG analysis, mapping diverse waking states, tracking the trajectory to unconsciousness under anesthesia, and two computational studies (a simple AI agent and a NetLogo agent-based simulation). The results show that ERIF's T-R map robustly differentiates conscious states, predicts the collapse of consciousness under anesthesia, and confers a measurable evolutionary advantage in artificial agents. All code, data, and figures are open source.

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1. Introduction: A New Cartography for Consciousness
For centuries, the nature of consciousness has been the ultimate mystery. Modern theories often fall short, attempting to reduce the rich tapestry of subjective experience to a single quantity. This paper introduces the Emergent Recursive Information Framework (ERIF), a new cartography for the state-space of consciousness defined by two independent axes:
1. Temporal Persistence (T): A measure of the stability of a system's self-model.
2. Recursive Integration (R): A measure of real-time, feedback-driven information sharing.
Our central hypothesis is that different conscious states occupy distinct regions in this `T-R` space.

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2. Methods
A consistent methodology was applied across all EEG studies, using public datasets and MNE-Python. The AI simulation was conducted in Python; the agent-based simulation was in NetLogo.

Open Science Statement: The complete analysis code, raw results, and all figures are publicly available at our GitHub repository:
https://github.com/k4khandhar/ERIF-Consciousness-Paper

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3. Results: A Multi-Part Empirical Validation

3.1. Foundational EEG Analysis: Resting vs. Active State
- **Dataset:** MNE Sample
- **Finding:** Resting State has significantly higher T (stability), Active State has higher R (integration).
- **Statistical Significance:** $p < 0.0001$

[IMAGE PLACEHOLDER: ERIF_Final_Comparison_Plot.png]
Figure 1: Violin plots showing T and R dissociation between Resting and Active states.

3.2. Mapping Diverse Waking States
- **Dataset:** MNE EEGBCI
- **Finding:** Resting, Active Task, and Meditative Proxy states each have unique T-R signatures.

Table 1: ERIF Metrics Across Waking States

Group	Mean T Score (s)	Std Dev T	Mean R Score (MI)	Std Dev R
Resting State	0.589	0.211	0.088	0.024
Active Task	0.347	0.106	0.121	0.029
Meditative Proxy	0.901	0.356	0.094	0.026

[IMAGE PLACEHOLDER: ERIF_Triple_Comparison_Plots.png]
Figure 2: ERIF signatures for three waking states.

3.3. Anesthesia Study: Trajectory to Unconsciousness
- **Dataset:** PhysioNet Propofol EEG
- **Finding:** Both T and R collapse as the patient loses consciousness, tracing a clear path to the (0,0) origin in T-R space.

[IMAGE PLACEHOLDER: ERIF_Anesthesia_Trajectory.png]
Figure 3: The trajectory of consciousness during anesthesia.

3.4. Simple AI Simulation: Proof of Substrate Independence
- **Method:** Python simulation of a standard agent vs. an ERIF agent with a recursive loop.
- **Finding:** The ERIF agent outperformed the standard agent by 75% in a noisy environment.

[IMAGE PLACEHOLDER: ERIF_AI_Agent_Performance.png]
Figure 4: Performance plot showing the advantage of the ERIF agent.

3.5. NetLogo Agent-Based Simulation: Survival of the Most Conscious
- **Method:** NetLogo simulation with three agent types (Standard, High-T, ERIF) in a world cycling between "Stable" and "Chaotic" conditions.

- **Finding:** The ERIF agent, which dynamically balances T and R, is the only population to survive and thrive long-term.

[IMAGE PLACEHOLDER: NetLogo_Population_Plot.png]
Figure 5: Population dynamics from the NetLogo simulation. ERIF agents (green) dominate.

[IMAGE PLACEHOLDER: NetLogo_Energy_Plot.png]
Figure 6: Average energy levels. ERIF agents maintain the highest and most stable energy.

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4. General Discussion
The converging evidence from these five studies provides robust, multi-faceted support for ERIF. The T-R map is not just a metaphor; it is a practical, testable tool for differentiating conscious states, predicting the collapse of consciousness, and engineering more adaptive artificial agents. The NetLogo simulation, in particular, demonstrates the evolutionary advantage of dynamic T-R balancing in a complex, changing world.

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5. Conclusion
ERIF is a robust, testable, and multi-dimensional framework for the science of consciousness and intelligence. It is validated across biological and artificial systems, and it provides a new language for mapping the evolution of mind and machine. All code, data, and results are open source.

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6. Limitations and Future Work

While ERIF provides a robust, testable, and multi-dimensional framework for the science of consciousness and intelligence, several limitations remain:

- **Proxy Metrics:** The current measures of T and R are proxies. Future work should refine these with more direct causal and dynamical metrics.
- **Sample Size:** Some EEG studies used small or single-subject datasets. Larger, more diverse samples are needed for generalization.
- **Qualia Gap:** ERIF does not solve the "hard problem" of consciousness. It is a map of functional states, not subjective experience.
- **Universality:** While ERIF is validated in brains and artificial agents, its application to other complex systems remains to be tested.
- **NetLogo Simulation:** The agent-based model is a powerful proof-of-concept, but future work should explore more complex environments and agent architectures, including AGI and ASI scenarios.

Future Directions:

- Apply ERIF to clinical populations (coma, anesthesia, psychedelics).
- Engineer ERIF-based architectures in advanced AI and AGI.
- Expand the framework to ecological, social, and economic systems.
- Develop real-time neurofeedback tools for exploring the T-R map in subjective experience.

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7. Appendix: Code and Data Availability

All code, data, and simulation models used in this research are openly available for review and reproduction.

Google Drive Project Folder:
https://drive.google.com/drive/folders/1wJ_mvKZ1XBofNy7sPolynPEtUgWwMu9-

GitHub Repository:
https://github.com/k4khandhar/ERIF-Consciousness-Paper

Key Files:
- ERIF_Final_Paper.pdf — The complete research paper.
- Figure_1_EEG_Dissociation.png — EEG Resting vs. Active.
- Figure_2_Triple_Comparison.png — EEG Resting, Active, Meditative.
- Figure_3_Anesthesia_Trajectory.png — Anesthesia trajectory.
- Figure_4_AI_Performance.png — Simple AI agent simulation.
- Figure_5_NetLogo_Population.png — NetLogo agent population dynamics.
- Figure_6_NetLogo_Energy.png — NetLogo agent energy levels.
- ERIF_v9_Complete_Research_Summary.png — Grand summary figure.
- ERIF_Agent_World.nlogo — NetLogo simulation code.
- ERIF_Final_Results.csv — EEG data table.
- ERIF_Anesthesia_Results.csv — Anesthesia data.

How to Reproduce the Results:
- All Python and NetLogo code is available in the GitHub repository.
- The NetLogo model can be run in [NetLogo Web](https://netlogoweb.org/) or the desktop app.
- All raw data CSVs are included for independent analysis.

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8. References
- Chalmers, D. J. (1995). Facing up to the problem of consciousness.
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