State-Space Modeling Reveals ECT-Induced Network Reorganization In Pain-Processing Circuits

01 Abstract

Electroconvulsive therapy (ECT) has shown promise in managing acute pain by influencing neural circuits involved in pain perception. However, quantifying the changes in brain connectivity during this process is challenging. Recent advances allow us to build state-space models from high-resolution neural recordings. We applied a computational neurophysiology algorithm to analyze 5-minute LFP recordings from four rodent brain regions across different phases: baseline, acute pain from formalin injection, and ECT at varying intensities. Formalin increased signal complexity, indicating heightened neural processing. Network analysis revealed changes in connectivity metrics, such as expanded network diameter and average path length, along with reduced clustering and assortativity, suggesting a shift to long-range interactions. ECT restored signal complexity to baseline levels and even reversed formalin-induced network expansion, demonstrating its role in stabilizing pain-related neural complexity and reshaping brain connectivity through homeostatic mechanisms.

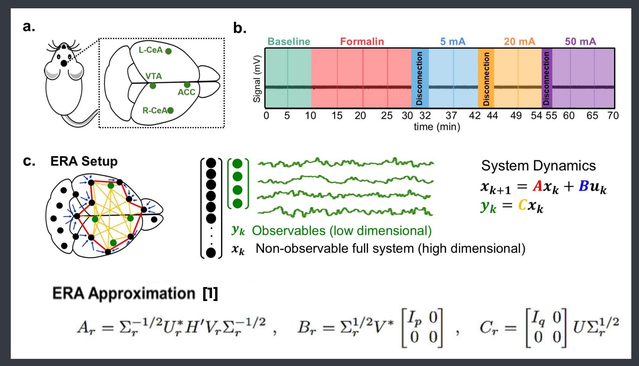
02 Objective

1. Utilize ERA methodology to identify governing equations for brain recording stages—baseline, pain, and treatment.

2. Monitor changes in connectivity properties of the full system (brain (**A**)) and their projection onto observable metrics (**C**), emphasizing node-specific characteristics throughout treatment.

3. Analyze how different ECT intensities affect LFP recordings in rats after formalin injection, focusing on pain suppression using statistical analysis.

03 Schematic & Methodology



Scan the QR code to access our online publication [2]: "ERA on Rodent Brain Signals During Euthanasia"

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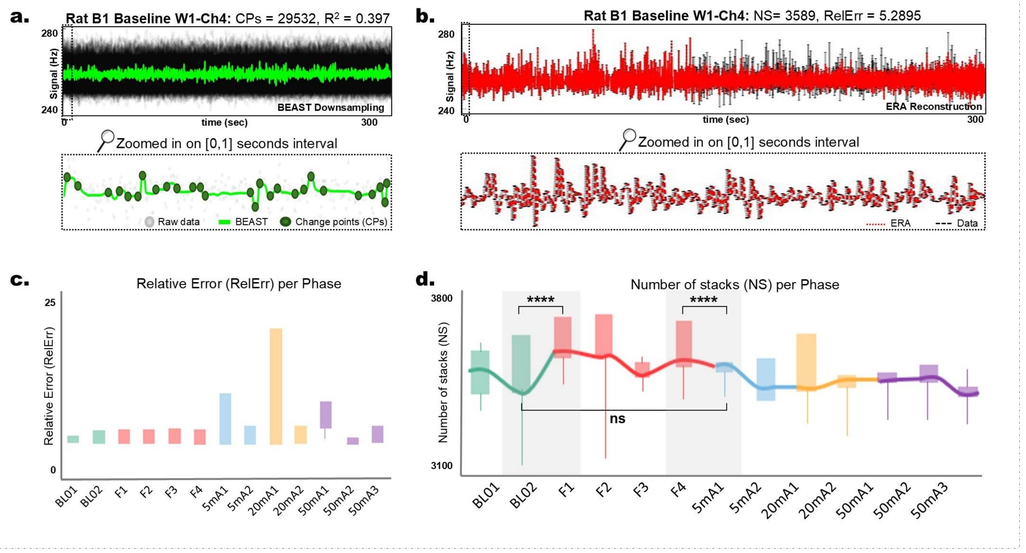
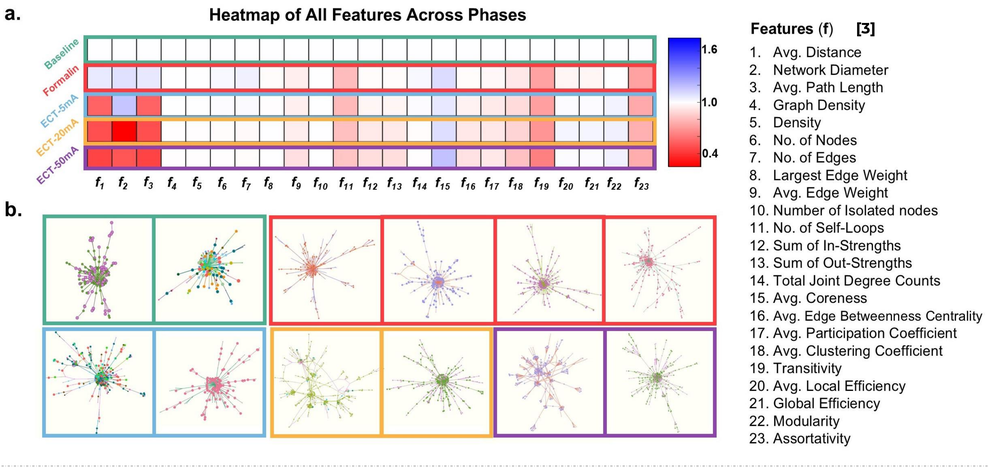
04 Results

I.



II.



05 Conclusions

1. We **successfully identified the governing equations** for different rats and phases of the experiment.

2. **NS reflects neural signal complexity**, increasing after formalin injection, indicating pain-induced network changes.

3. **ECT restores complexity to baseline**, with a significant NS drop from F4 (formalin) to 5mA1 (ECT). This suggests that ECT helps reorganize neural activity, bringing it closer to baseline conditions.

06 References

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[2] Aqel, K., Wang, Z., Peng, Y. B., & Maia, P. D. (2024). Reconstructing rodent brain signals during euthanasia with eigensystem realization algorithm (ERA). Scientific Reports, 14(1), 12261.
[3] M Rubinov, R Kotter, P Hagmann, O Sporns, Brain connectivity toolbox: a collection of complex network measurements and brain connectivity datasets. NeuroImage 47, S169 (2009).
[4] J Trejo, "Anti-nociception induced by high-intensity electrical brain stimulation," M.Sc. thesis, The University of Texas at Arlington (2023).