Phenomenological Renormalization Group analysis on population dynamics of the primary visual cortex under chronic stress

Edson Vinícius[1], Mauro Copelli[1] & Nivaldo Vasconcelos[2]
[1]Physics Department, Federal University of Pernambuco
[2]Department of Biomedical Engineering, Federal University of Pernambuco

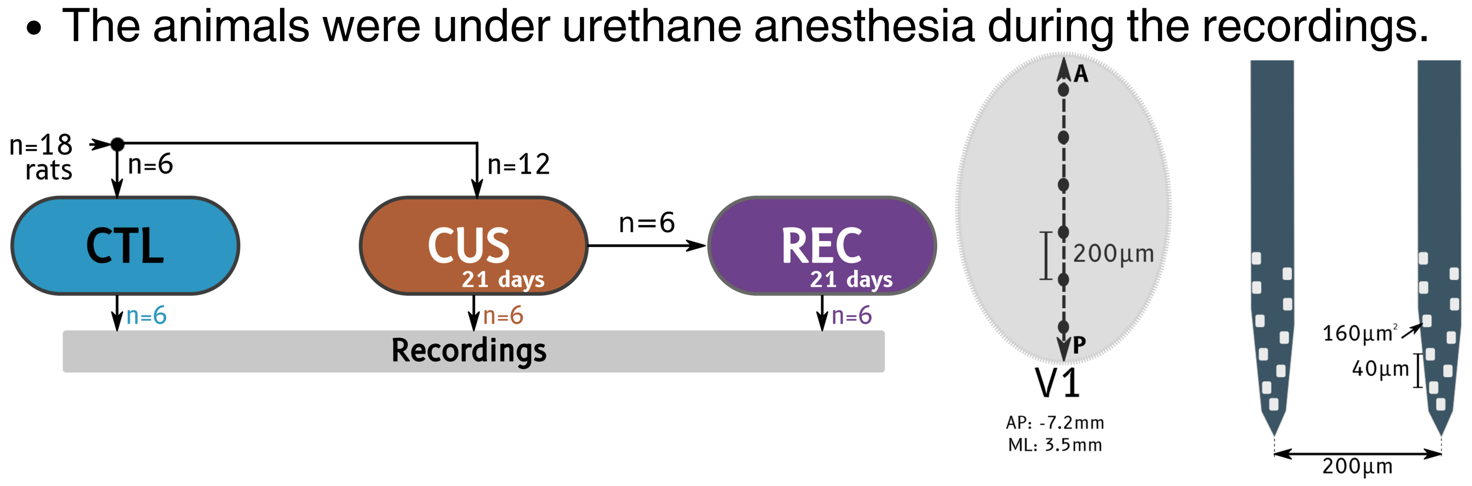
UFPE

INTRODUCTION

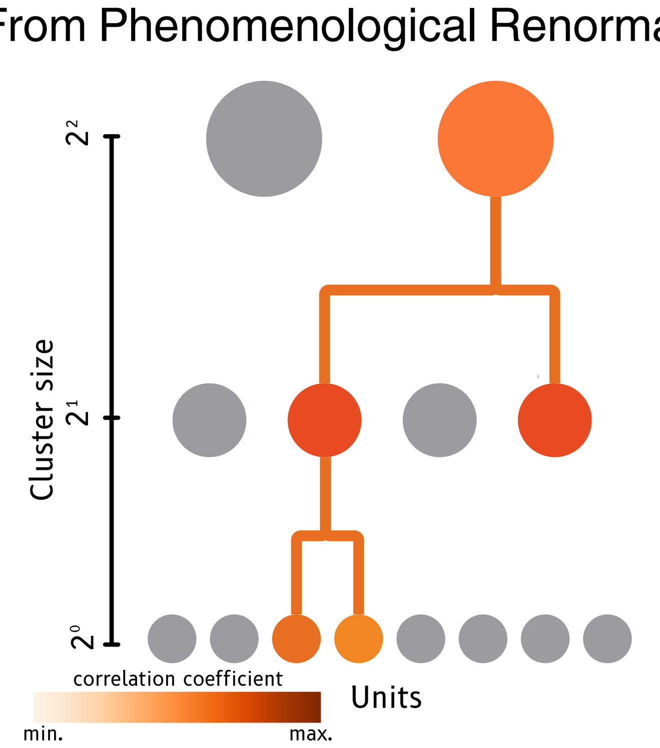
- Despite extensive evidence that chronic stress alters sensory processing, the underlying mechanisms, particularly at the level of large neuronal populations, remain elusive.
- We implemented a chronic unpredictable stress (CUS) protocol in rats to model long-term stress effects, and recorded large neuronal populations in the primary visual cortex.
- To assess how chronic stress influences the dynamics of neuronal spiking populat.ions directly linked to the sensory preception, especificaly in the primary visual cortex, across multiple scales, we applied the Phenomenological Renormalization Group (PRG) method.

MATERIALS AND METHODS

- The rats were allocated into three groups: control (CTL), stress (CUS), and recovery (REC).
- For 21 consecutive days, each animal from the CUS and REC groups experienced one of five aversive stimuli: hot air stream, overcrowding, cold water at 18°C, vibration, or restraint; for 1 hour per day, chosen randomly each day. The REC group was allowed an additional 21 days without any exposure to aversive stimuli.
- The animals were under urethane anesthesia during the recordings.



- From Phenomenological Renormalization Group analysis



$$M_2(C_{\text{size}}) \propto C_{\text{size}}^{\tilde{\alpha}}$$

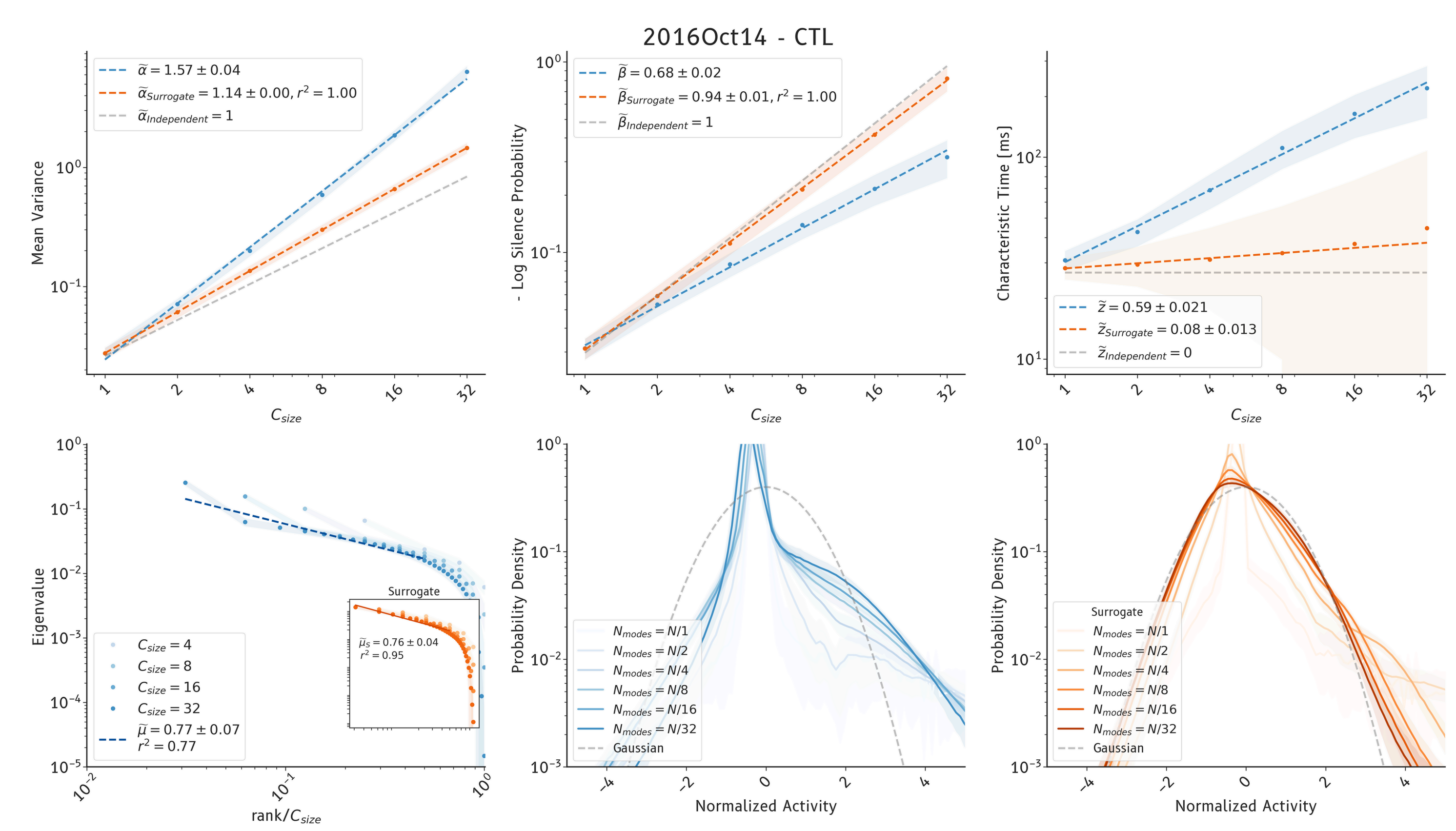
$$-\log P_{\text{silence}} \propto C_{\text{size}}^{\tilde{\beta}}$$

$$\lambda_r \propto \left(\frac{C_{\text{size}}}{r}\right)^{\tilde{\mu}}$$

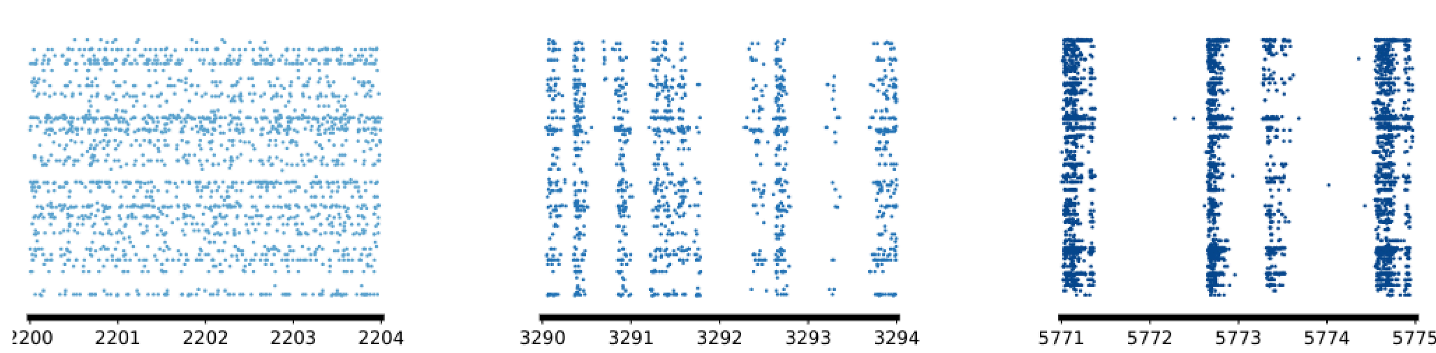
$$\tau_c \propto C_{\text{size}}^{\tilde{z}}$$

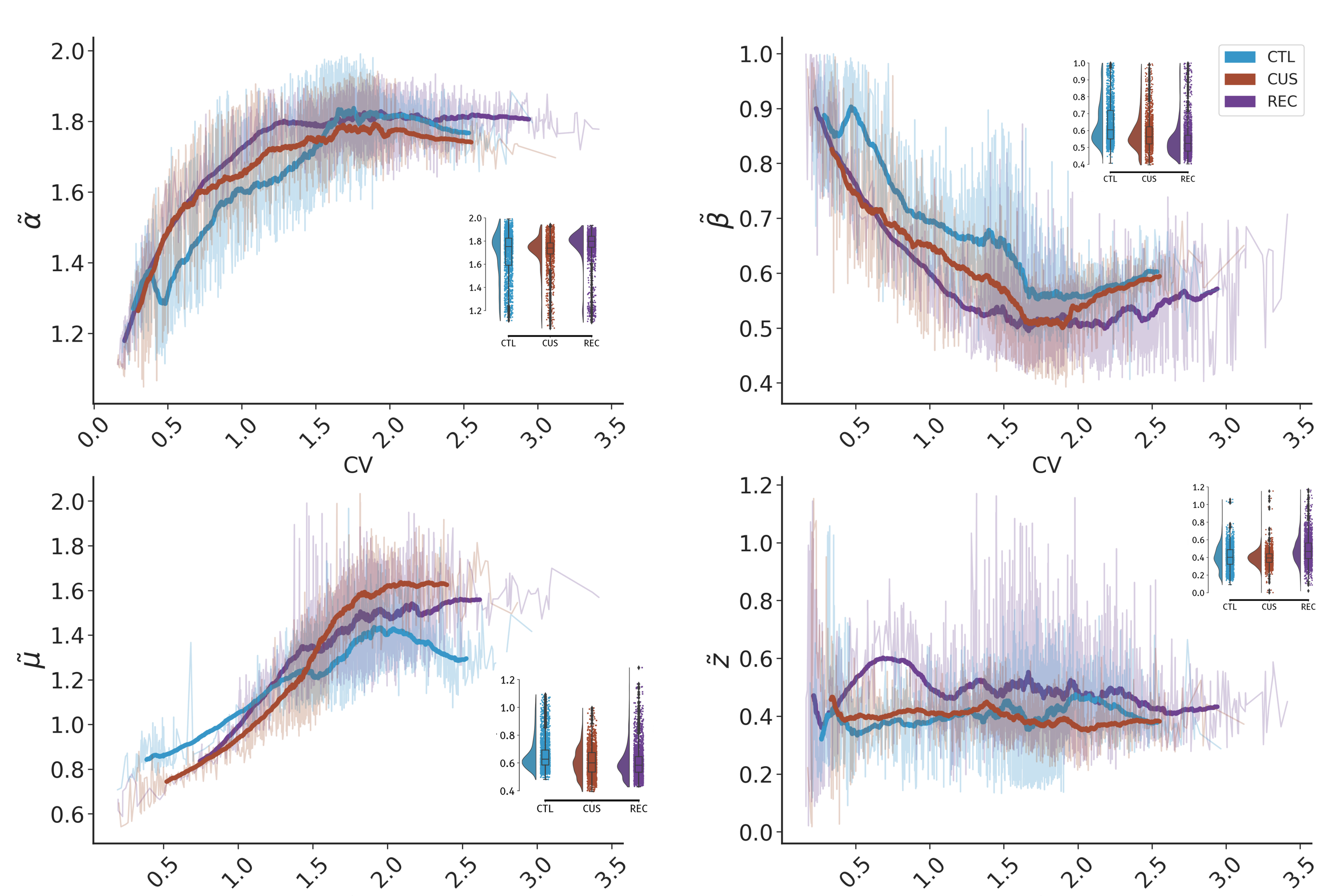
RESULTS

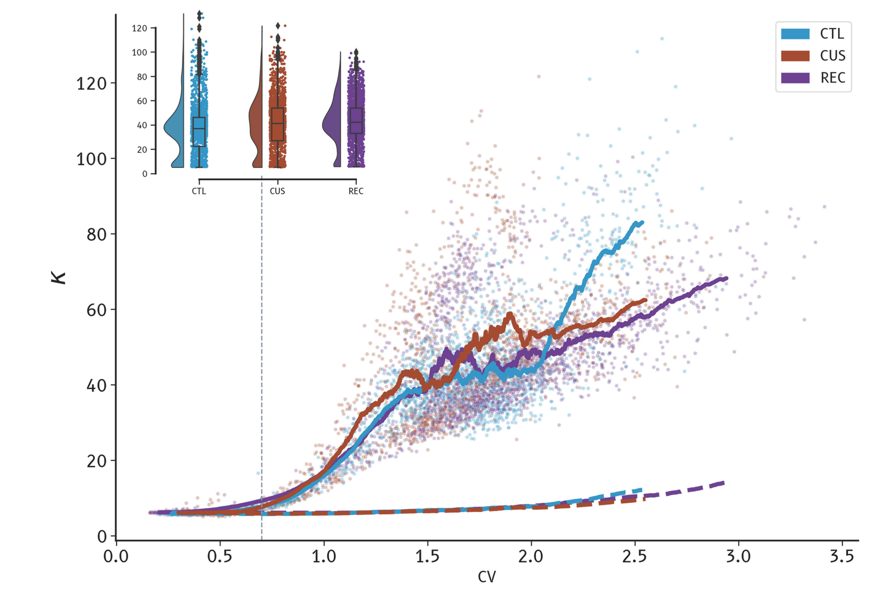
- Exponents from a single animal



- Coefficient of variation (CV) as a proxy for cortical state







CONCLUSIONS

- Around CV = 0.7, the kurtosis for all three groups starts to diverge from that of the surrogates, indicating the presence of scaling.
- Another divergence is observed around CV = 2.0, where the kurtosis of the control group (CTL) increases more rapidly than that of the recovery (REC) and stress (CUS) groups, suggesting that chronic stress impacts cortical function at higher levels of synchronization.
- Despite the variability, it is possible to observe that the mean exponents differ across experimental groups. This differentiation occurs according to the level of synchronization.

ACKNOWLEDGMENTS

- This work has been supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq.

REFERENCES

- R Magalhães, et al., White matter changes in microstructure associated with a maladaptive response to stress in rats. Transl. Psychiatry 7 (2017).
- DM Castro, et al., In and out of criticality? State-dependent scaling in the rat visual cortex. PRX Life 2, 023008 (2024).

edson.vinicius@ufpe.br