A Spike in Entropy Precedes the Mismatch Negativity; Linking Entropy and Prediction Error

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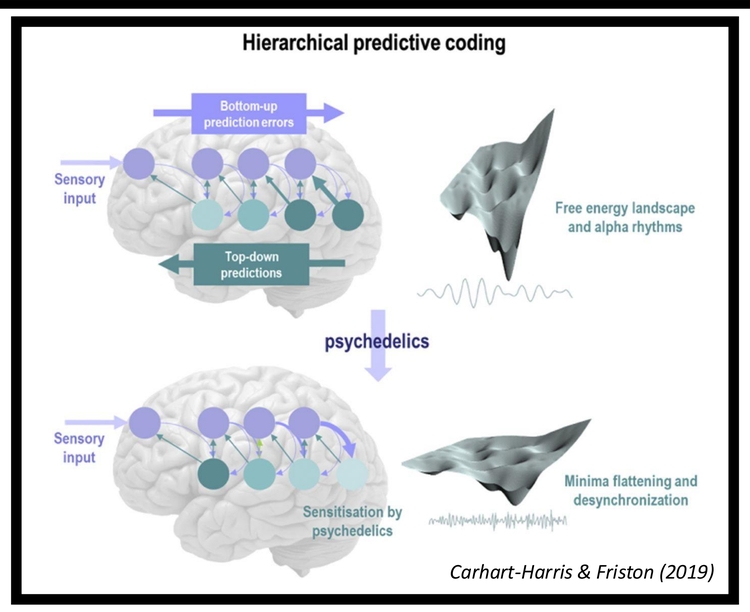
Main Research Question:

Does prediction error in the auditory system have associated changes in entropy?

Introduction



Carhart-Harris & Friston (2019)

Our Interest in Brain Entropy:

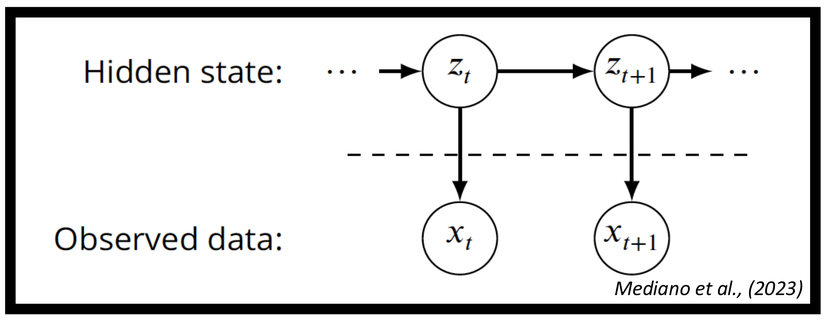
- **Predictive Coding** -> the brain suppresses predicted stimuli
- **REBUS** -> psychedelics relax top-down predictions -> increases diversity of brain states (entropy)
- **Lempel-Ziv Complexity** -> quantifies diversity -> increased on psychedelics
- **We don't know if the increases in entropy are related to prediction error**

Methods

The Novel Measure of Entropy: CSER

- **CSER** -> estimates entropy rate using state space modeling
- Enables entropy measurements on ERP data (like the MMN)

State-Space Process:

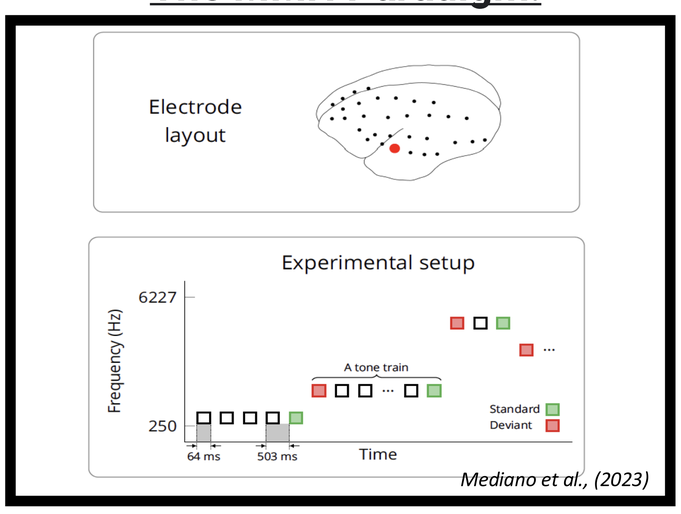


Mediano et al., (2023)

The Measure of Prediction Error: MMN

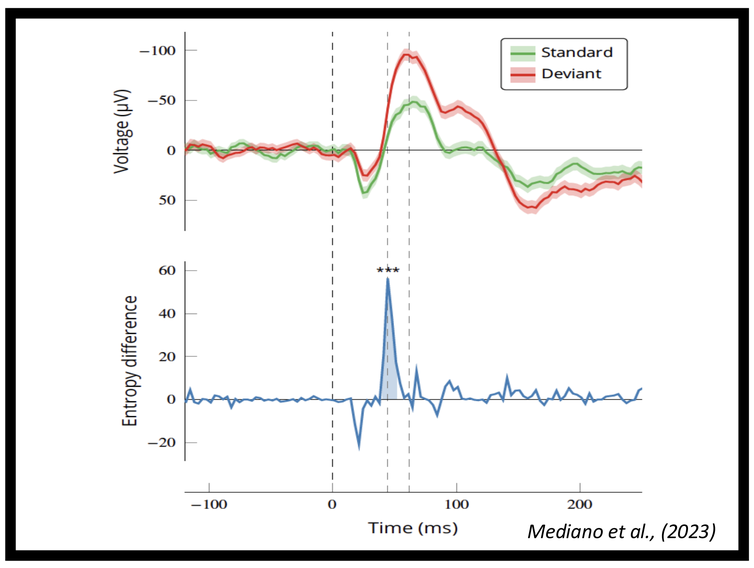
- MMN -> ERP evoked by auditory surprise (thought to represent prediction error)

The MMN Paradigm:



Mediano et al., (2023)

Preliminary Findings with CSER:

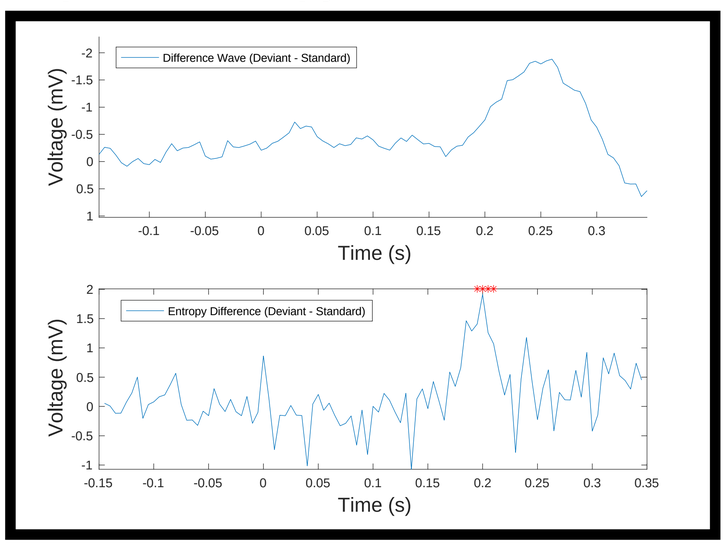


Mediano et al., (2023)

- Entropy spiked with prediction error (ECG of single Macaque monkey)
- **Aim: confirm and explore deeper**

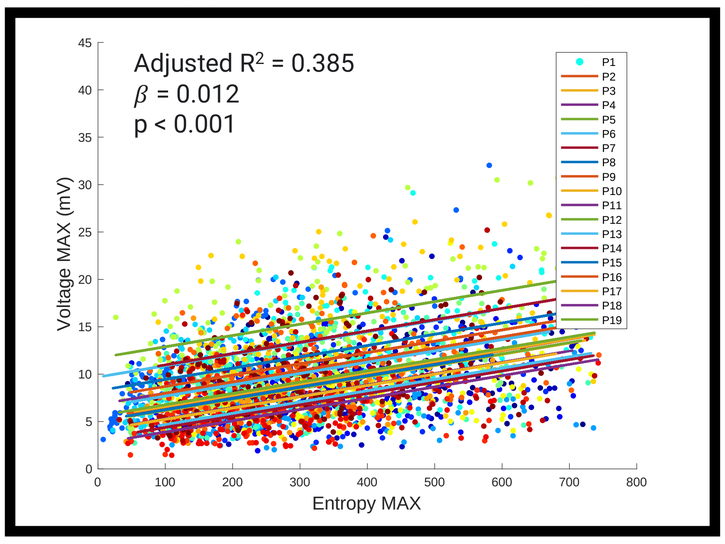
Results

A Spike in Entropy Precedes the MMN:



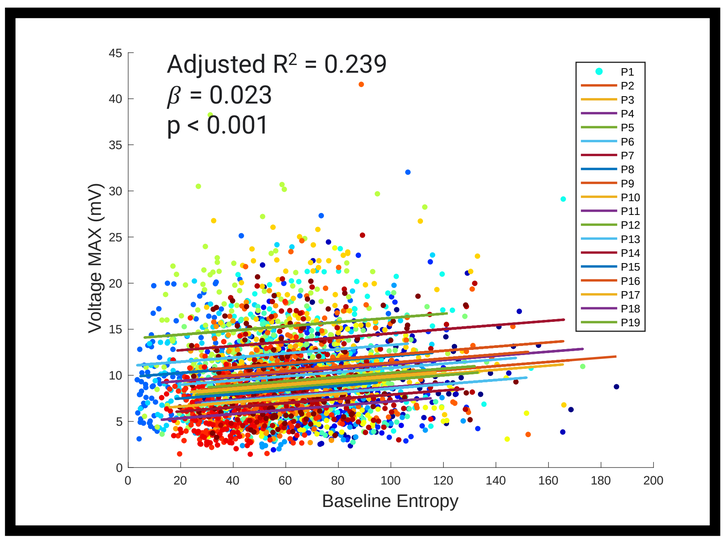
Entropy spiked in deviant trials -> confirms preliminary findings in human EEG data (n = 19)

Max Entropy Predicts MMN Amplitude:



Peak voltage and peak entropy related within deviant trials -> relates entropy to strength of prediction error

Baseline Entropy Predicts MMN Amplitude:



Baseline entropy related to peak entropy -> high prestimulus entropy predisposes subjects to strong prediction error

Conclusions

Main Finding:

- Increases in entropy <-> inability to suppress sensory information -> direct link between prediction error and entropy, supporting REBUS and Entropic Brain Hypothesis

Main Limitation:

- Local sensory modality -> still unclear if global brain entropy <-> failure to suppress information

References

1. Carhart-Harris, R. L., & Friston, K. J. (2019). REBUS and the Anarchic Brain: Toward a Unified Model of the Brain Action of Psychedelics. *Pharmacological Reviews*, *71*(3), 316–344. https://doi.org/10.1124/pr.118.017160
2. Mediano, P. A. M., Rosas, F. E., Luppi, A. I., Noreika, V., Seth, A. K., Carhart-Harris, R. L., Barnett, L., & Bor, D. (2023). *Spectrally and temporally resolved estimation of neural signal diversity* (p. 2023.03.30.534922). bioRxiv. https://doi.org/10.1101/2023.03.30.534922
3. Spriggs, M. (2018). *Electrophysiological Markers of Sensory Plasticity and Connectomics in Ageing and Mild Cognitive Impairment* [Thesis, ResearchSpace@Auckland]. https://researchspace.auckland.ac.nz/handle/2292/47524