Brain chaoticity and avalanche criticality are markers of anesthetic-induced unconsciousness

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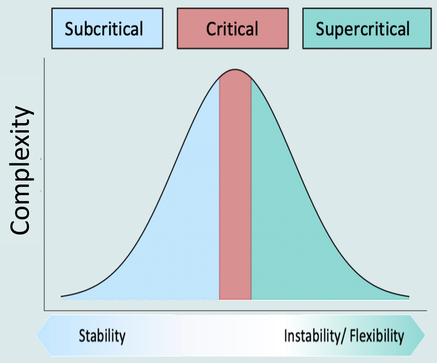
INTRODUCTION

Criticality occurs when a system is poised between two dynamical regimes, such as stability and chaos



Electrophysiological (EEG) dynamics at criticality underpin:

- Healthy brain function [1,2]
- The emergence of consciousness [2]

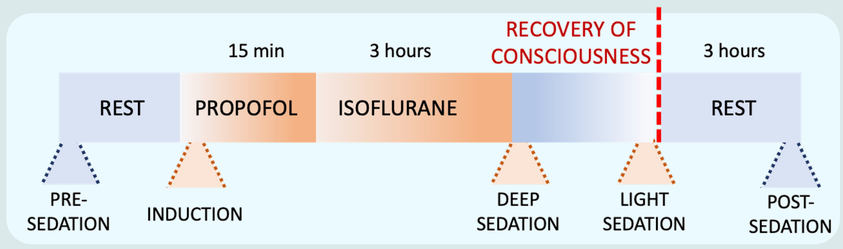
Our aim is to:

Investigate the **effect of anesthesia** on **avalanche criticality** and the **edge of chaos** in **healthy adults**.

METHODS

DATASET A
Healthy adults (n=9)

Data acquisition
- High-density EEG
- 5min recording during 5 states of an anesthetic protocol (see below)



DATASET B[4]
Healthy adults (n=15) undergoing exposure to:
- Propofol (n = 5)
- Xenon (n=5)
- Ketamine (n=5)

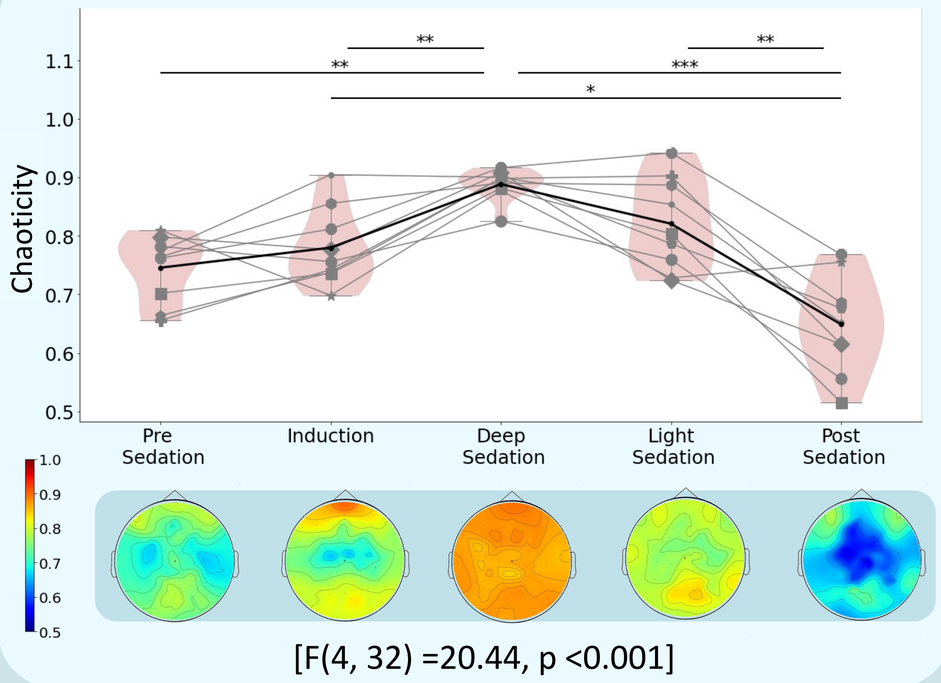
Data acquisition[4]
- 60 channel EEG
- 5min recording before and during drug exposure

Avalanche Criticality
- Avalanche detection using threshold of 2 standard deviations and a bin size of 8 milliseconds
- Deviation from criticality coefficient (ratio of distribution of avalanche size, duration and size/duration)

Edge of chaos
- Peak detection using FOOOF package[3] or lowpass filter ranging between 1 and 20 Hz
- Modified 01-Chaos test[2]

RESULTS

DATASET A



[F(4, 32) =20.44, p <0.001]

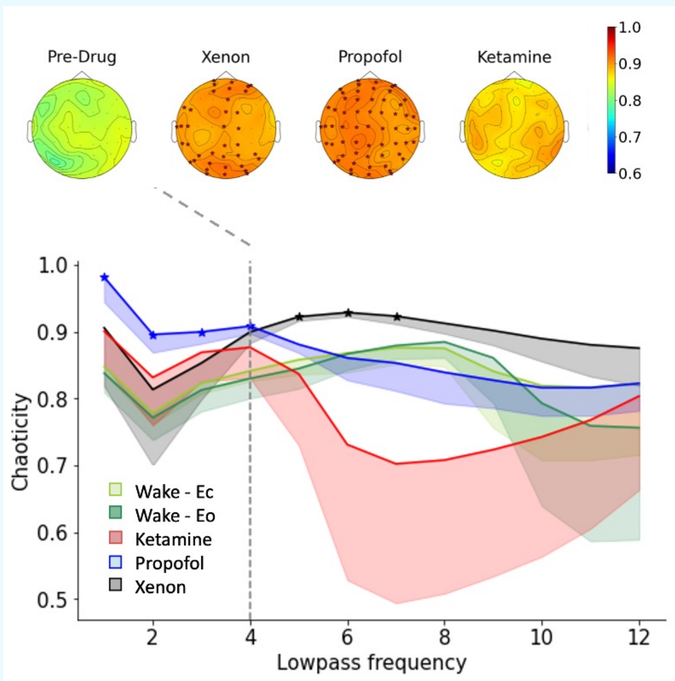
1 Increased brain chaoticity during anesthetic-induced unconsciousness

Stronger chaoticity during anesthetic-induced unconsciousness, using isoflurane ($p < 0.01$), propofol ($p < 0.05$), and xenon ($p < 0.05$)

Chaoticity did not increase during exposure to Ketamine

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

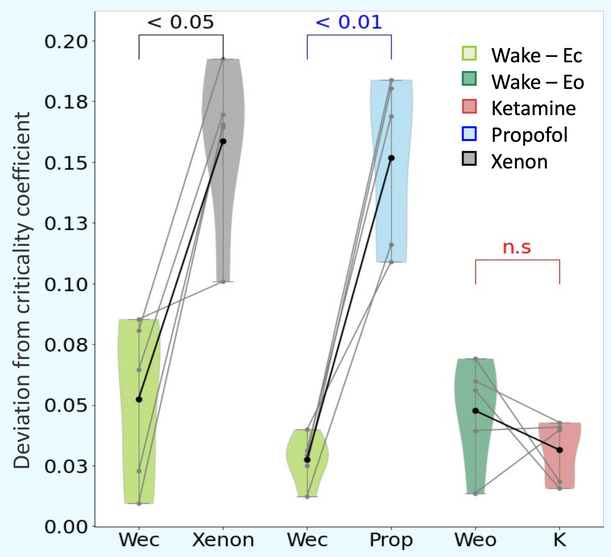
DATASET B



2 Propofol and xenon, but not ketamine, induce a shift away from avalanche criticality

Only propofol ($P < 0.01$) and xenon ($P < 0.05$) resulted in a larger deviation from the criticality coefficient

Ketamine did not significantly alter DCC with respect to wakefulness



CONCLUSION

Our results:

1) Support the theory that **consciousness requires the brain to be poised near criticality.**

2) Suggest that **different types of criticality** – namely the edge of chaos and avalanche criticality - can be used as a **marker of anesthetic-induced loss of consciousness**.

[1] J. O'Byrne and K. Jerbi, "How critical is brain criticality?," Trends Neurosci., Sep. 2022.
[2] D. Toker et al., "Consciousness is supported by near-critical slow cortical electrodynamics," Proc. Natl. Acad. Sci., vol. 119, no. 7, Feb. 2022.
[3] T. Donoghue et al., "Parameterizing neural power spectra into periodic and aperiodic components," Nat. Neurosci., vol. 23, no. 12, pp. 1655–1665, Dec. 2020.
[4] Sarasso, S. *et al.* (2015) 'Consciousness and Complexity during Unresponsiveness Induced by Propofol, Xenon, and Ketamine', *Current Biology*, 25(23)