

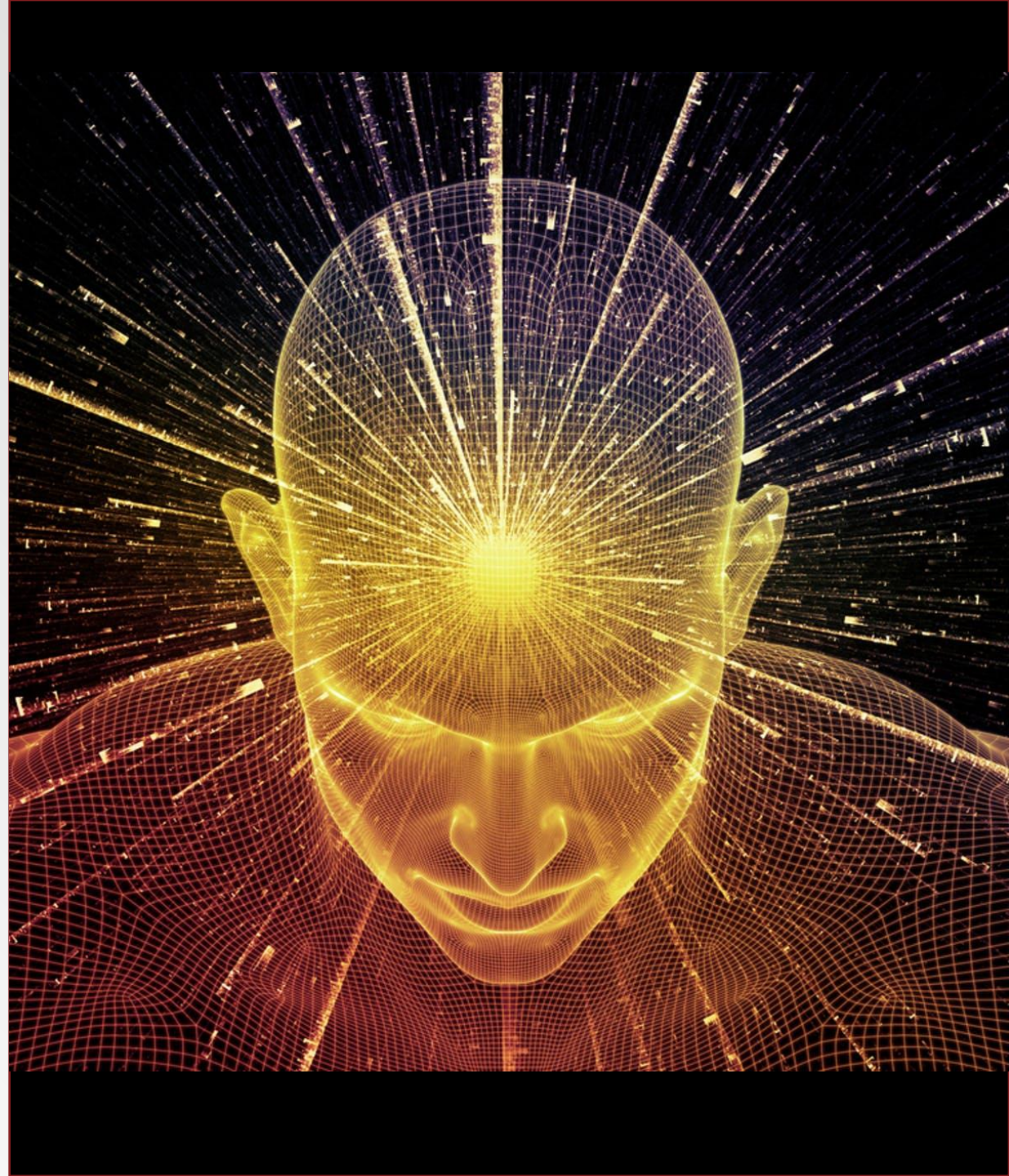
Introduction to the Neuroscience of Consciousness

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CANADA RESEARCH CHAIR IN CONSCIOUSNESS AND
PERSONHOOD TECHNOLOGIES

MCGILL UNIVERSITY

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Overview

1. History of consciousness
2. Nomenclature of consciousness
3. Strategy of consciousness science
4. Example 1: Anesthesia
5. Example 2: Disorders of consciousness

History of Consciousness Science

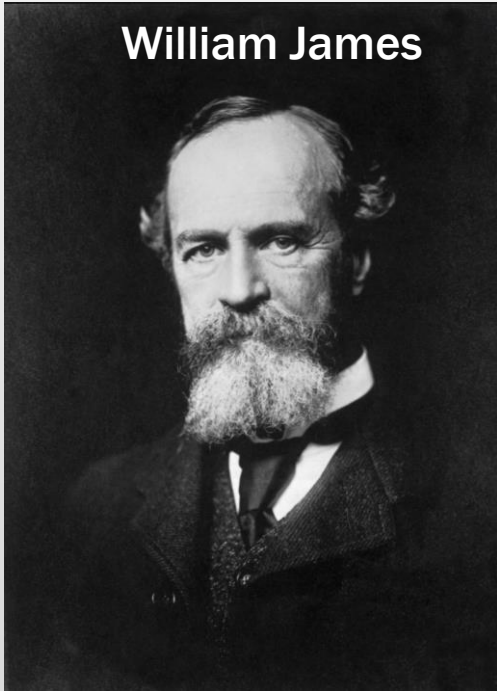
1892

Early 1900s

Early 1990s

Mid 1990s

William James



- Behaviorism
- Psychoanalysis

Bernard Barrs
- Global workspace theory

**First conference on
consciousness in Tucson**

Francis Crick and Christophe Koch, 1990

“It is remarkable that most of the work in both
cognitive science and the neurosciences makes
no reference to consciousness (or “awareness”).”

Gerald Edelman and Giulio Tononi

Sir Roger Penrose

Journals:

- **Journal of Consciousness
Studies**
- **Journal of Consciousness
and Cognition**

Nomenclature of consciousness

What is it like to be a bat? Nagel, T. Philos Rev, 1974: 83: 435-50.

“There is something it is like to be that organism”



What disappears when we fall into a dreamless sleep and what returns the next morning when we wake up.

‘What abandons us every night when we fall into a dreamless sleep’

Tononi, Biol Bull 2008: 215:216-242

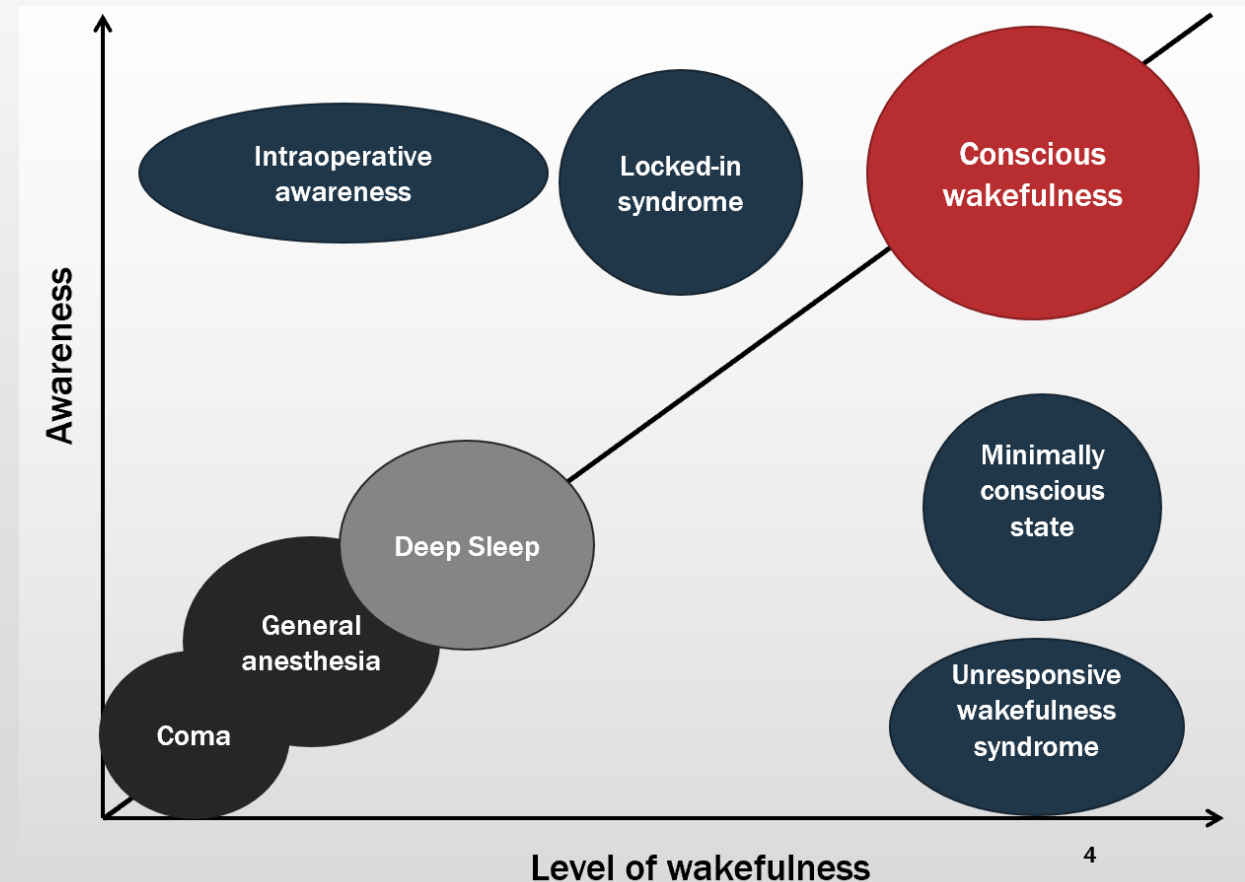
Nomenclature of consciousness

- Easy vs. hard problem of consciousness

- David Chalmers, philosopher of mind

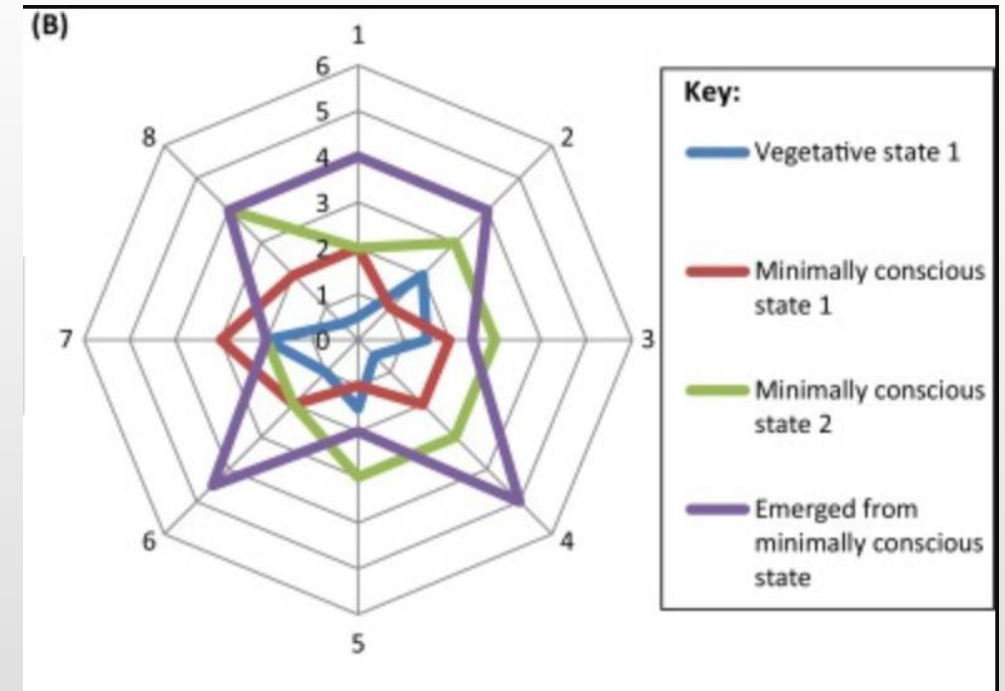
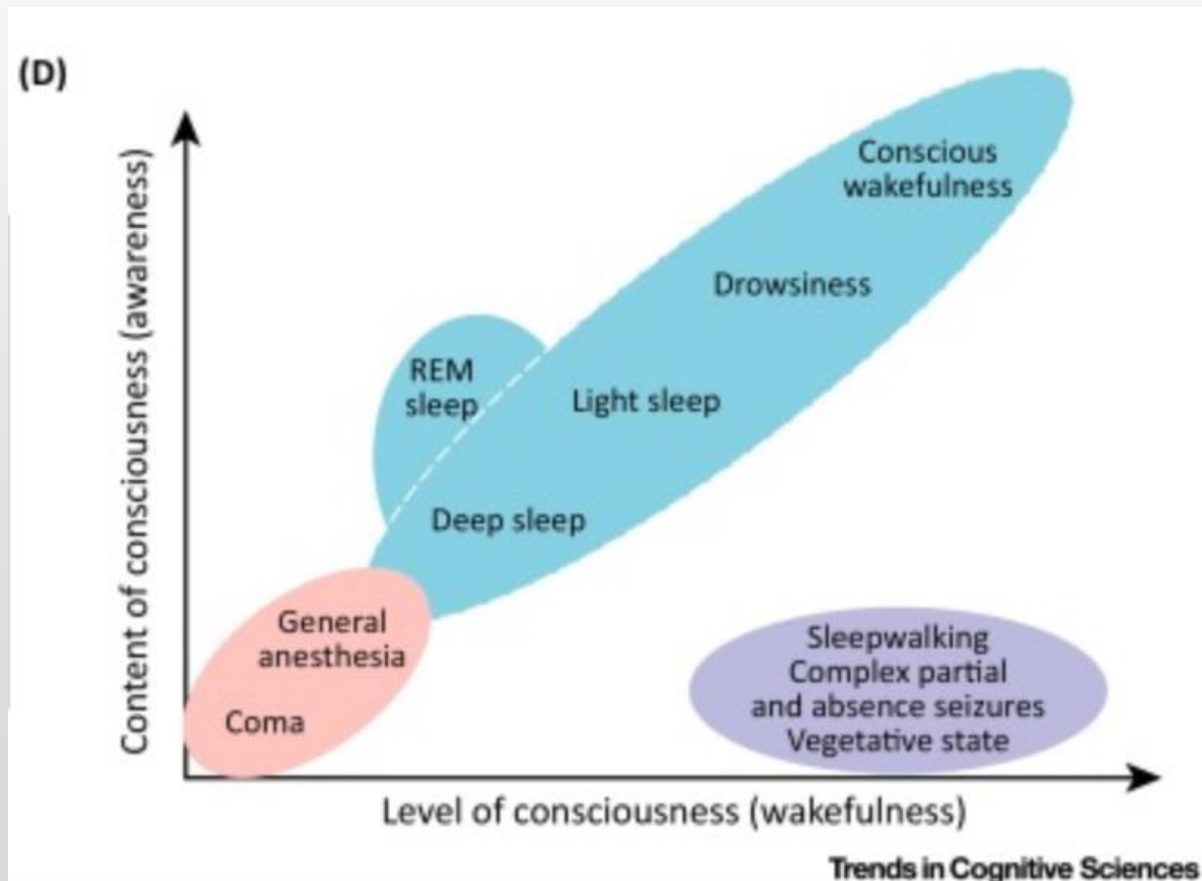


- Awake vs. aware



Nomenclature of consciousness

- Level vs. content of consciousness



Bayne, T., Hohwy, J., & Owen, A. M. (2016). Are There Levels of Consciousness? *Trends in Cognitive Sciences*, 20(6), 405–413.

<https://doi.org/10.1016/j.tics.2016.03.009>

Strategies of consciousness science

“The main strategy within consciousness science lies in connecting objective (third-person) data about the brain and behavior, with subjective (first-person) data about the properties of conscious experience (including whether they are present at all). Within this broad multidisciplinary scope there is an increasing focus on the brain as the primary biological substrate for awareness.”

Editorial from the inaugural issue of the “Neuroscience of Consciousness”

Anil Seth, Biyu J. He, Jakob Hohwy

Strategies of consciousness science

Interactions between conscious
and unconscious processes

Selfhood, embodiment,
interoceptive awareness

Intention, volition, agency and
awareness of others

Individual differences
in consciousness

Metacognition and higher-
order consciousness

Altered states of
consciousness: sleep,
dreaming, anesthesia

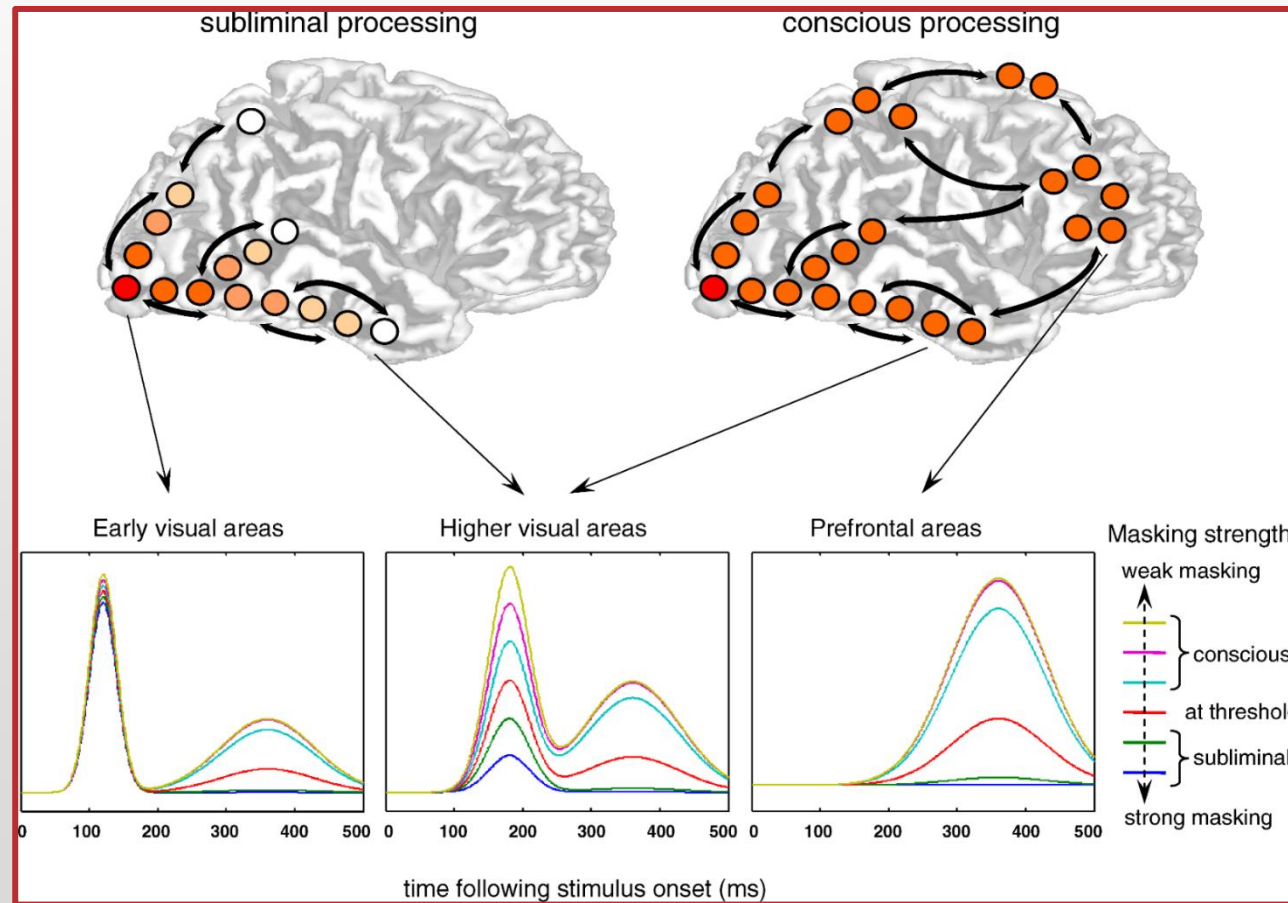
Emotional awareness

Disorders of
consciousness

Consciousness in infants
and non-human animals

Strategies of consciousness science

Manipulating the contents of consciousness



Strategies of consciousness science

Manipulating the levels of consciousness

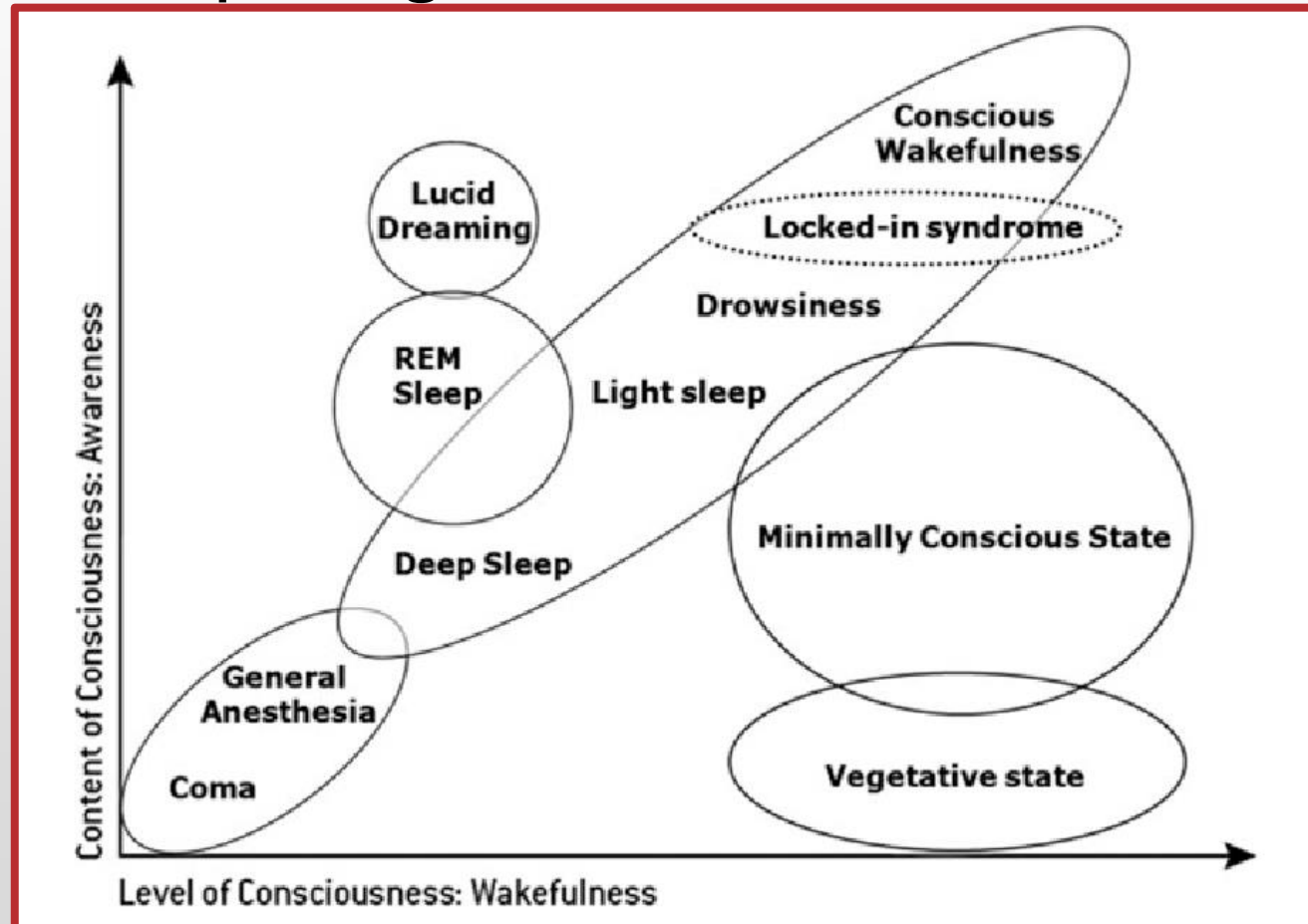
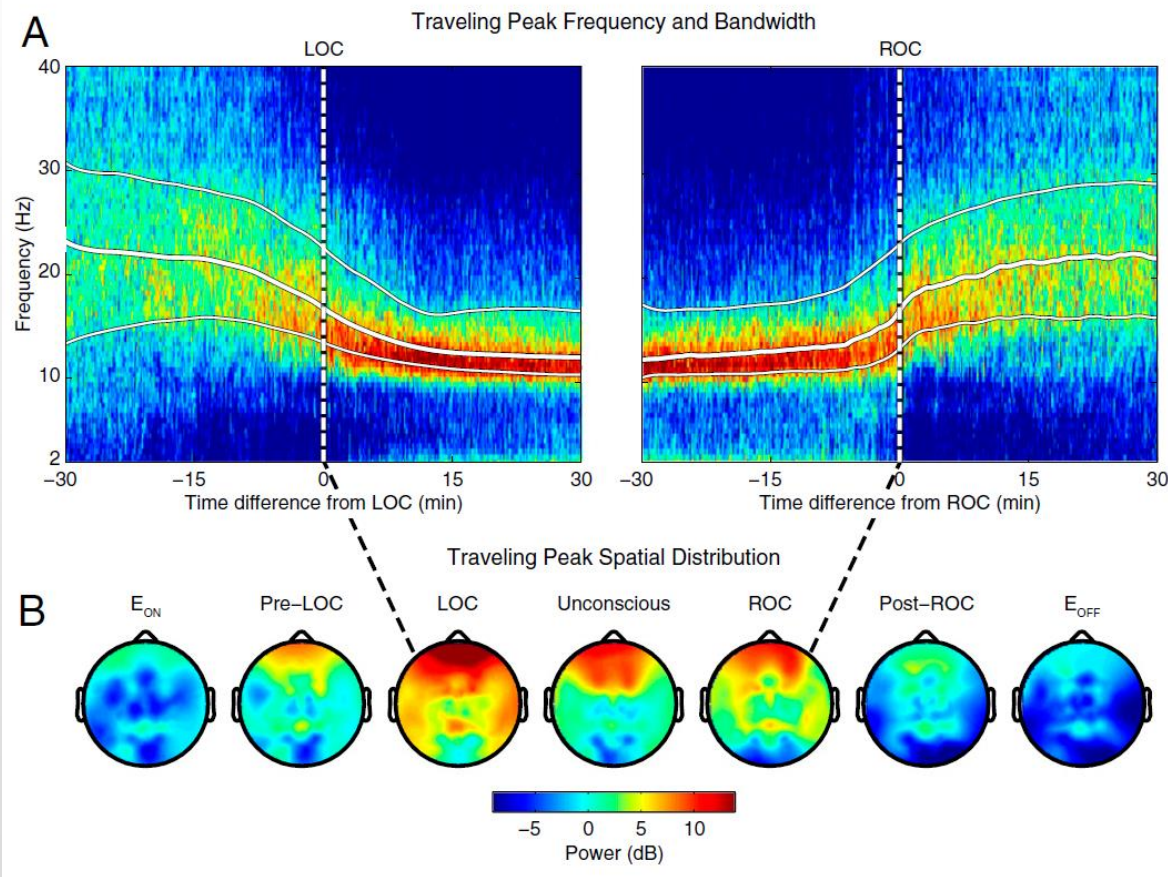
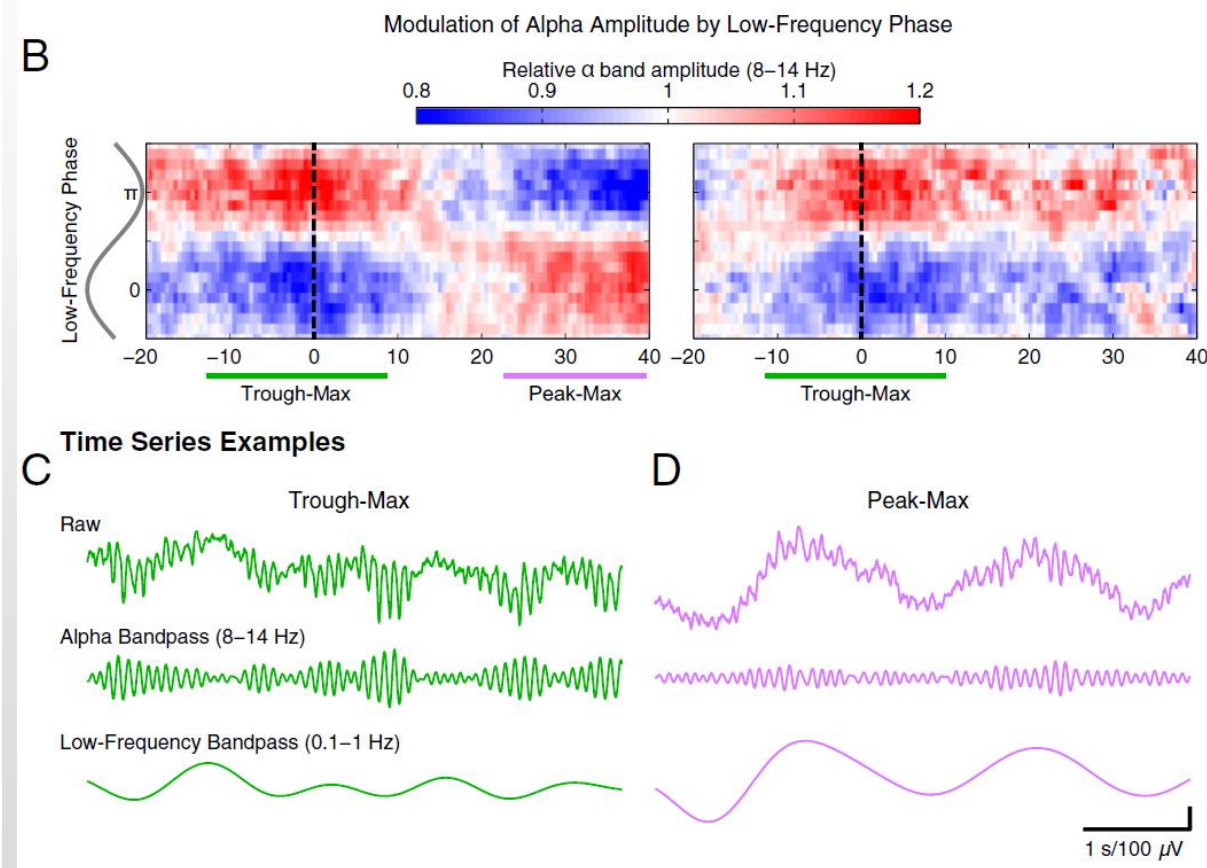


Figure from: Gosseries et al. (2011) Disorders of consciousness: Coma, Vegetative and Minimally Conscious State.

Insights from anesthetic-induced unconsciousness

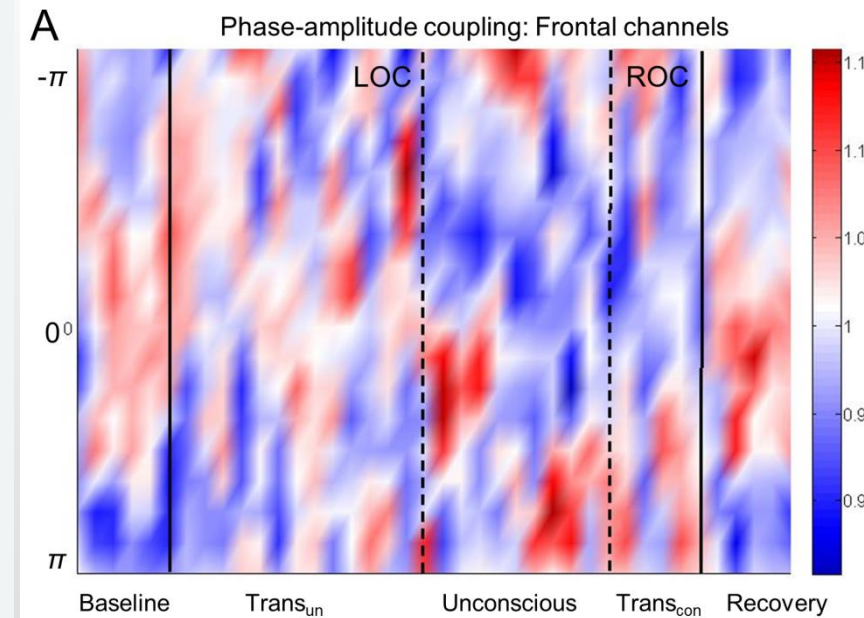
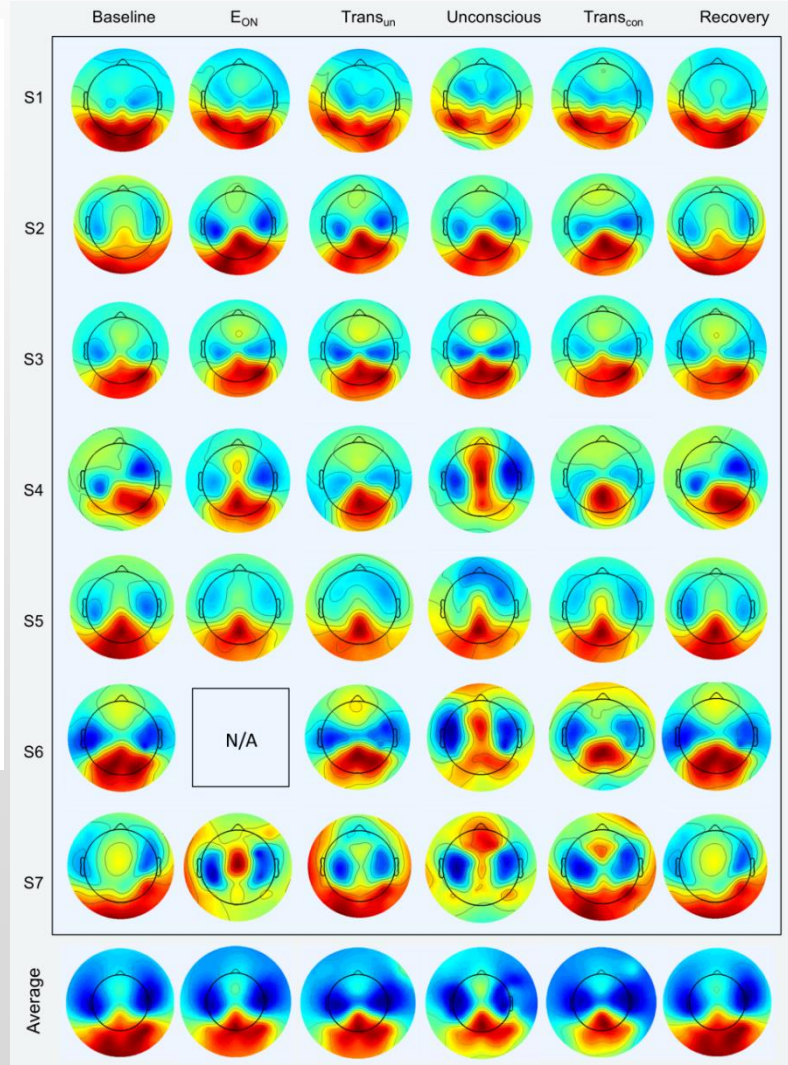
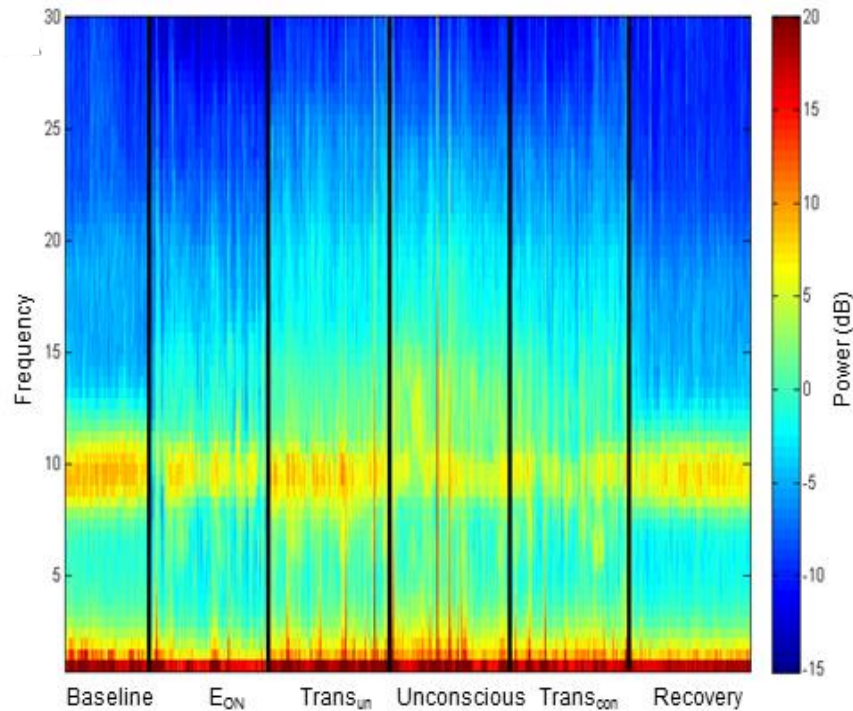


- Travelling peak
- Anteriorization of alpha



- Trough-max vs. peak-max coupling

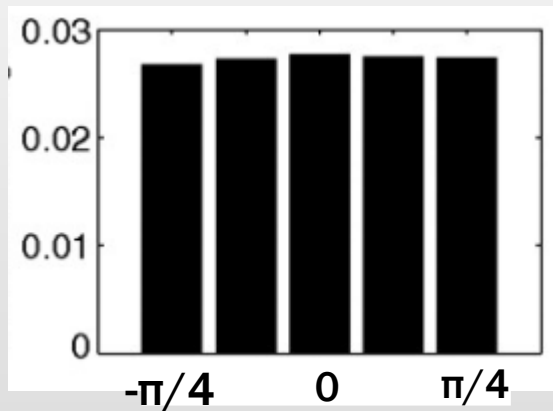
EEG correlates of sevoflurane-induced unconsciousness



EEG Functional Connectivity

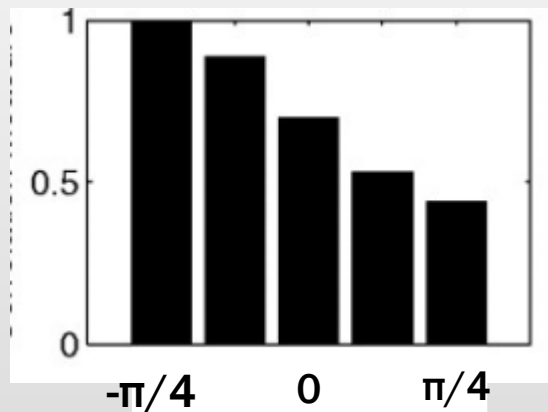
Phase lag index

No phase coupling



Phase difference

Phase coupling



Phase difference

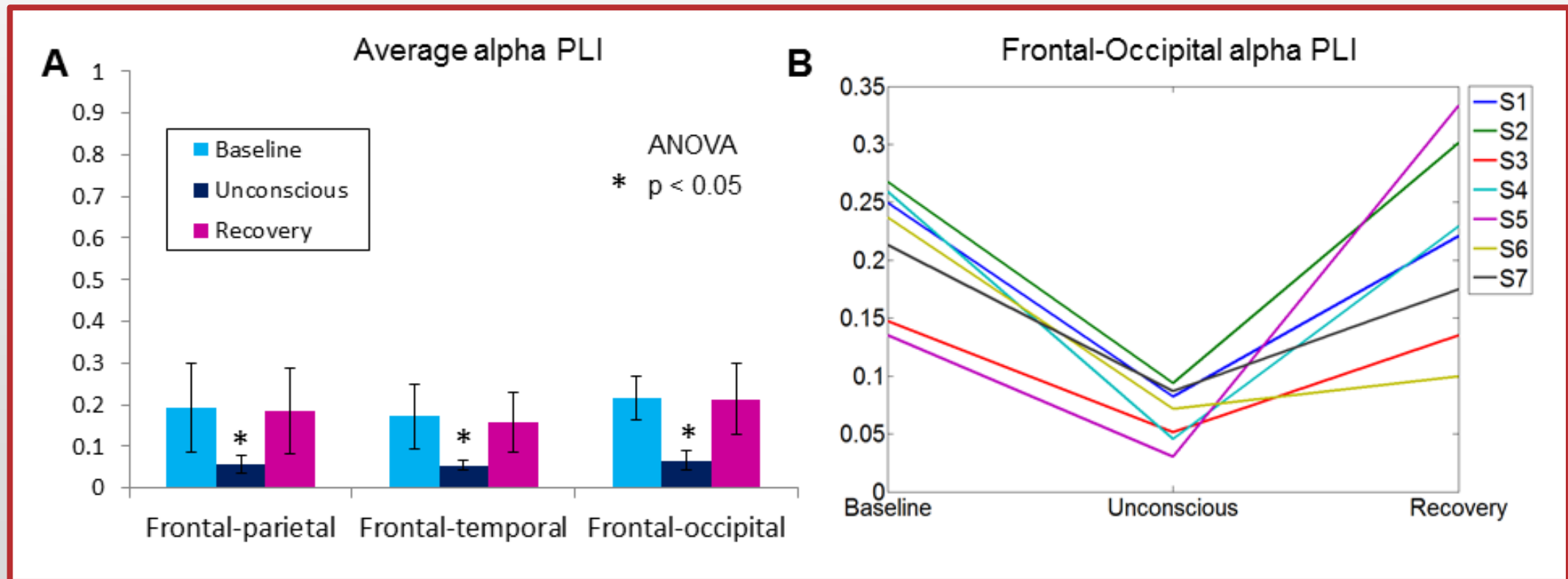
- Asymmetry implies presence of consistent, nonzero phase difference
- If common source, phase difference centers around 0 mod π

$$PLI = |\langle \text{sign}[\Delta\phi(t_k)] \rangle|$$

- $0 \leq PLI \leq 1$
- 0 = coupling; 1 = perfect phase locking
- Test significance with surrogate data

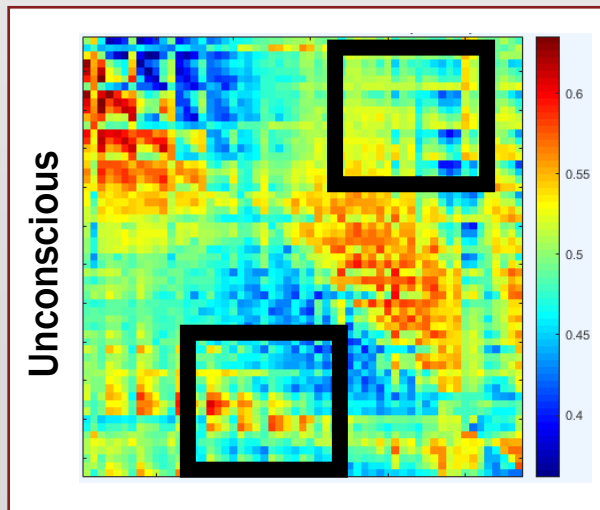
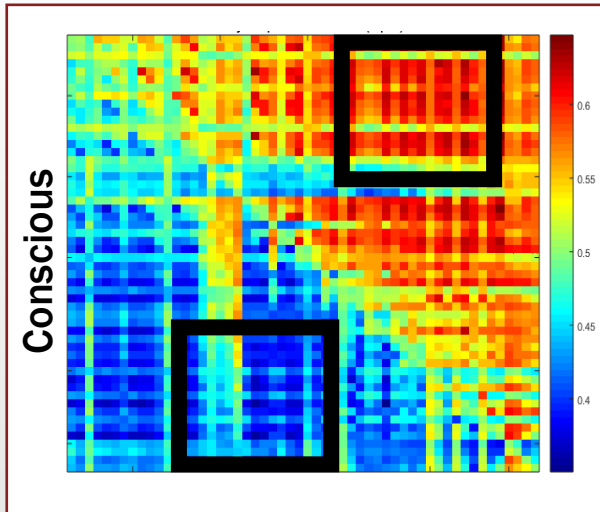
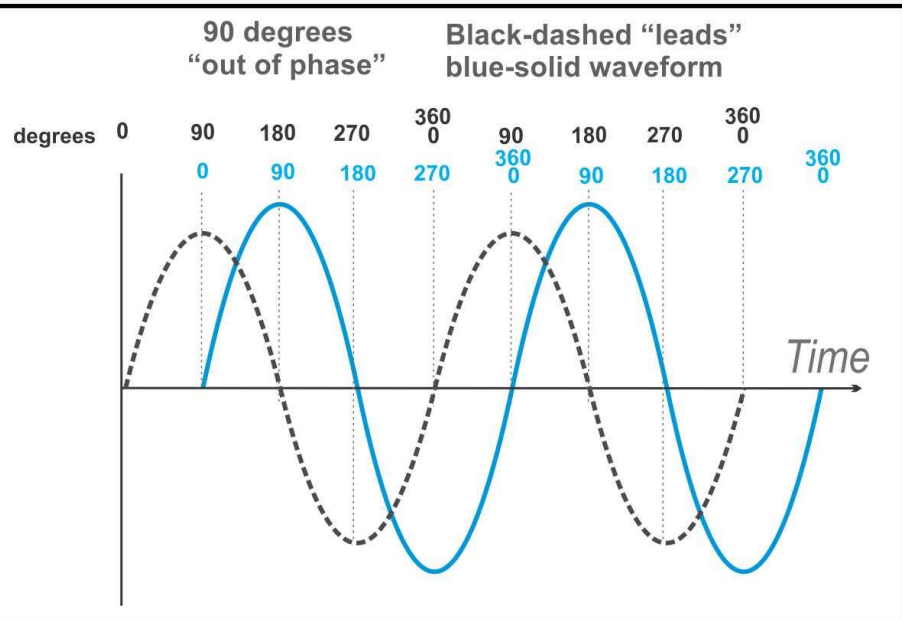
Insights from anesthetic-induced unconsciousness

- Anesthetic: Sevoflurane
- Data: n = 7 healthy volunteers, 64-channel EEG
- Functional connectivity metric: phase lag index (PLI)

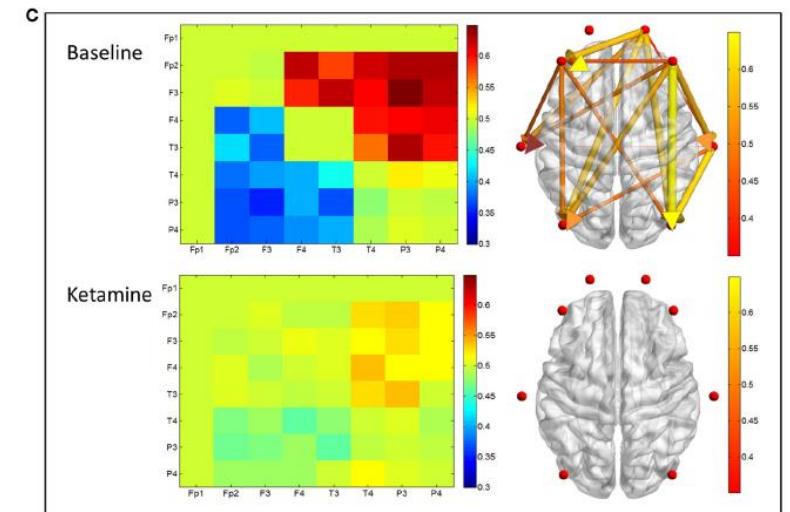


Insights from anesthetic-induced unconsciousness

Directed Functional Connectivity



Directed phase lag index (dPLI)

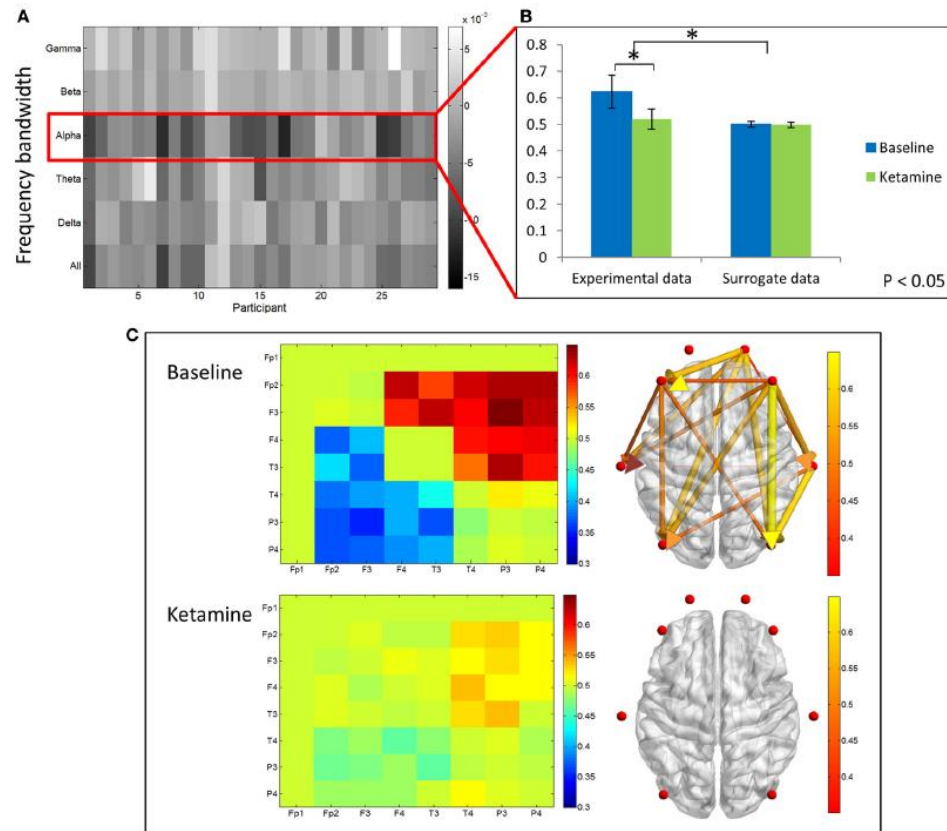


Blain-Moraes et al. Frontiers in Systems Neuroscience, 2014, 8:114.

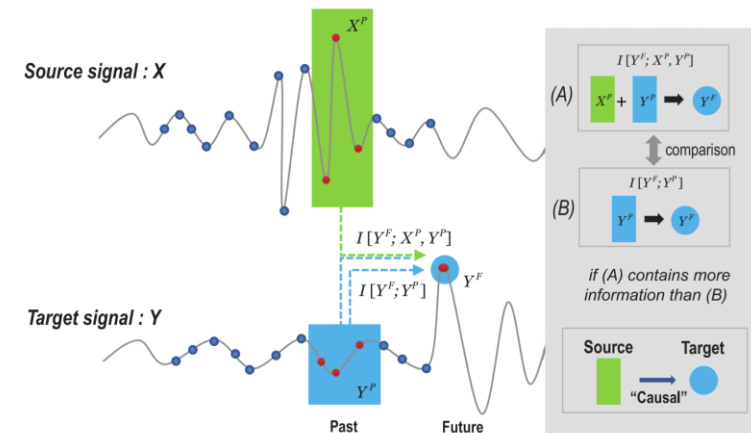
Insights from anesthetic-induced unconsciousness

- Frontoparietal feedback-dominant connectivity neutralizes during unconsciousness

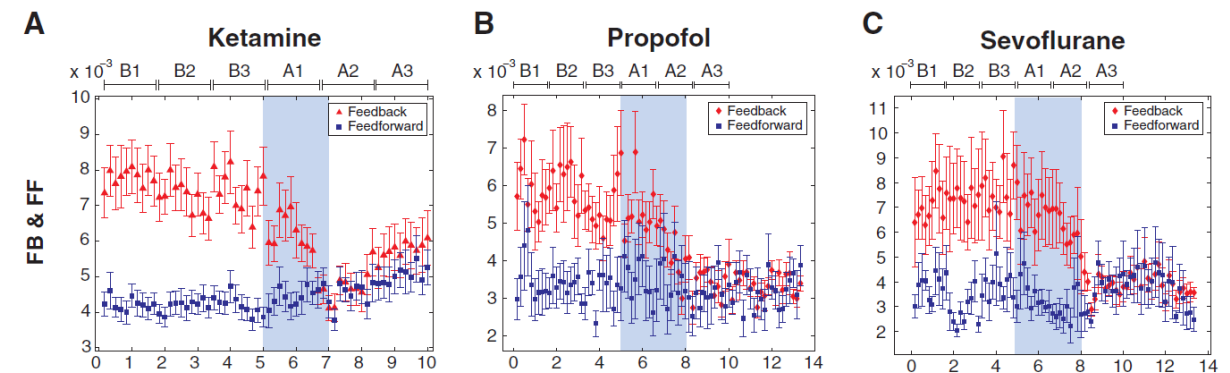
Directed Functional Connectivity (dPLI)



Blain-Moraes et al. Frontiers in Systems Neuroscience, 2014, 8:114.

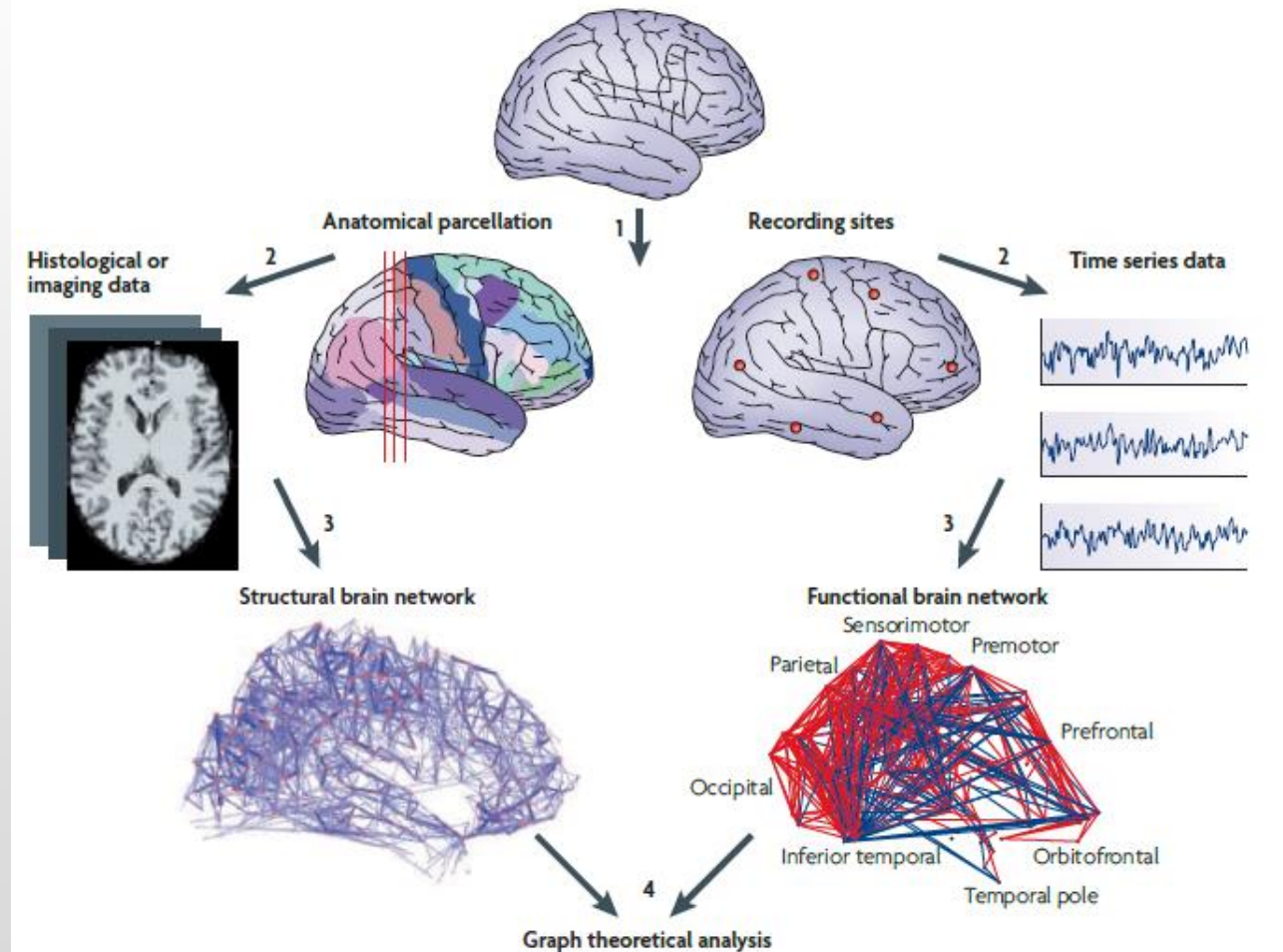
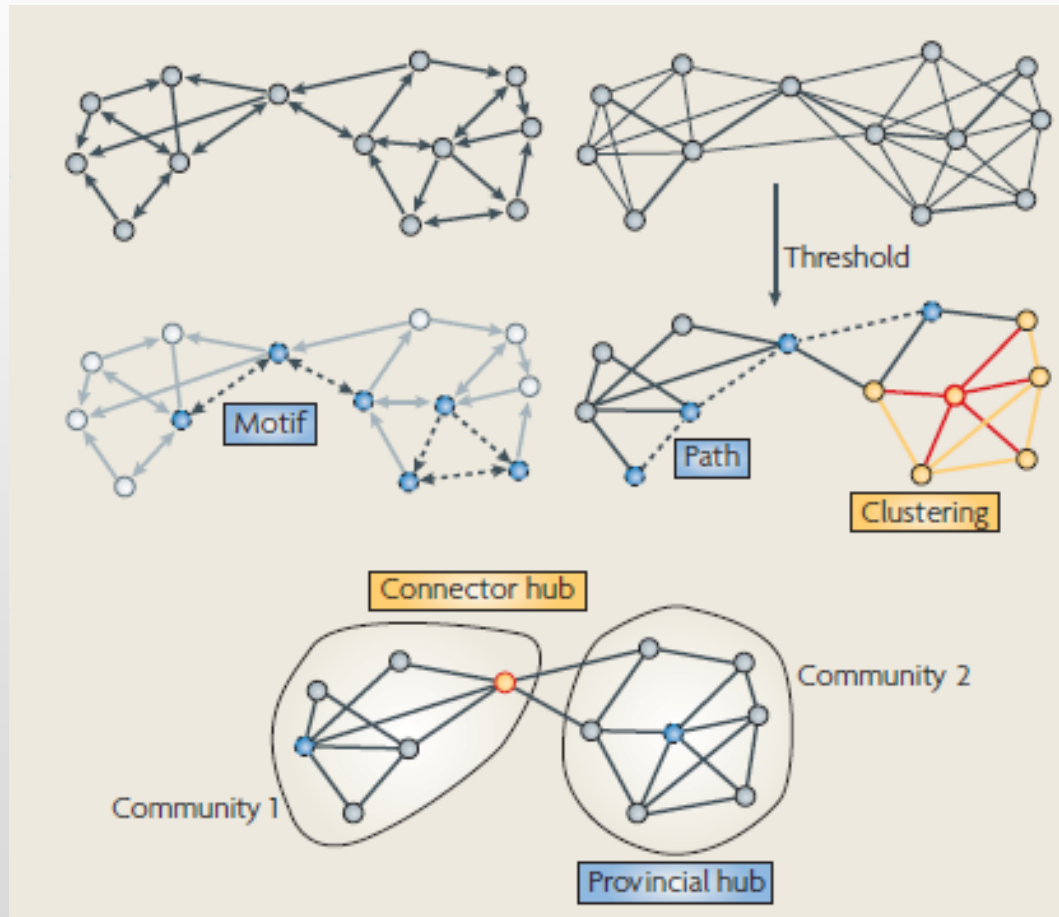


Symbolic Transfer Entropy (STE)



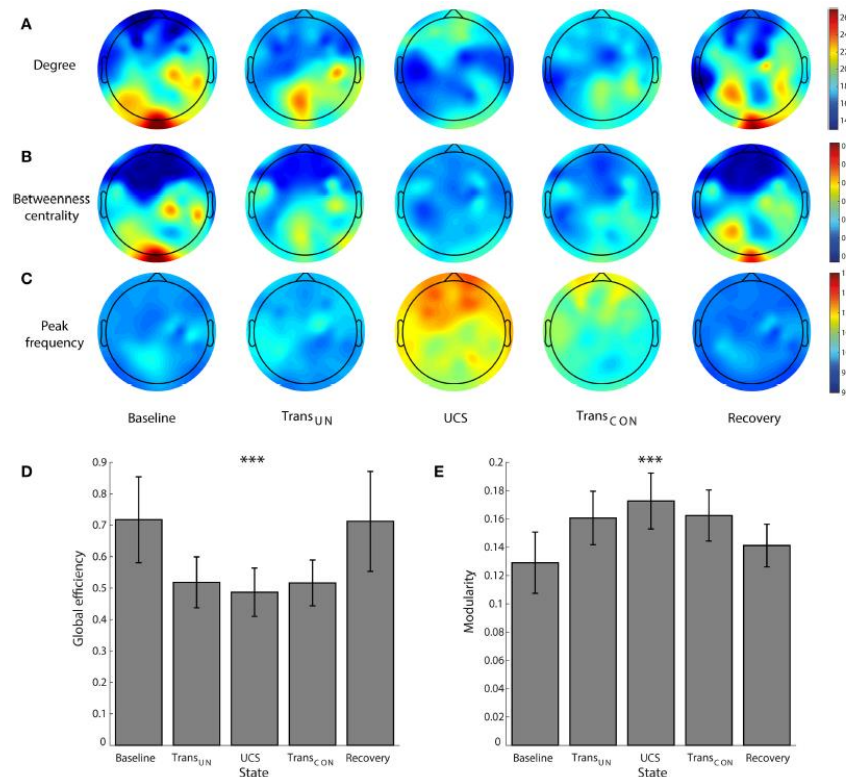
Lee et al. Anesthesiology, 2013, 118:1264-75.

Graph theoretical analysis of brain networks



Insights from anesthetic-induced unconsciousness

▪ Network hubs undergo anteriorization during unconsciousness



- Anesthetic: Sevoflurane
- Data: n = 7 healthy volunteers, 64-channel EEG
- Functional connectivity metric: weighted phase lag index (wPLI)
- Network construction: top 30% of wPLI
 - Degree
 - Betweenness centrality
 - Peak frequency

Kim et al. Front. Comput. Neurosci. (2016) 10:1.

Insights from disorders of consciousness

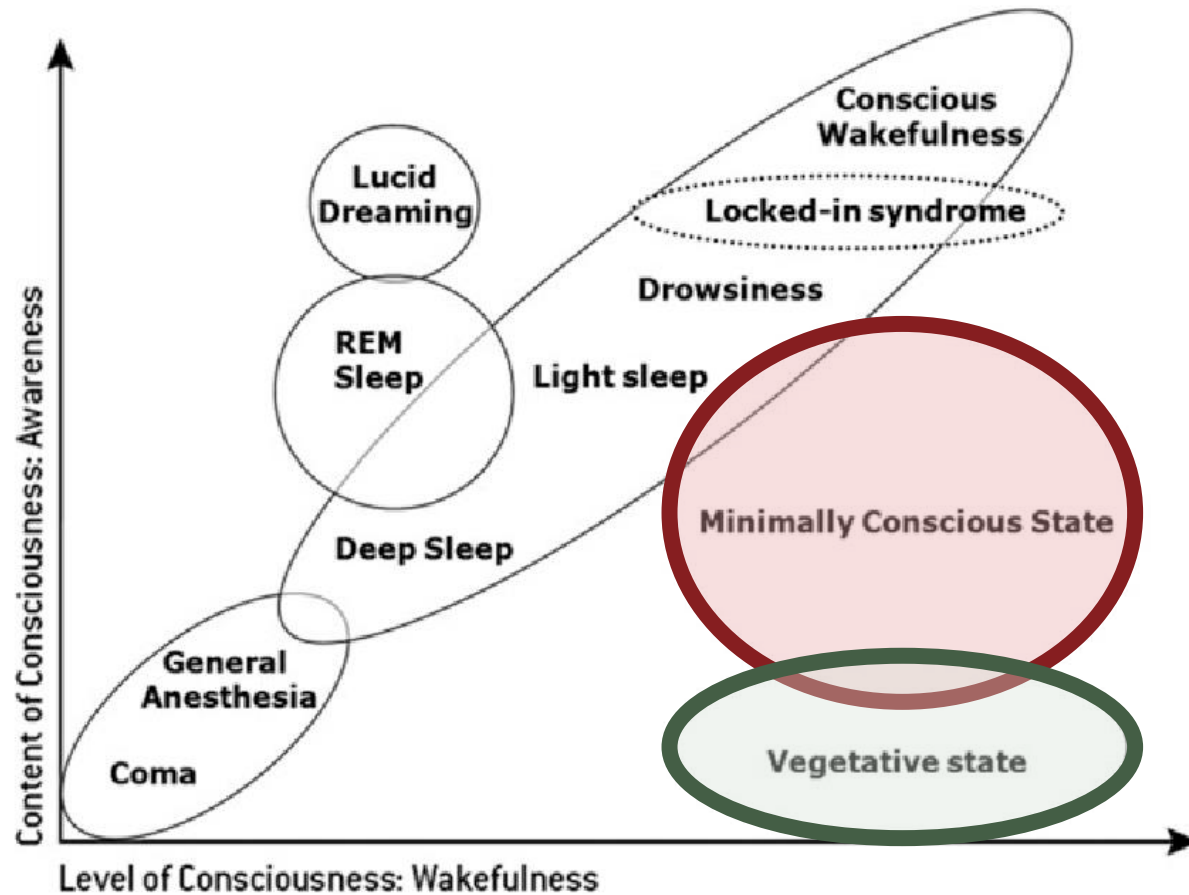


Figure from: Gosseries et al. (2011) Disorders of consciousness: Coma, Vegetative and Minimally Conscious State.

- Clinically assessed behaviourally
 - Coma Recovery Scale – Revised (CRS-R)
- Misdiagnosis rate of over 40% ¹
- Detecting consciousness in the fMRI ²
- Detecting consciousness with EEG ³

¹ Schnakers (2009) BMC Neurology. 9(1):35.

² Owen et al. (2006) Science 313(5792):1402.

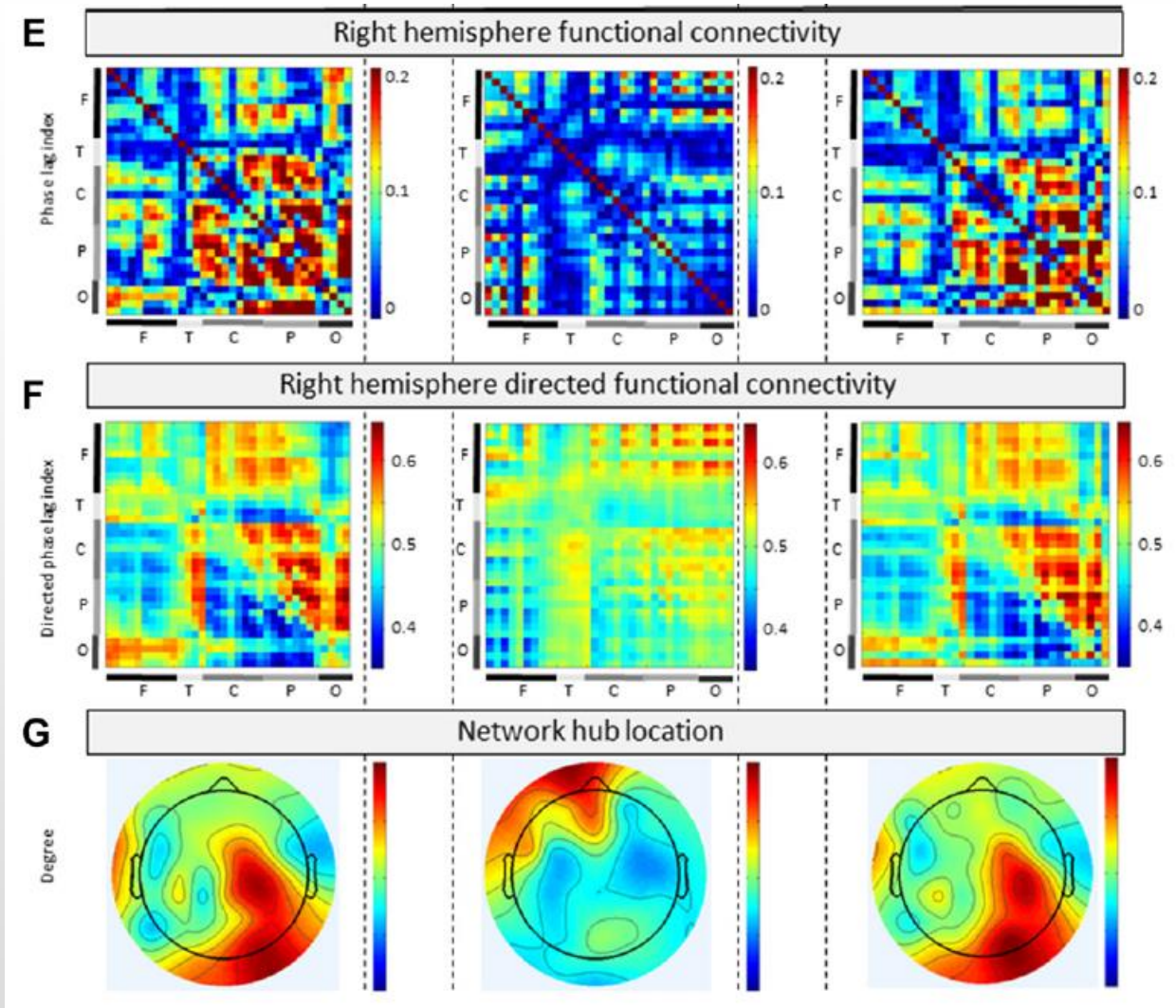
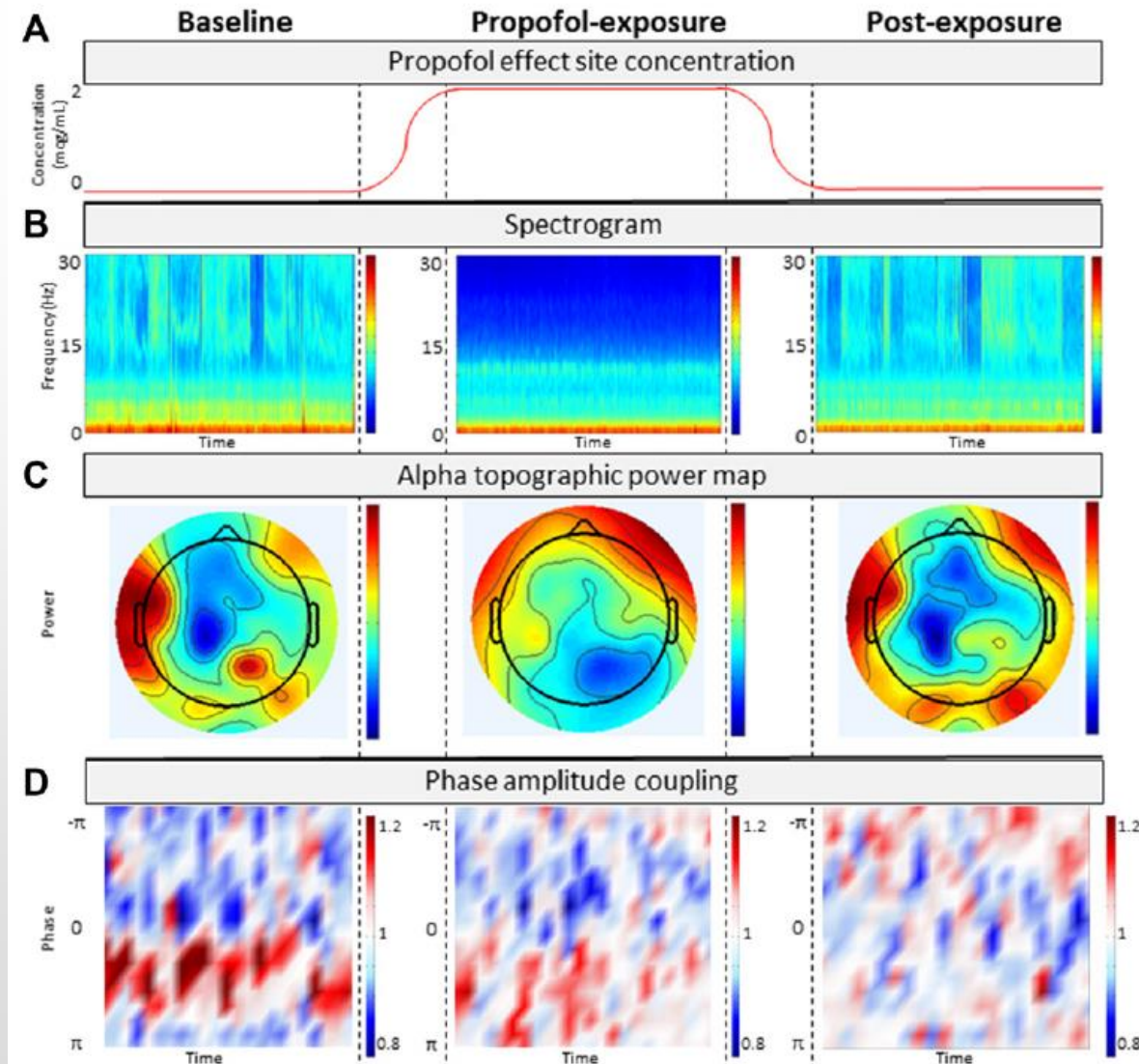
³ Cruse et al. (2012) The Lancet. 378(9809):2088-2094.

Case study

- 29-year old male involved in motor vehicle collision
- Admitted to ICU, intubated and mechanically ventilated
- EEG report (day 21): “... *this is an abnormal EEG due to the presence of generalized slowing... frontally dominant alpha-like activity may suggest alpha coma... poor prognostic features include paucity of waveforms as well as lack of response to multiple afferent stimuli*”
- CT scan (day 43) post-trauma: right parietal subdural hematoma, acute traumatic subarachnoid hemorrhage, diffuse axonal injury
- Consciousness assessed with behavioural tests (day 56)
 - Glasgow Coma Scale = 4
 - Coma Recovery Scale-Revised = 4



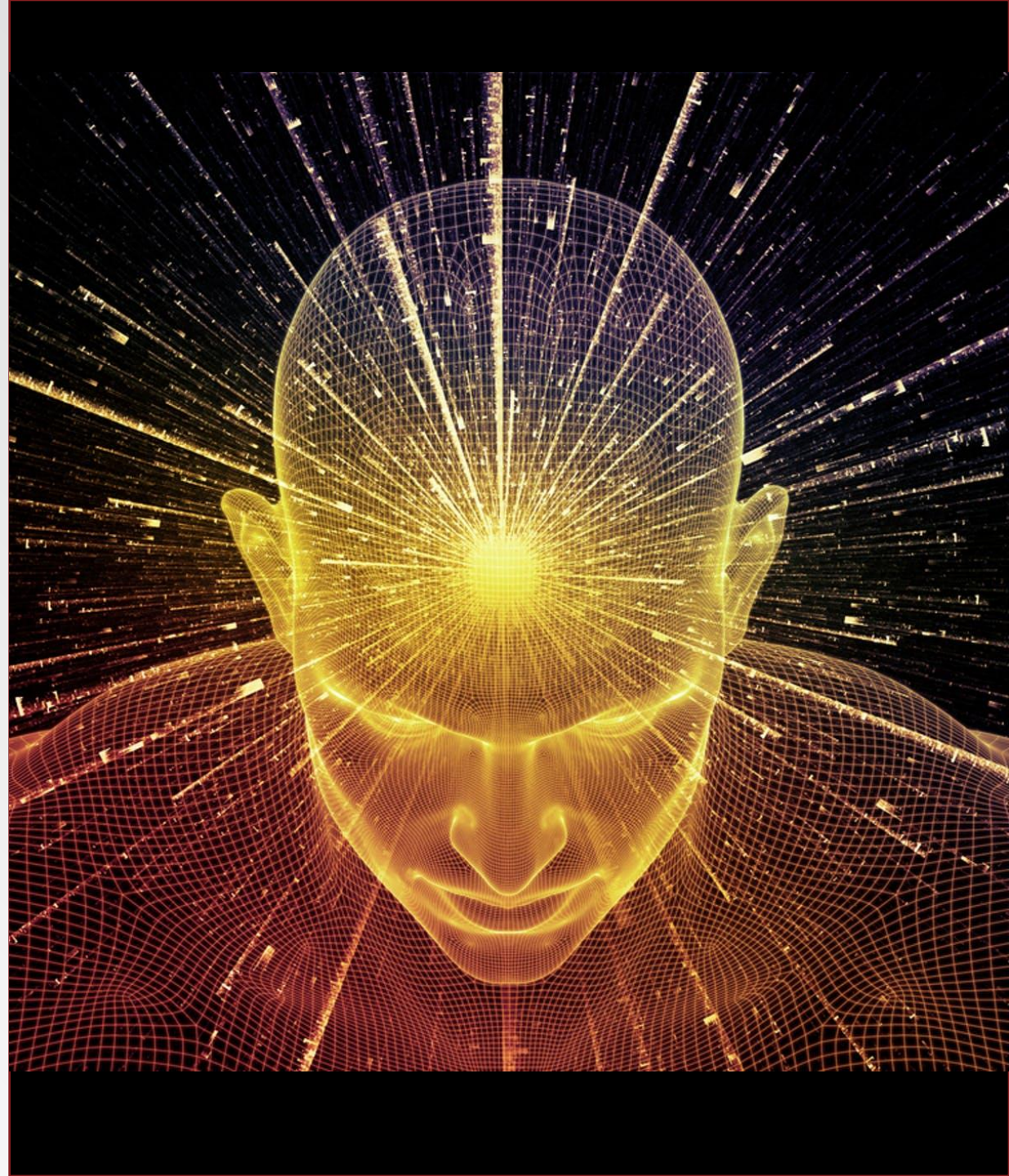
Is this patient conscious?



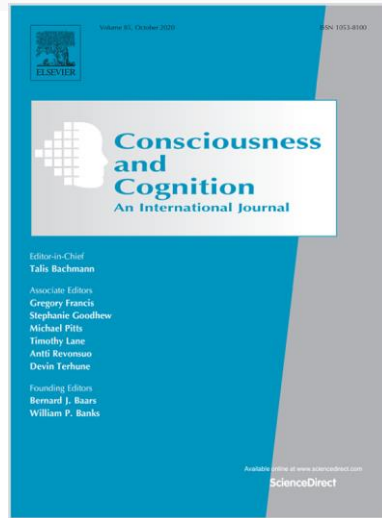
Upon 1-month follow up, patient had recovered consciousness clinically
(Glasgow Coma Scale = 14; Coma Recovery Scale-Revised = 23)

Questions

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Neuroscience of Consciousness



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Study of Consciousness**

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**Center for
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CENTER FOR CONSCIOUSNESS SCIENCE
UNIVERSITY OF MICHIGAN MEDICAL SCHOOL

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