How to avoid **trouble** when talking about consciousness

Conscious access / conscious content

perception & information processing in the brain accompanied by subjective, first person, reportable experiences (“*I saw X*”)

Conscious awareness

a brain state extended in time in which a stream of conscious information access is possible

Alertnesss / vigilance

a brain state of wakefulness and reactivity

- Conscious awareness without vigilance (dreams in deep sleep)
- Vigilance without conscious awareness (vegetative state patients)
- Conscious awareness without conscious content (certain meditation practices)

“Hard” problem: “What is it like to be someone that you are not – even with unlimited information about his/her brain”

“Easy” problem: Neural correlates of conscious access and conscious awareness

Warning

Avoid discussing with philosophers unless you prepare yourself beforehand

Tip #1: this slide is not enough

Nothing is conscious  Everything is conscious

Tip #2: you don’t want to be in this line

seminars in THE NEUROSCIENCES, Vol 2, 1990 : pp 263-275

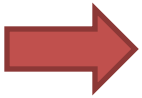
Towards a neurobiological theory of consciousness

Francis Crick and Christof Koch

Neural correlates of consciousness

When?

Where?



Fast forward 20 years and hundreds of papers

Models of consciousness

When?

Where?

How? (mechanism)

What makes a good model of consciousness?

Knowing how ⟶ knowing when and where

We address two mainstream models:

global workspace theory & information integration theory

Global workspace theory


Changeux


Dehaene

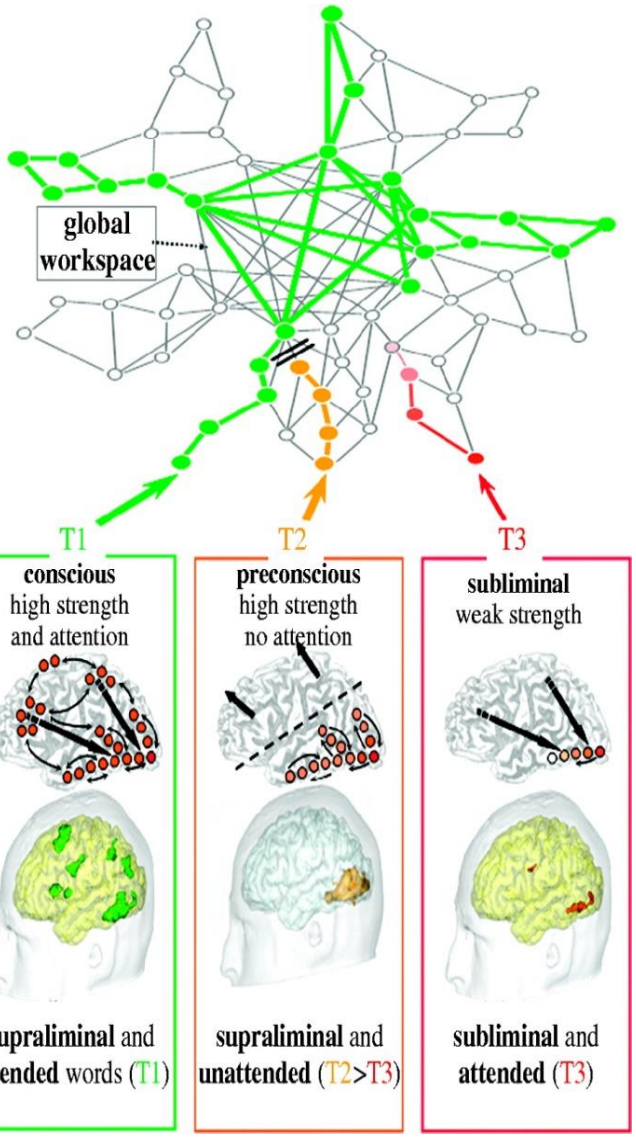

Baars

Dehaene et al., 2006. TICS

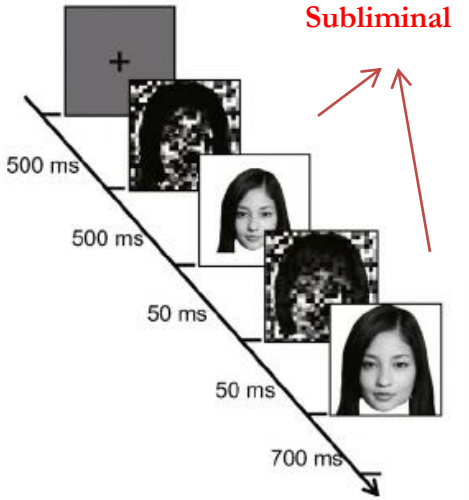
Incoming sensory stimuli **compete**

Conscious access = **self-sustained activity** spreading to the "global workspace"

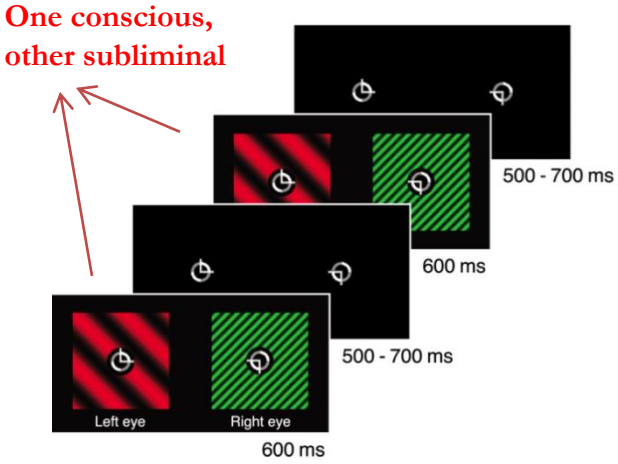
"Ignition" = conscious access is all-or-none



Forward masking

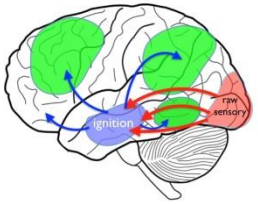


Binocular rivalry

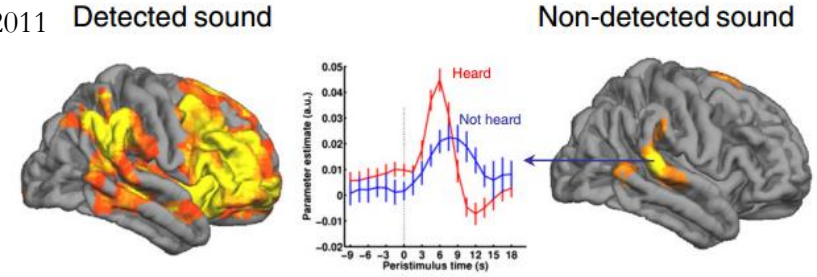


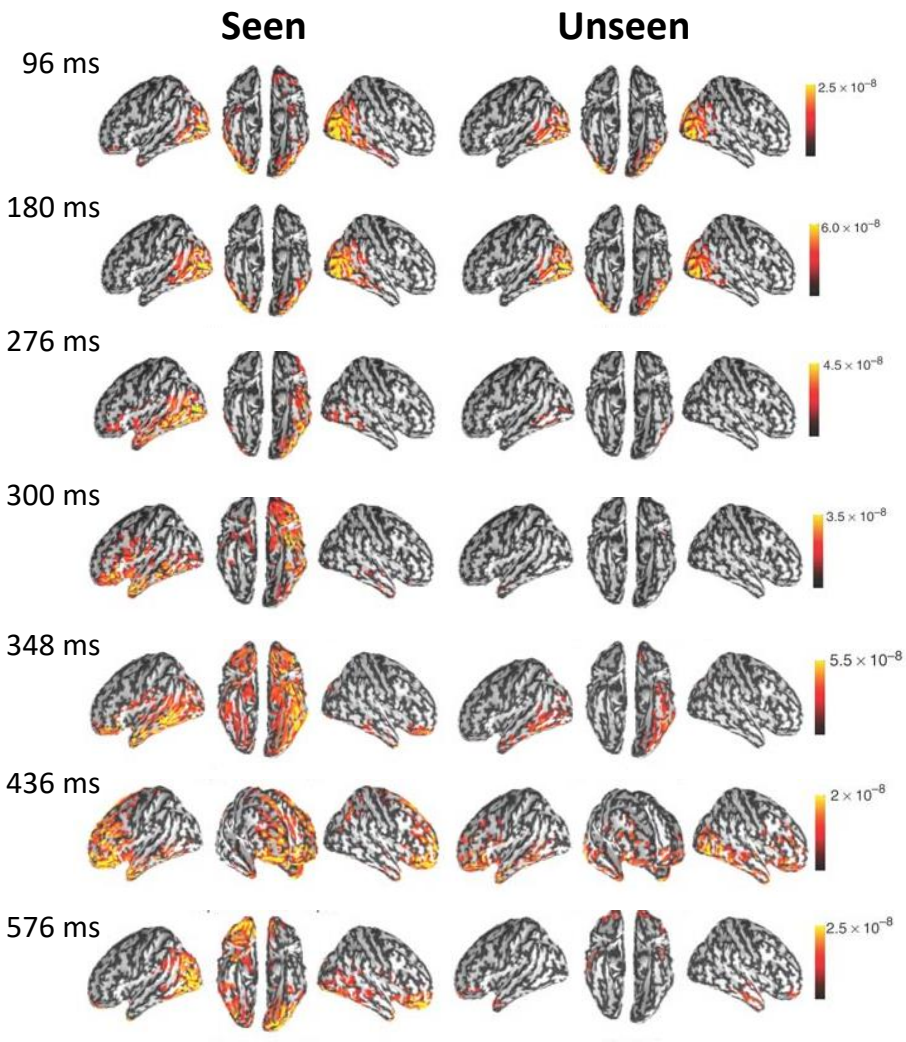
Competition for access: one stimuli becomes self-sustained and takes over the global workspace, blocking the other

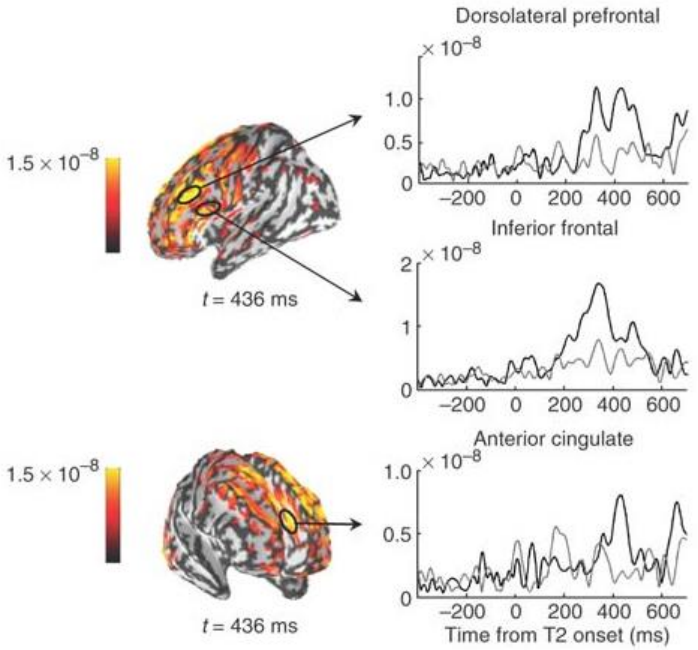
Global workspace = **fronto-parietal cortex**

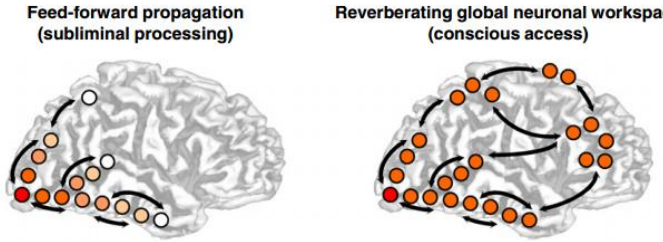


Dehaene et al 2011
Neuron





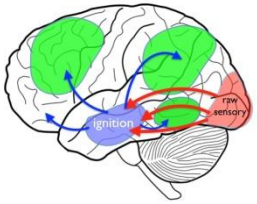




Sargent et al., 2005
Nat Neurosci

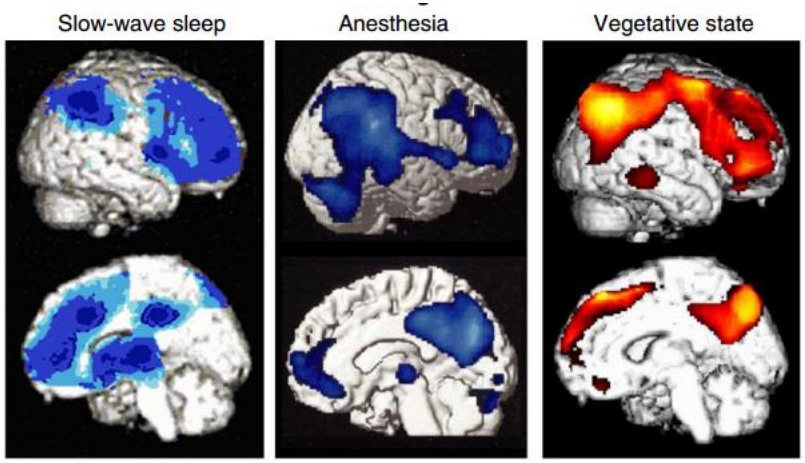
Activity of a few cells in the visual cortex elicits global widespread activation = high susceptibility

Global workspace = **fronto-parietal cortex**



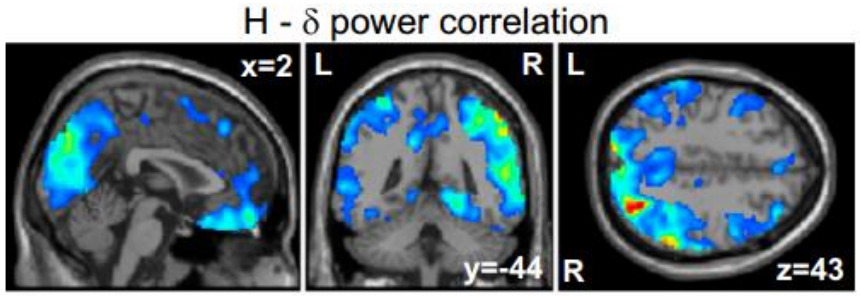
Evidence from states of diminished conscious awareness

Reduced metabolism



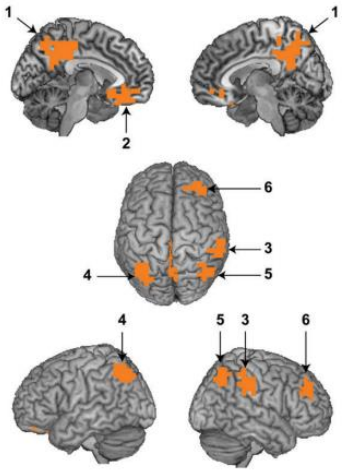
Dehaene et al 2011
Neuron

Reduced temporal correlations (sleep)



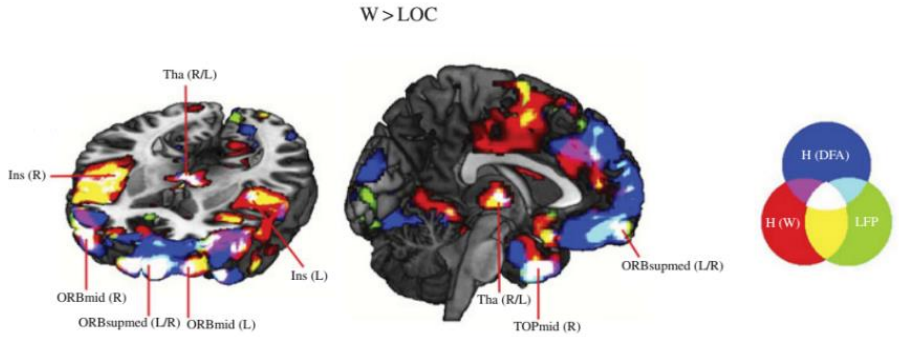
Tagliazucchi et al., 2013
PNAS

Reduced spatial correlations (sleep)



Uehara et al. 2014
Cer. Cortex

Reduced temporal correlations (propofol)



Tagliazucchi, Chialvo, et al., 2016
J. Roy. Soc. Interface

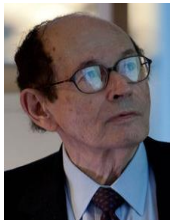
Global workspace theory

How: sensory stimuli compete for the "ignition" of the global workspace; successful stimuli become globally available for a sustained period of time and enter consciousness

When: when a stimuli is strong enough and receives attention

Where: the fronto-parietal cortex

Information integration theory



Edelman

Tononi

Brain activity during conscious must be highly differentiated

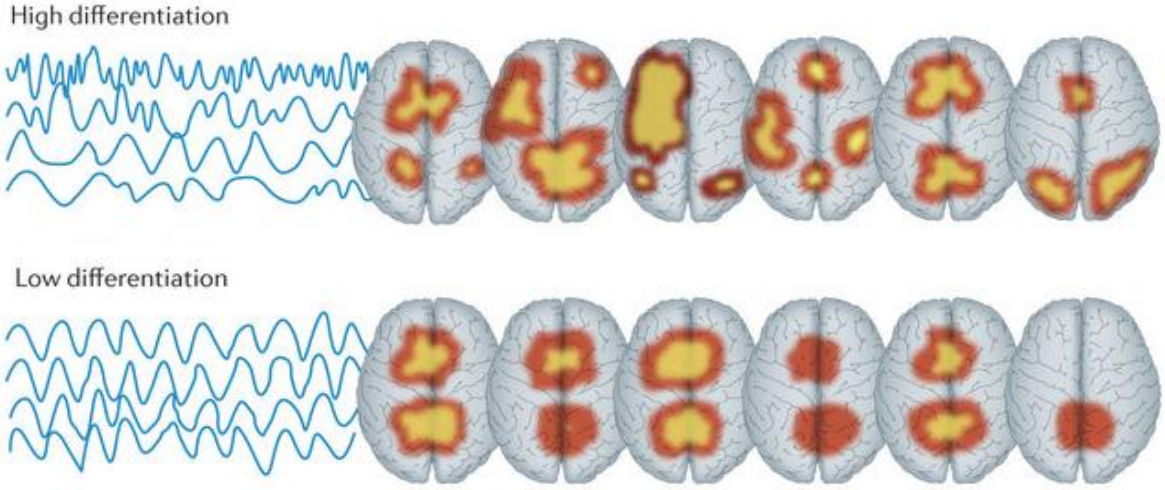
(think of the number of possible conscious experiences)

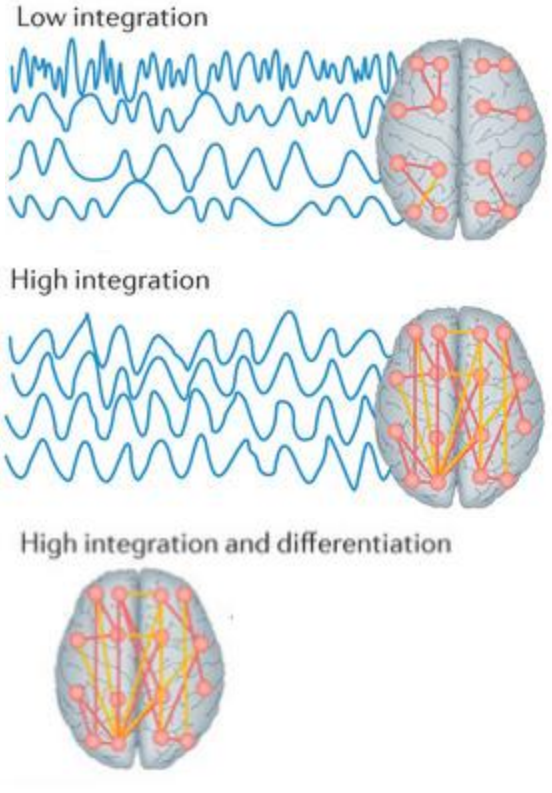
It must also be integrated

(otherwise it's just a bunch of independent systems)

So it must be both integrated and segregated.

Tononi et al., 2016
Nat Rev Neurosci





"Explains" why loss of conscious awareness is in general associated with massive over-synchronization / integration / loss of differentiation

Quantifying information integration?

Derive from "first principles" :

Necessary conditions for conscious awareness

Sufficient conditions for conscious awareness

The minimal set of neurons involved in conscious perception

In practice:

Combinatorial algorithms (exploring all sub-partitions of the system)

In newest metrics, need to causally manipulate all subsets of the system at will

The theory reincarnated several times

Proc. Natl. Acad. Sci. USA
Vol. 91, pp. 5033–5037, May 1994
Neurobiology

A measure for brain complexity: Relating functional segregation and integration in the nervous system

GIULIO TONONI, OLAF SPORNS, AND GERALD M. EDELMAN
The Neurosciences Institute, 3377 North Torrey Pines Court, La Jolla, CA 92037

Contributed by Gerald M. Edelman, February 17, 1994

BMC Neuroscience

Research article

An information integration theory of consciousness

Giulio Tononi*

Archives Italiennes de Biologie, 150: 290-326, 2012.

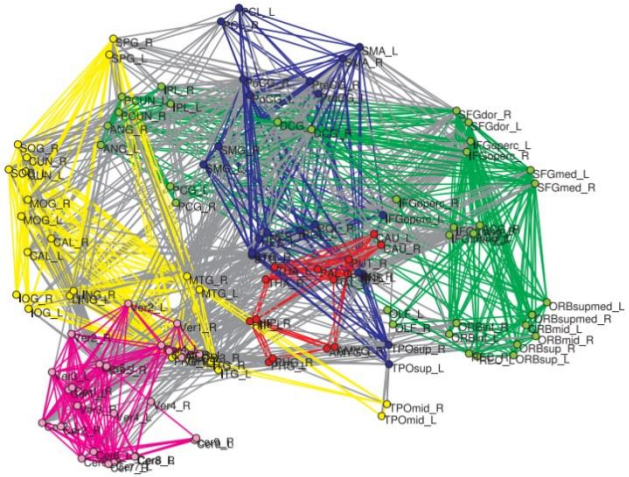
Integrated information theory of consciousness: an updated account

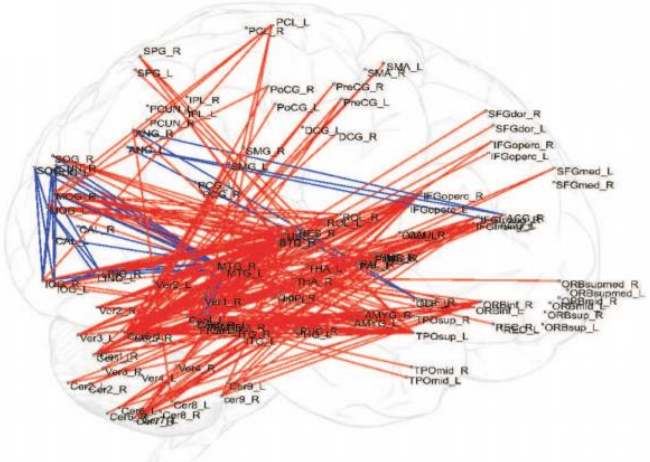
G. TONONI
Department of Psychiatry, University of Wisconsin, Madison, WI, USA

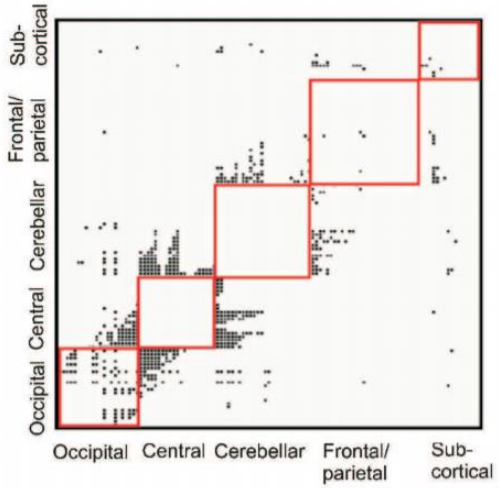
OPEN ACCESS Freely available online
PLOS | COMPUTATIONAL BIOLOGY

From the Phenomenology to the Mechanisms of Consciousness: Integrated Information Theory 3.0

Masafumi Oizumi[1,2], Larissa Albantakis[1], Giulio Tononi[1]*
1 Department of Psychiatry, University of Wisconsin, Madison, Wisconsin, United States of America, 2 RIKEN Brain Science Institute, Wako-shi, Saitama, Japan



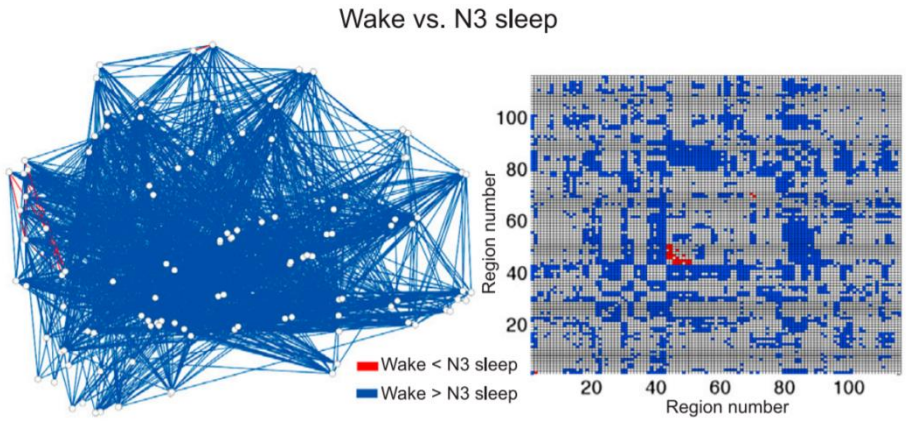


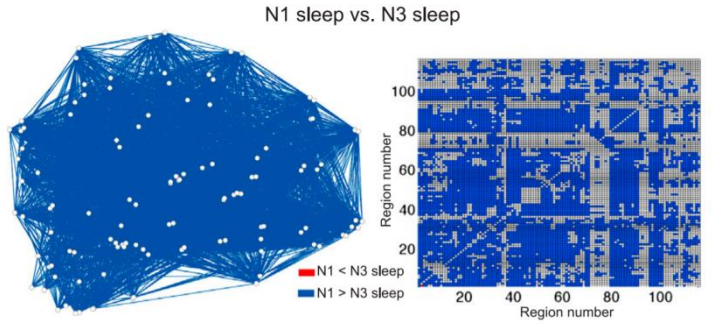


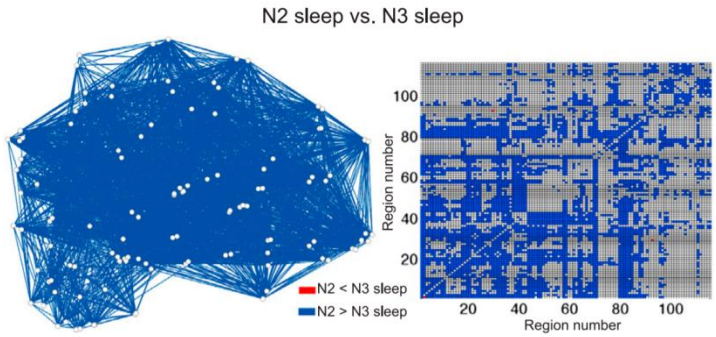
Tagliazucchi et al., 2013.
Neuroimage

Delta (EEG) ↑ ↓ Connectivity (fMRI)

Intra-module correlation
Inter-module correlation







Tagliazucchi et al., 2014.
Neuron

Information integration theory

How: different metrics of information integration are proposed and conscious content is associated with their maximization

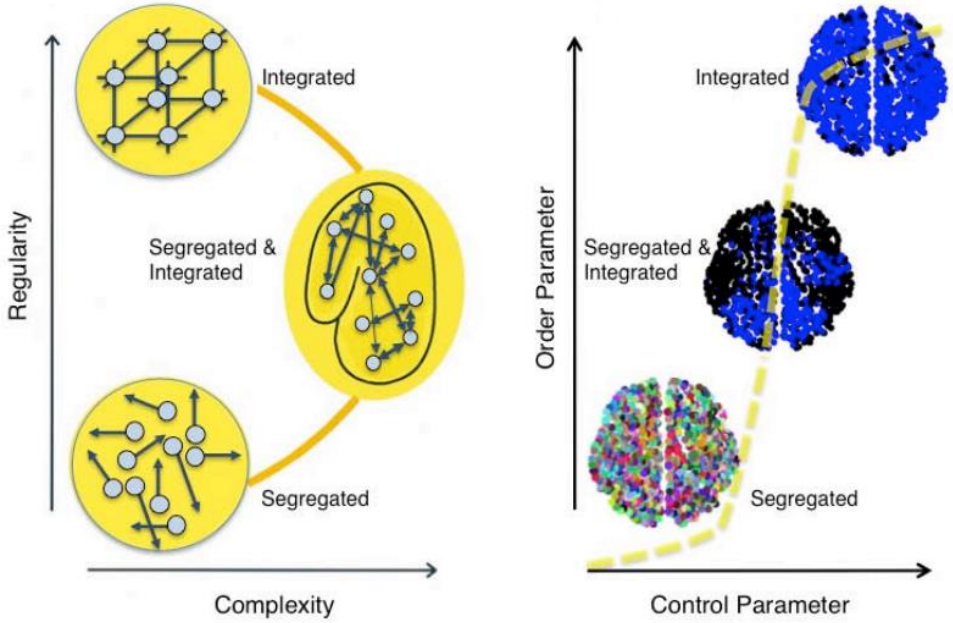
When: when predicted from the maximization

(can't compute)

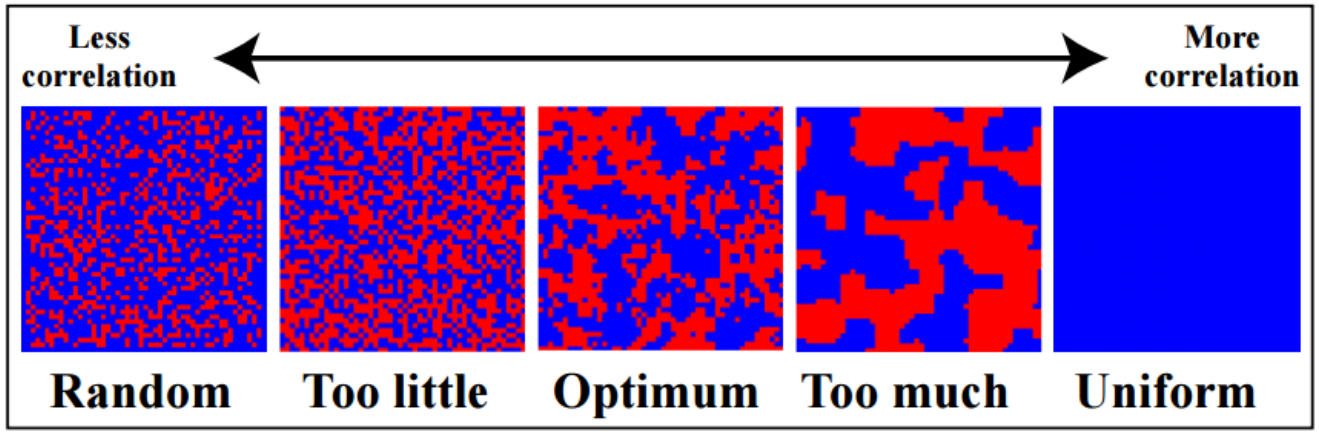
Where: where predicted from the maximization

(can't compute)

Integration-segregation in the language of phase transitions



Tagliazucchi & Chialvo, 2014



Tegmark, 2015

FIG. 2: The panels show simulations of the 2D Ising model on a 50×50 lattice, with the temperature progressively decreasing from left to right. The integrated information Φ drops to zero bits at $T \to \infty$ (leftmost panel) and to one bit as $T \to 0$ (rightmost panel), taking a maximum at an intermediate temperature near the phase transition temperature.

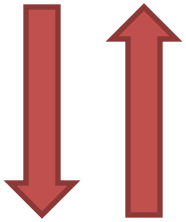
Decreased **information integration** in the vegetative state

Current Biology 23, 1914–1919, October 7, 2013 ©2013 Elsevier Ltd All rights reserved http://dx.doi.org/10.1016/j.cub.2013.07.075

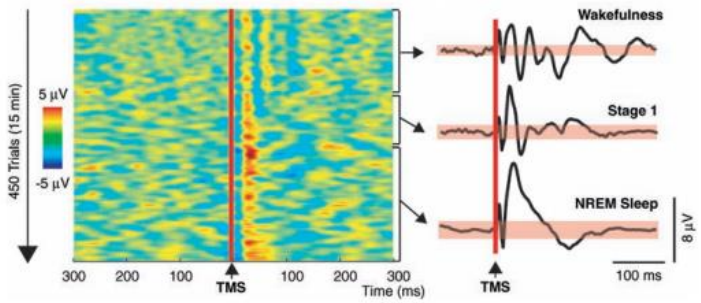
Report

Information Sharing in the Brain Indexes Consciousness in Noncommunicative Patients

Jean-Rémi King,[1,2,3,9,*] Jacobo D. Sitt,[1,2,3,9,*] Frédéric Faugeras,[3,4] Benjamin Rohaut,[3,8] Imen El Karoui,[3] Laurent Cohen,[3,4,5] Lionel Naccache,[3,4,5] and Stanislas Dehaene[1,2,6,7]



Magnetic perturbations fail to elicit **global, sustained and reverberating response** during deep sleep



Breakdown of Cortical Effective Connectivity During Sleep

Marcello Massimini,[1,2] Fabio Ferrarelli,[1] Reto Huber,[1] Steve K. Esser,[1] Harpreet Singh,[1] Giulio Tononi[1*]

Either both models are not incompatible or they are vague enough to accommodate evidence supporting the opposing model

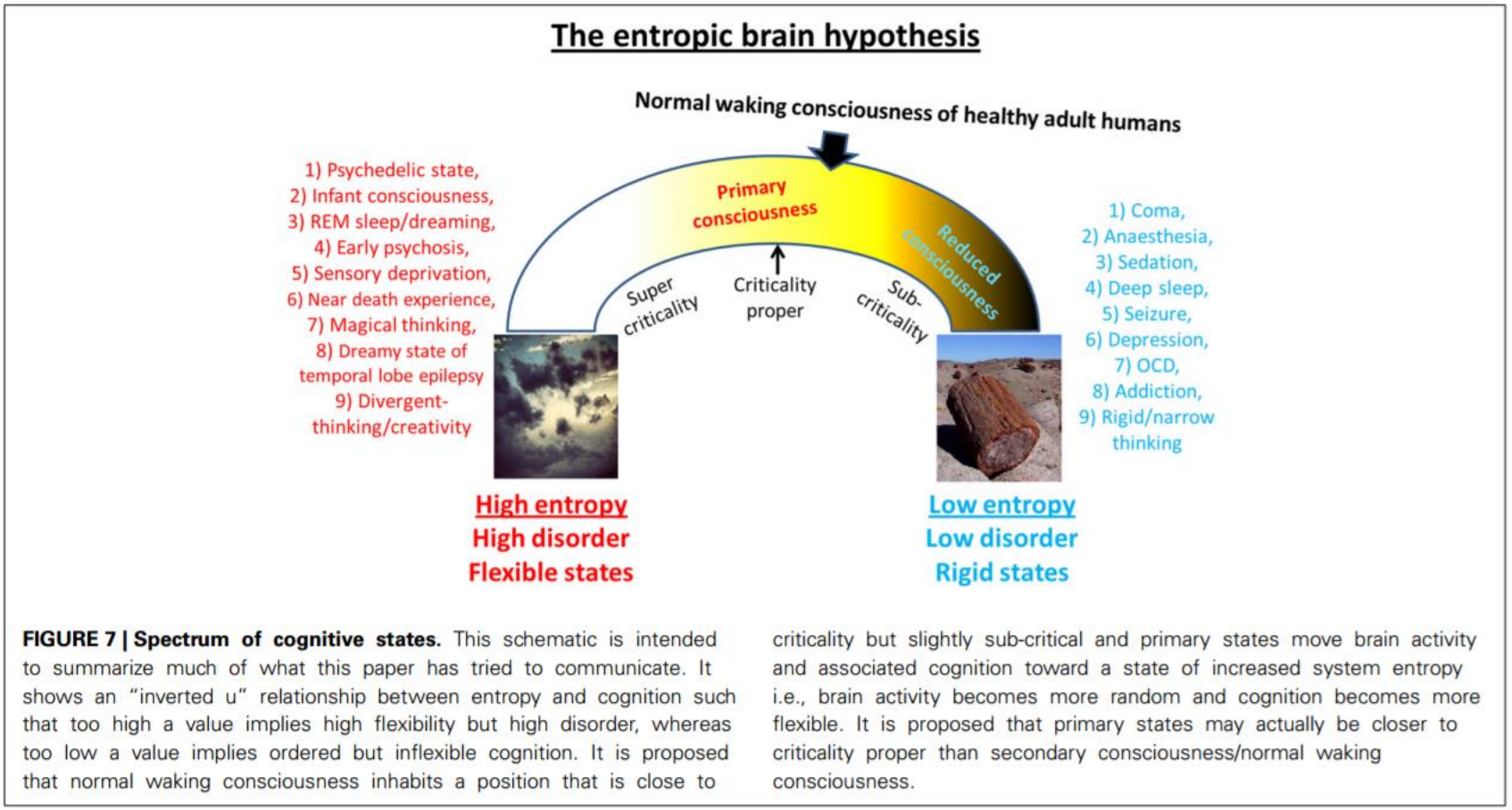
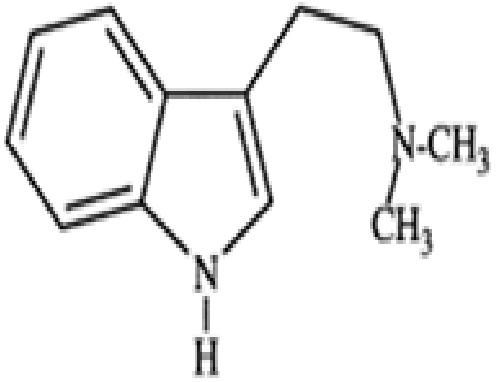


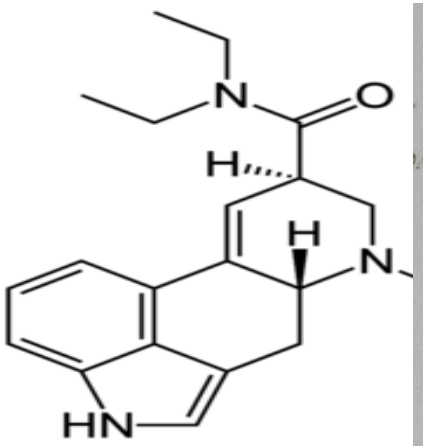
FIGURE 7 | Spectrum of cognitive states. This schematic is intended to summarize much of what this paper has tried to communicate. It shows an "inverted u" relationship between entropy and cognition such that too high a value implies high flexibility but high disorder, whereas too low a value implies ordered but inflexible cognition. It is proposed that normal waking consciousness inhabits a position that is close to criticality but slightly sub-critical and primary states move brain activity and associated cognition toward a state of increased system entropy i.e., brain activity becomes more random and cognition becomes more flexible. It is proposed that primary states may actually be closer to criticality proper than secondary consciousness/normal waking consciousness.

Carhart Harris et al., 2015.
Frontiers in Neuroscience

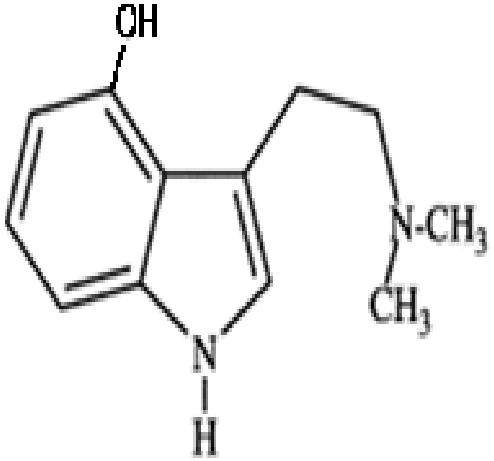
Serotonergic psychedelics



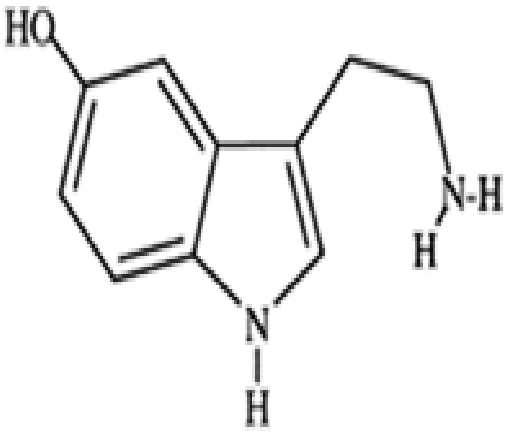
DMT



LSD

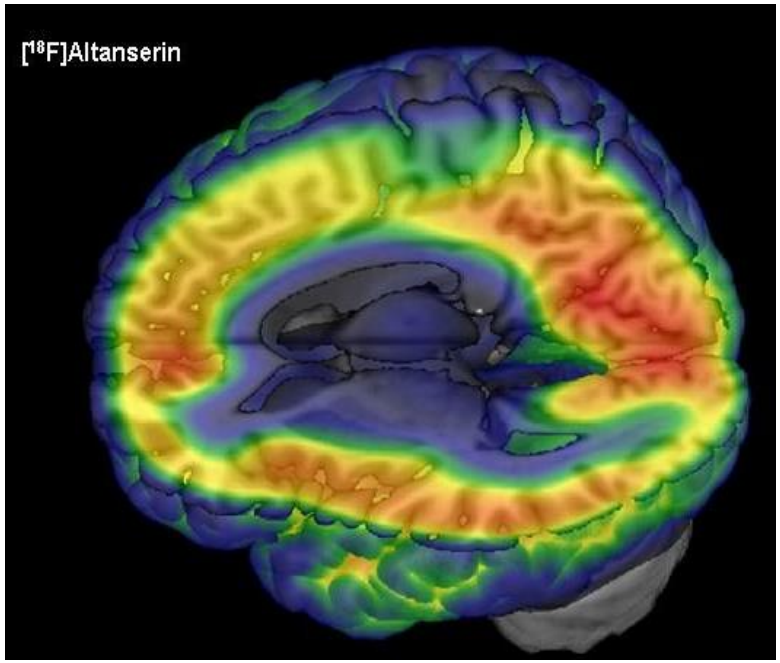


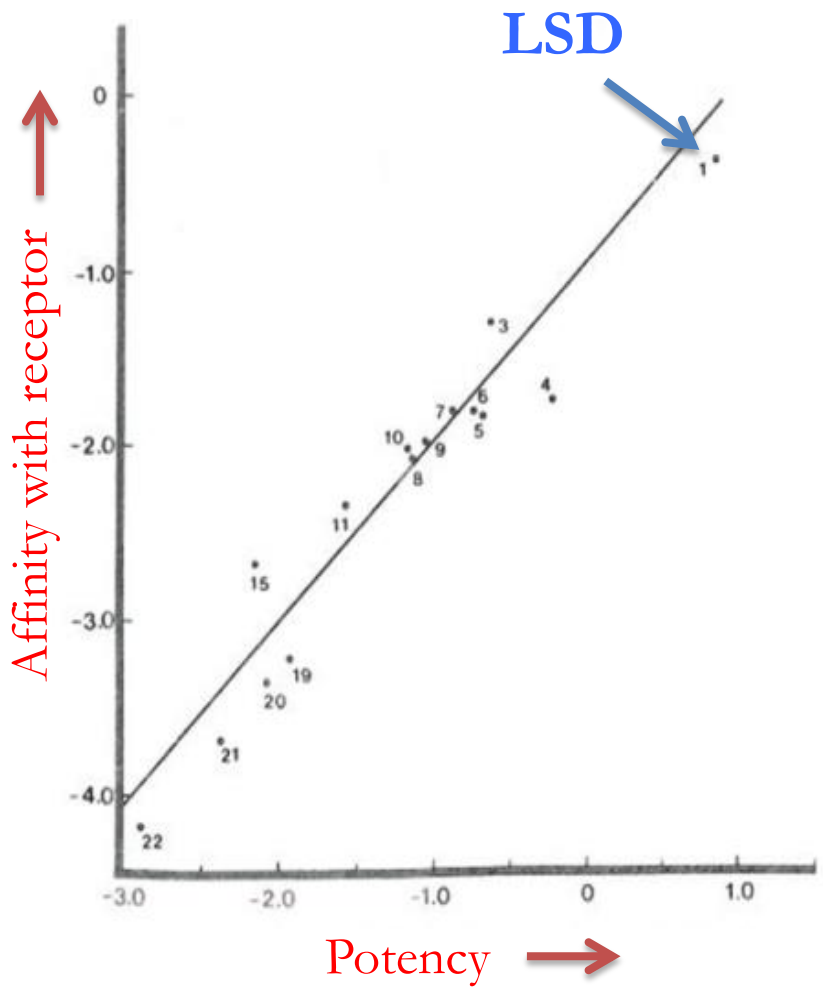
Psilocybin



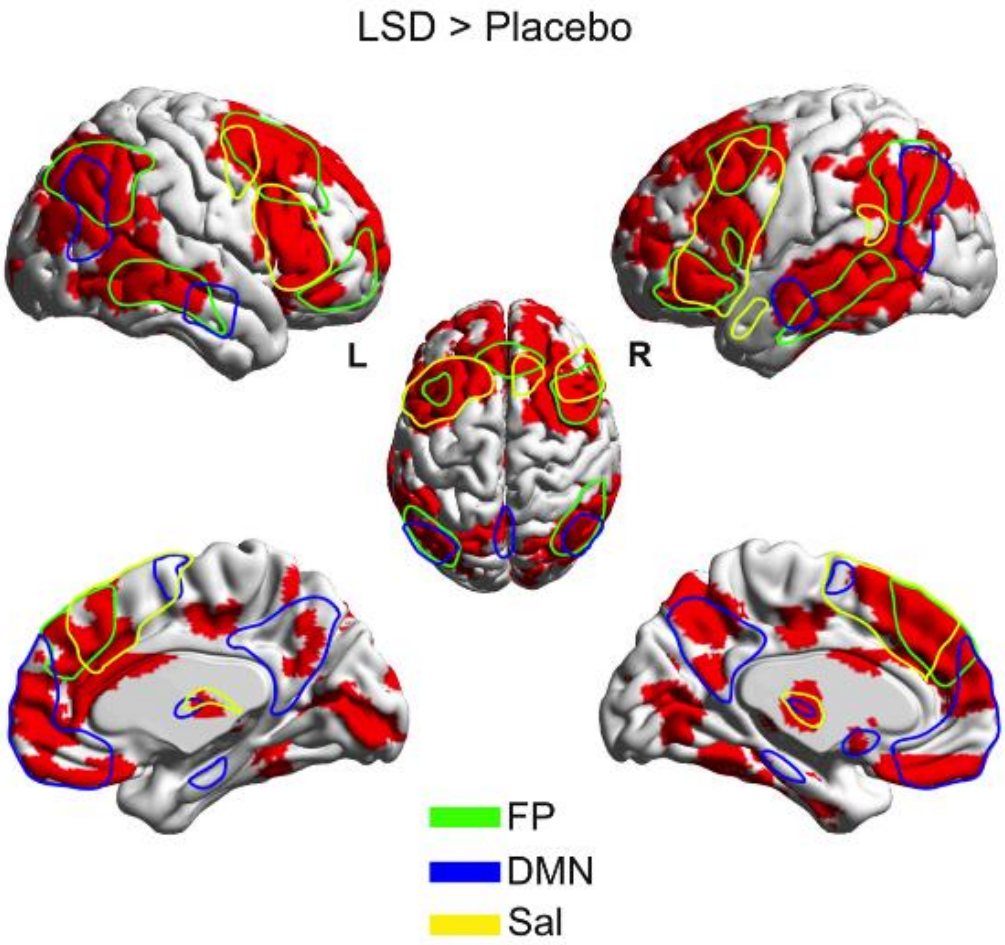
Serotonin

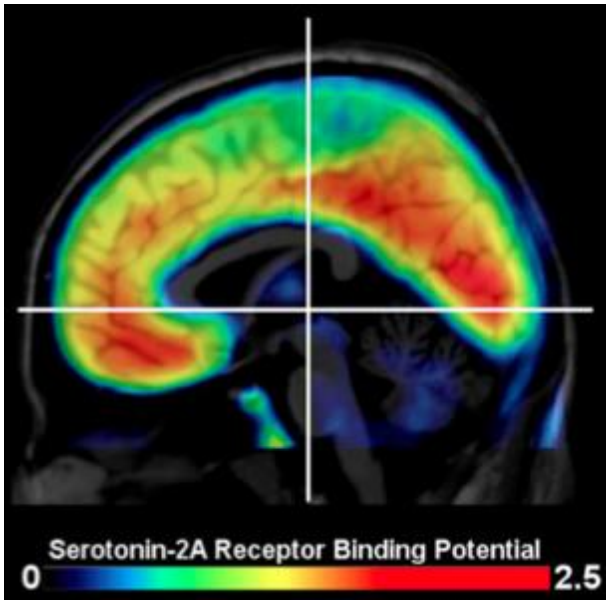
Action by similarity with a certain serotonin receptor (5HT2A agonists)





LSD expands fronto-parietal connectivity and metabolism
(as opposed to unconsciousness)

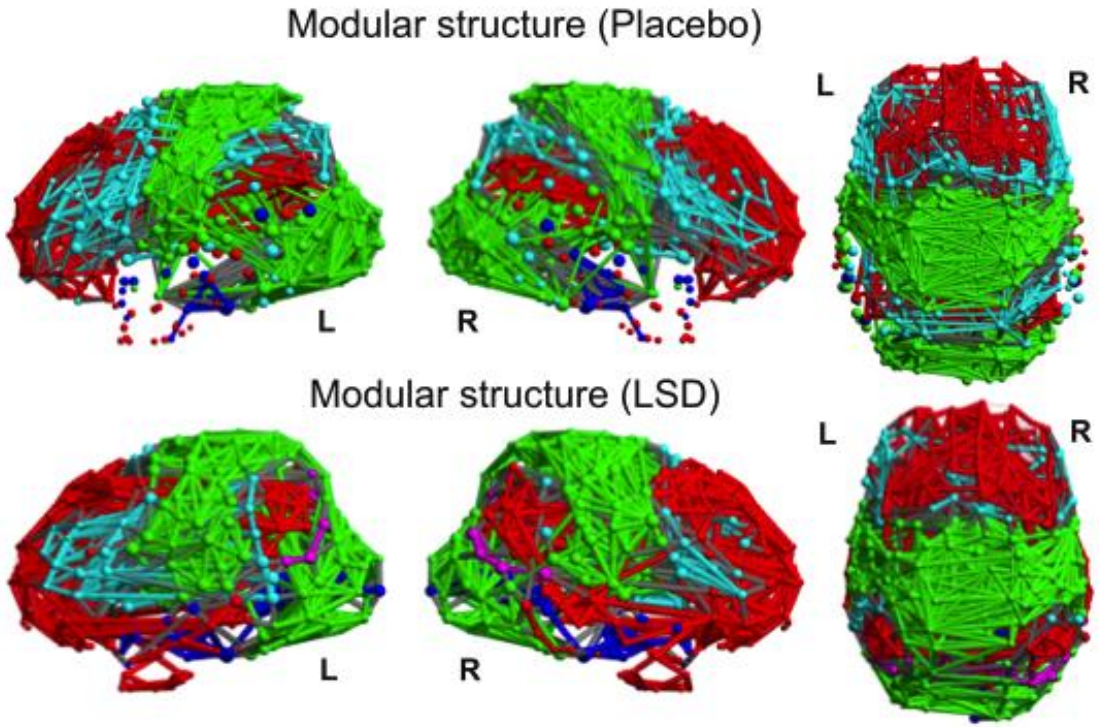


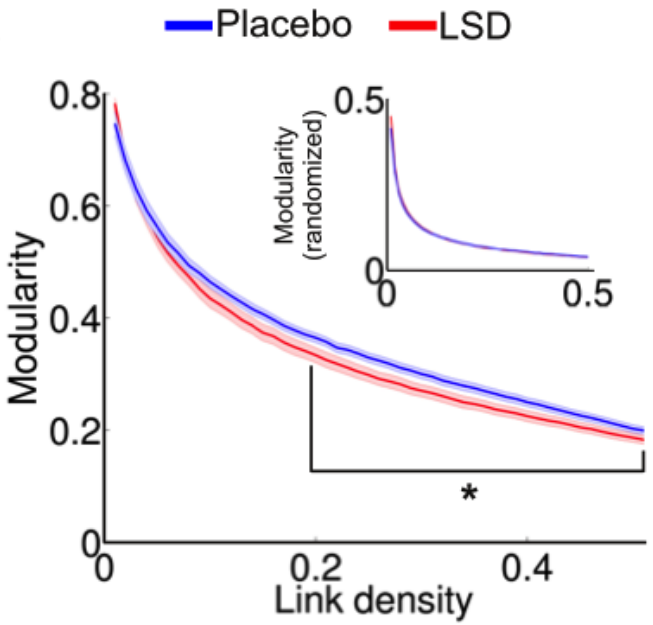


Tagliazucchi et al., 2015.
Current Biology

LSD reduces network modularity (i.e. increases integration)

(as opposed to unconsciousness)

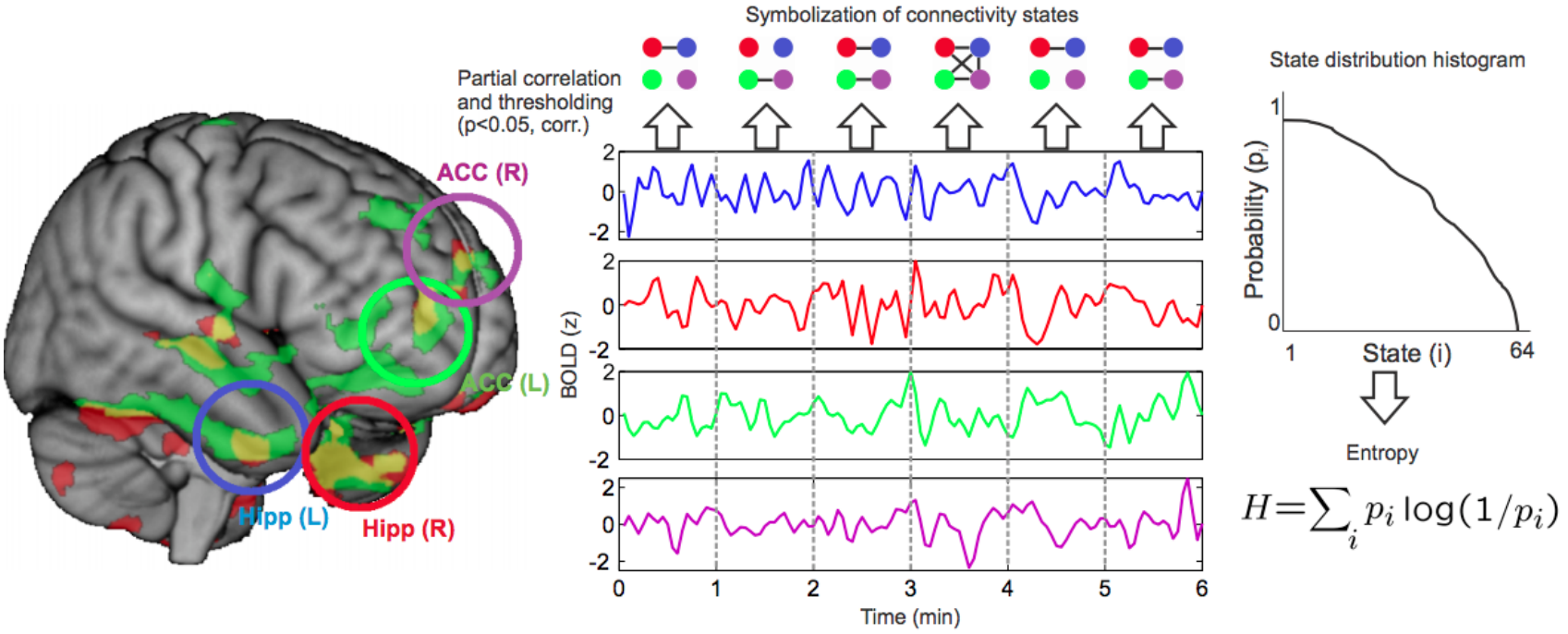




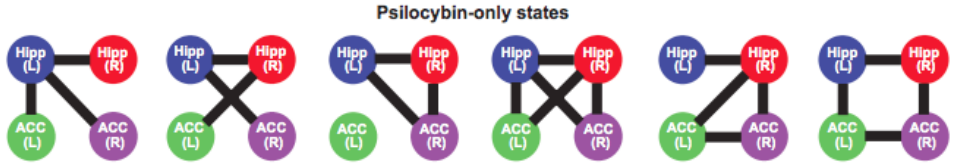
Tagliazucchi et al., 2015. Current Biology

Psilocibyn increases the entropy of visited states

(as opposed to unconsciousness)



Symbolic entropy of the sequence of visited states



Tagliazucchi et al., 2014.
Human Brain Mapping