

Brain dynamics as a means to quantify consciousness states and ongoing thinking

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States of (Un)consciousness



Clinical

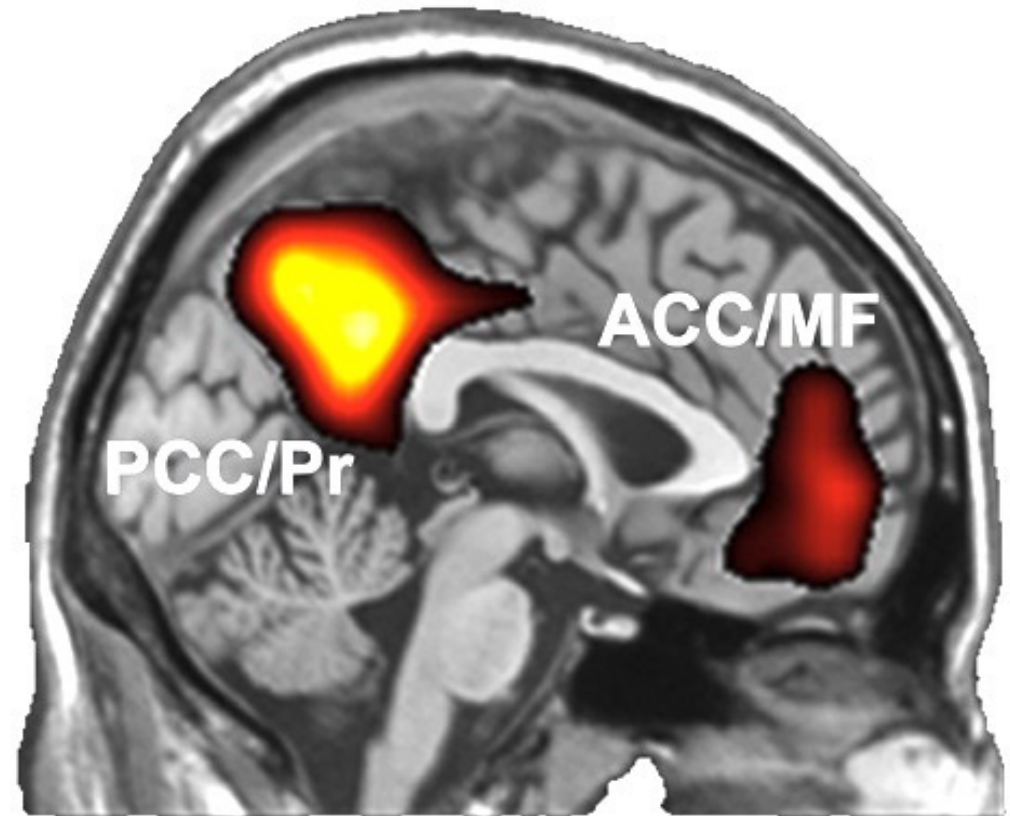


Physiological



Wakefulness

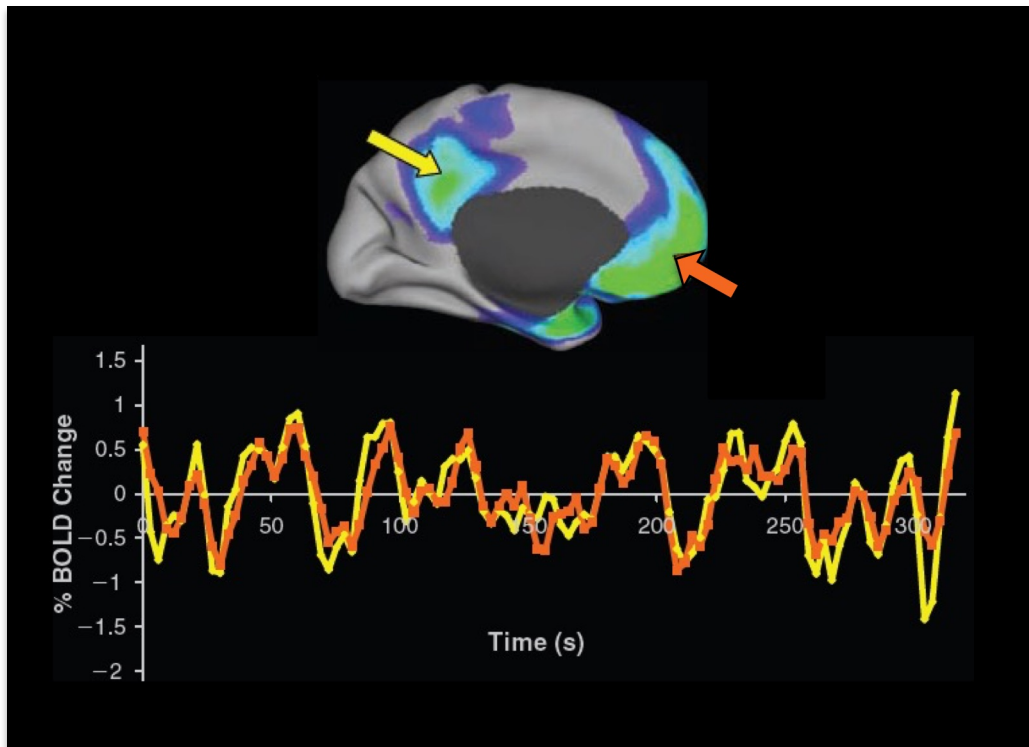
Spontaneous brain



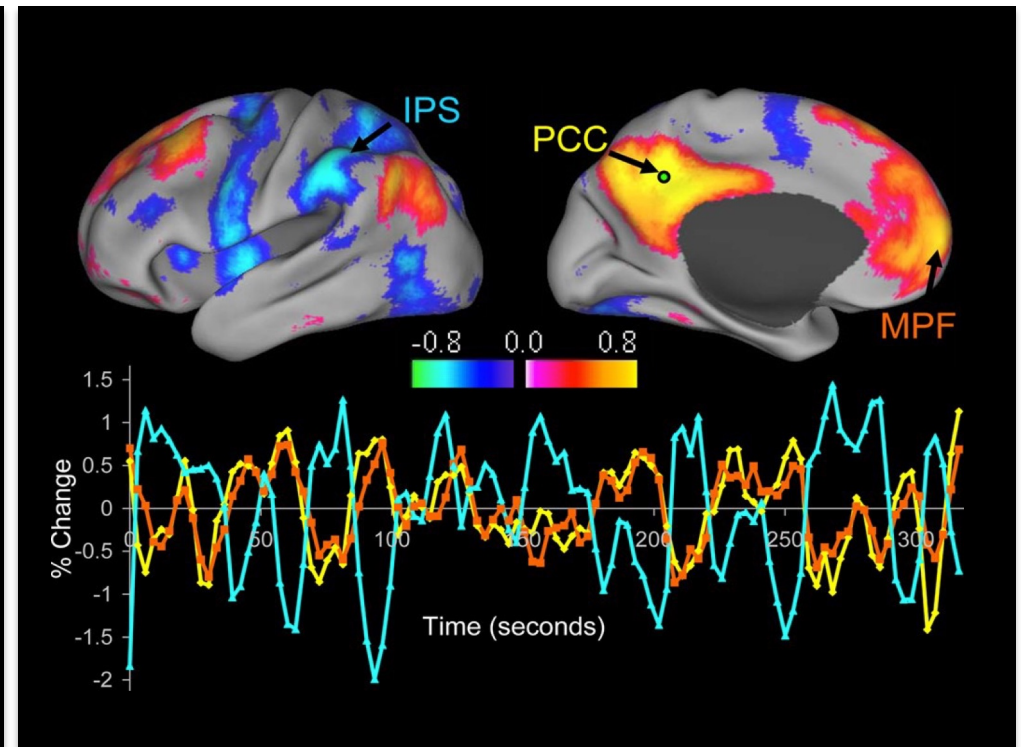
Demertzi & Whitfield-Gabrieli, in: *Neurology of Consciousness* 2nd ed. 2015
 Demertzi, Soddu, Laureys, *Curr Opin Neurobiology* 2013
 Demertzi et al, *Front Hum Neurosci* 2013
 Raichle et al, *PNAS* 2001

Default mode of function

Default Mode Network



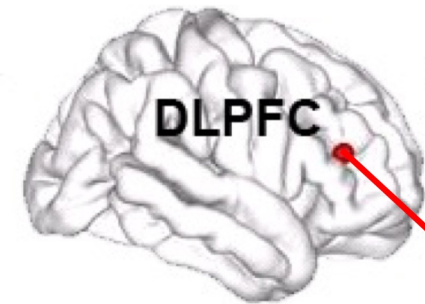
Functional Anticorrelations



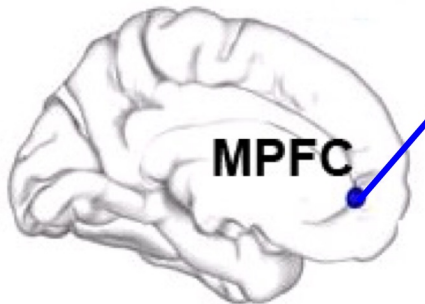
Demertzi & Whitfield-Gabrieli, In: *Neurology of Consciousness* 2nd ed. 2015
Demertzi, Soddu, Laureys, *Curr Opin Neurobiology* 2013
Raichle et al, *PNAS* 200
Fox et al, *PNAS* 2005

Anticorrelations reflect cognition

External awareness
or anticorrelated network

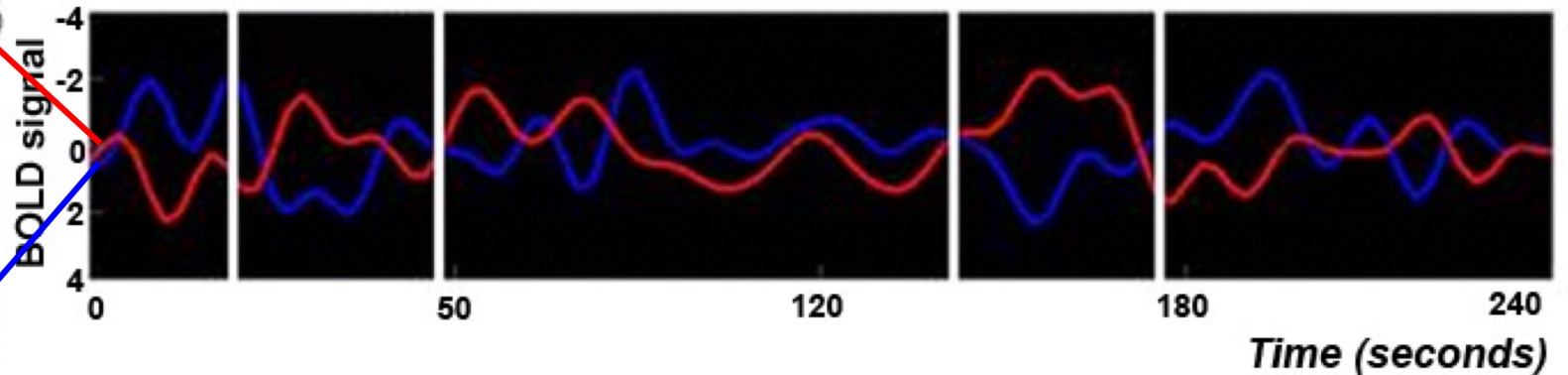


DLPFC

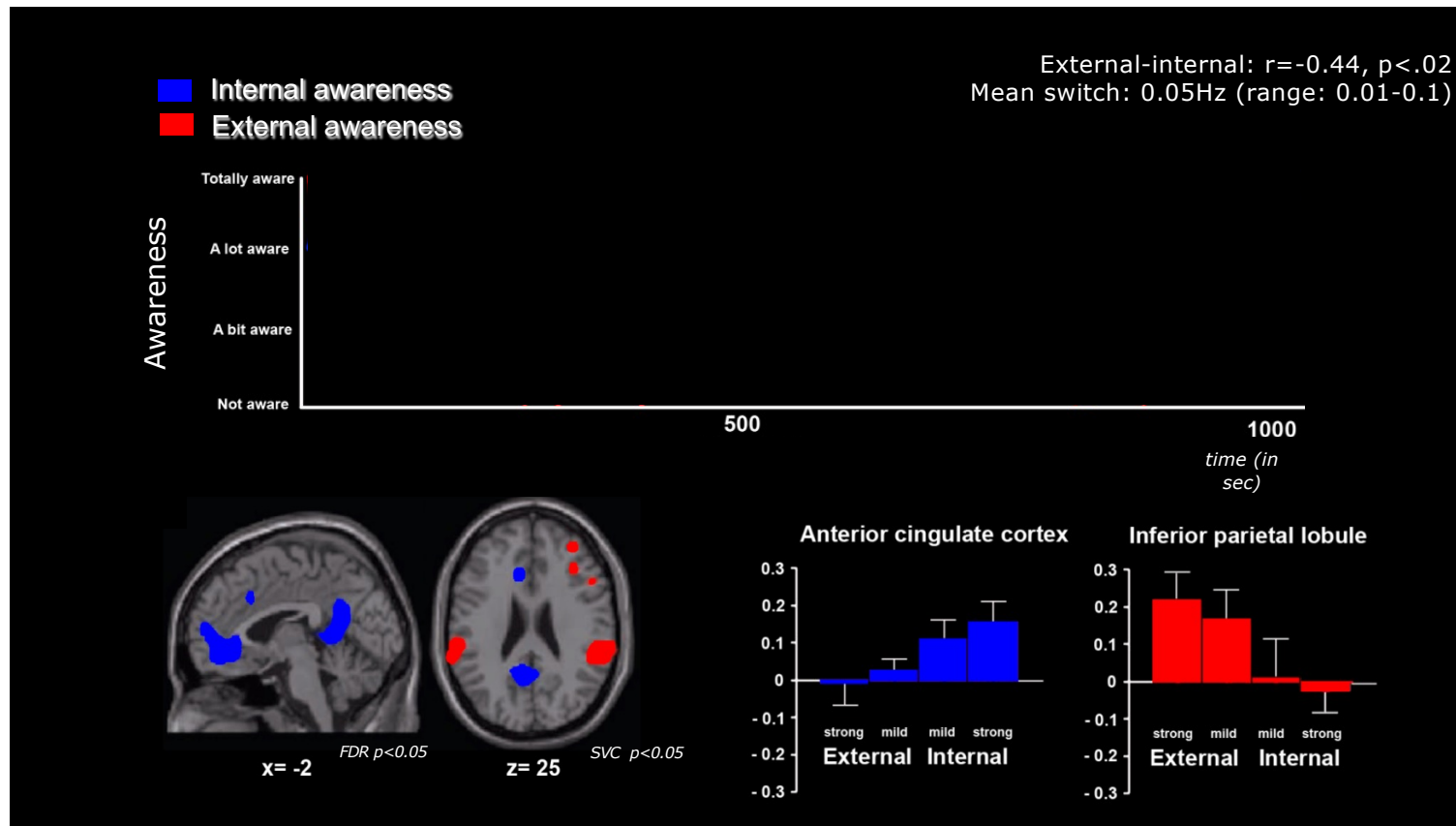


MPFC

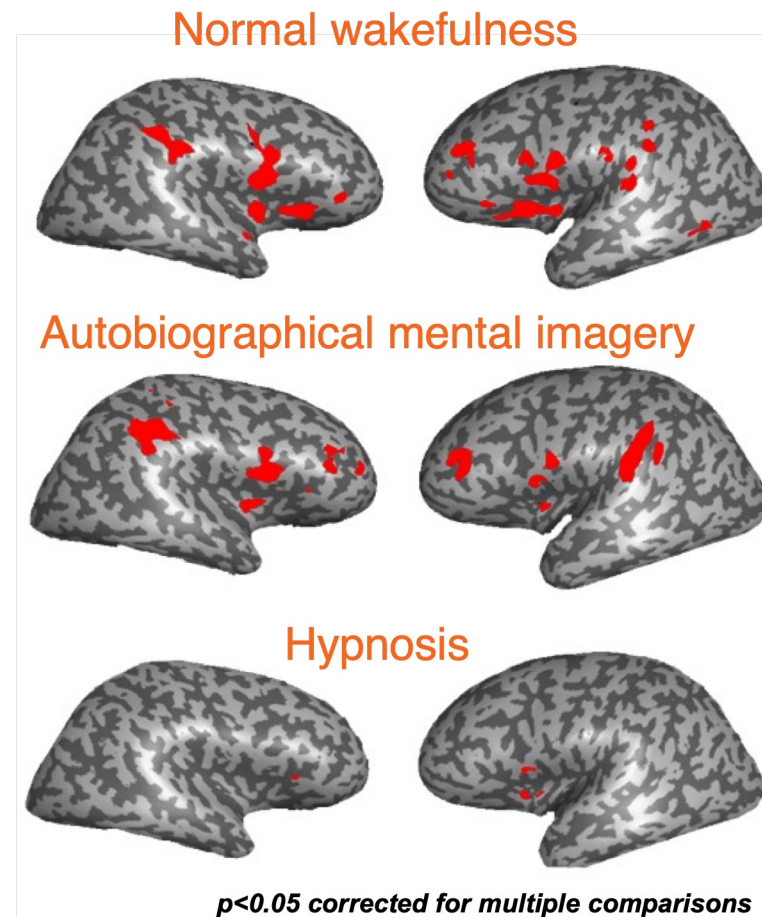
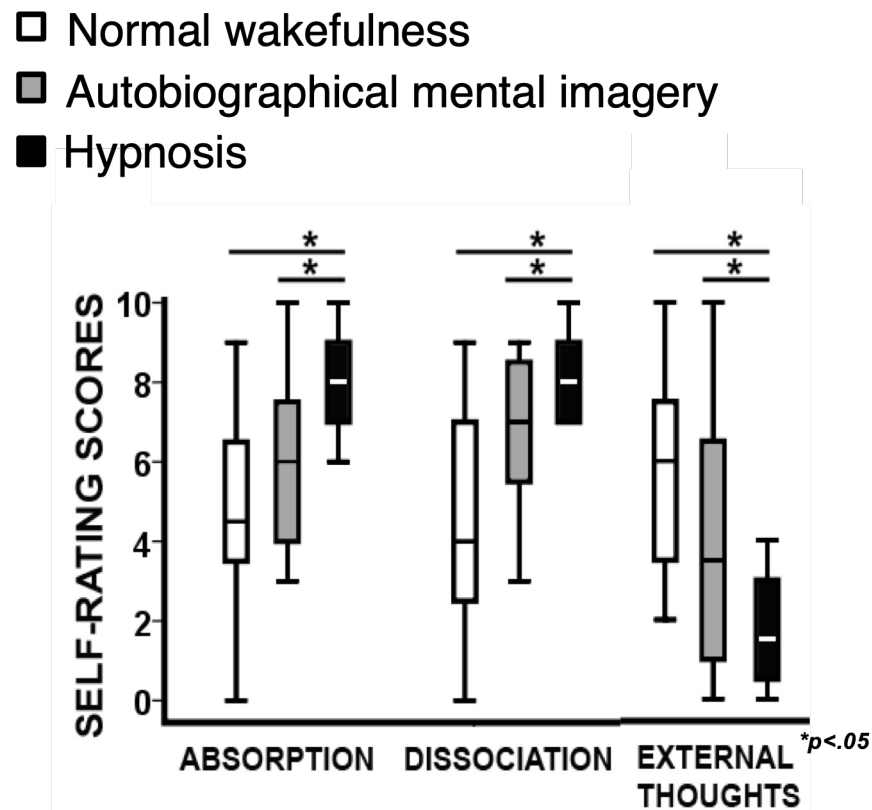
Internal awareness
or Default mode network



Anticorrelations reflect cognition



Anticorrelations reduce in hypnosis

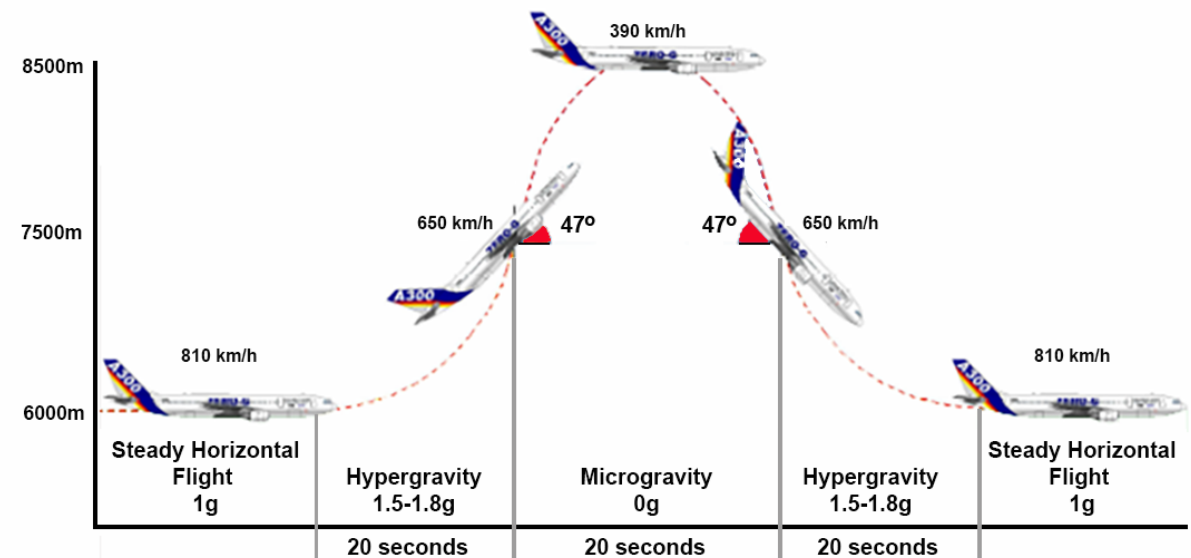


Anticorrelations reduce in extreme environments

Parabolic flight



Parabolic flight Trajectory

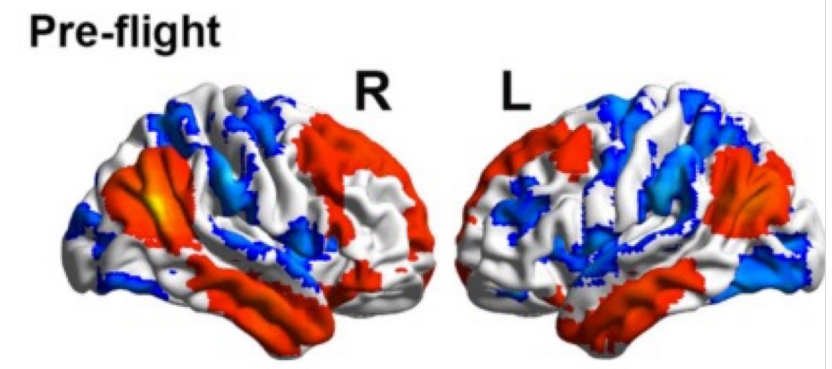
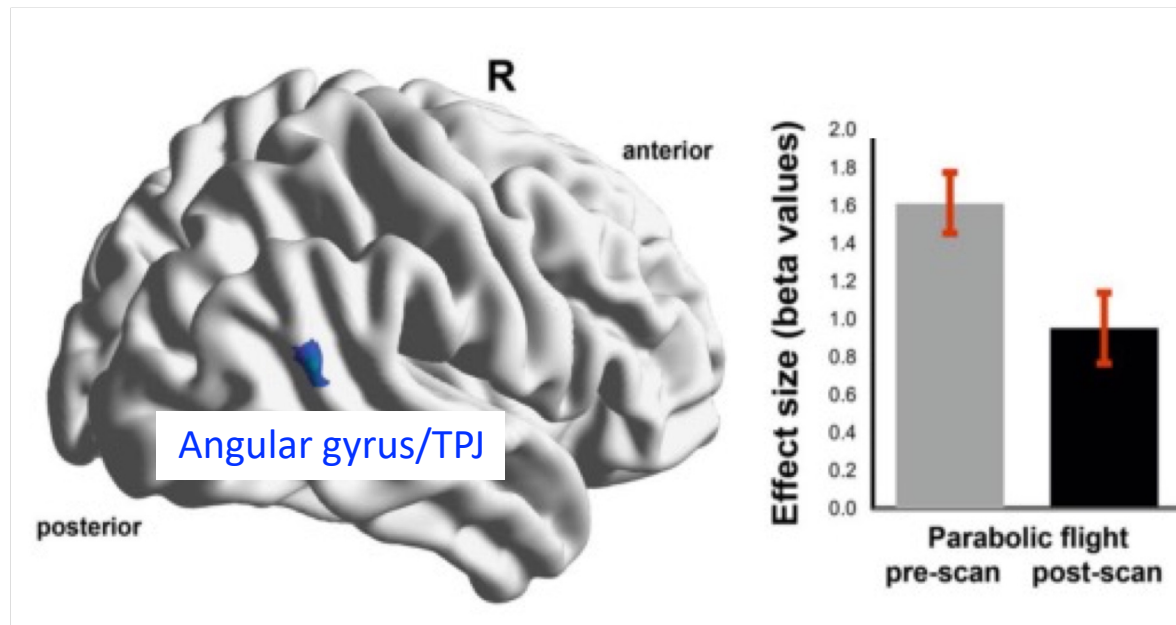


Angelique Van Ombergen¹, Floris L. Wuyts¹, Ben Jeurissen², Jan Sijbers², Floris Vanhevel³, Steven Jillings¹, Paul M. Parizel³, Stefan Sunaert⁴, Paul H. Van de Heyning¹, Vincent Dousset⁵, Steven Laureys⁶ & Athena Demertzi^{6,7}

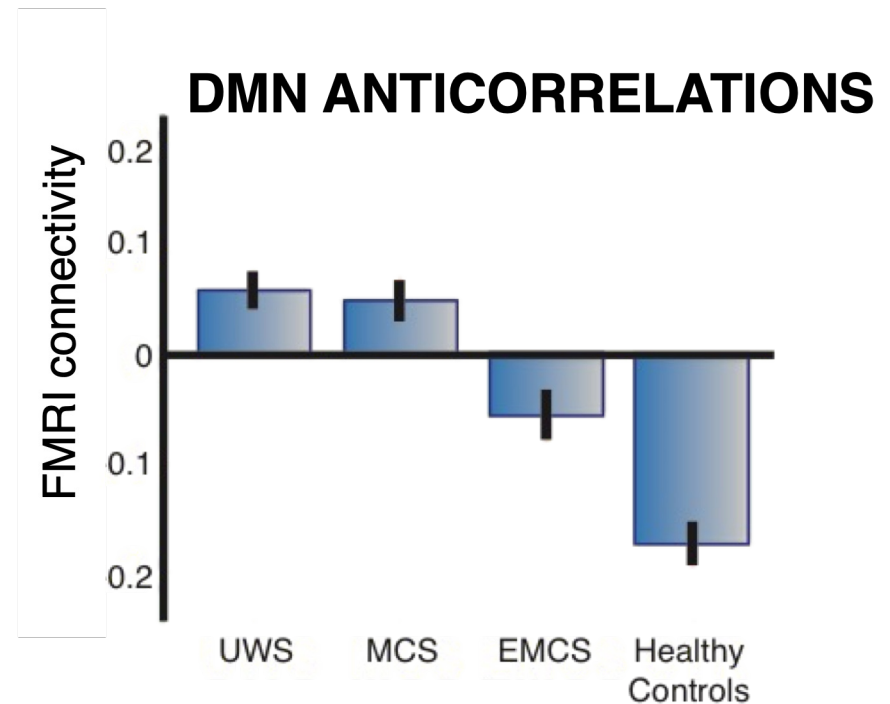
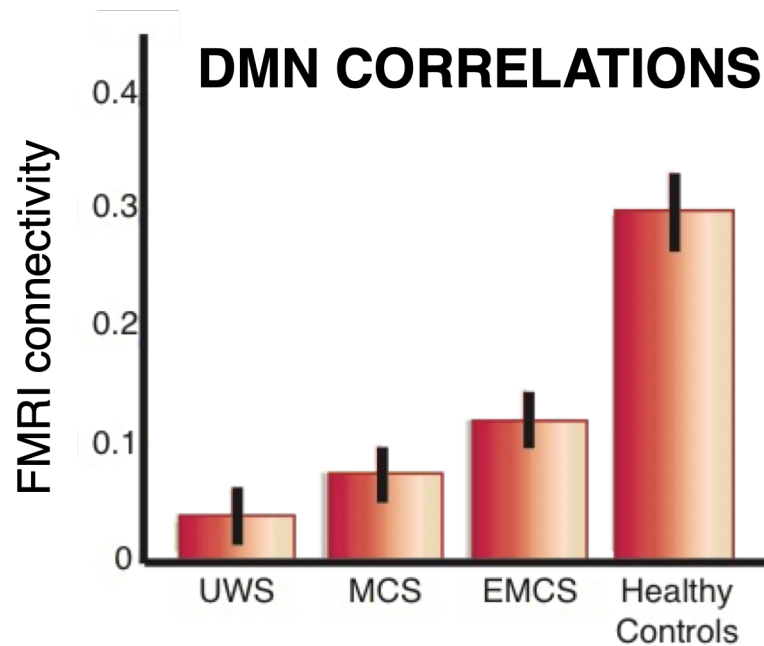
SCIENTIFIC REPORTS



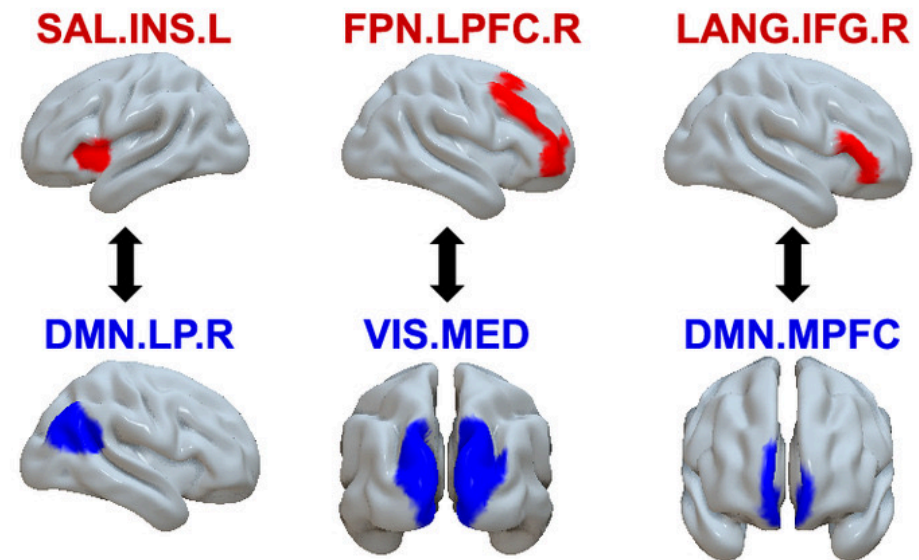
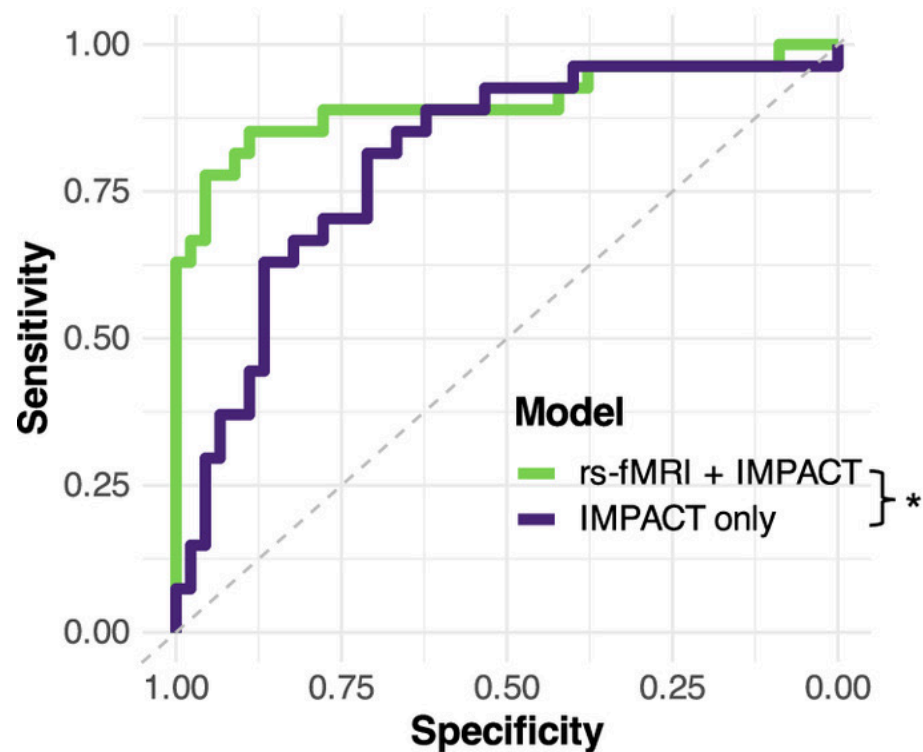
Anticorrelations reduce in extreme environments



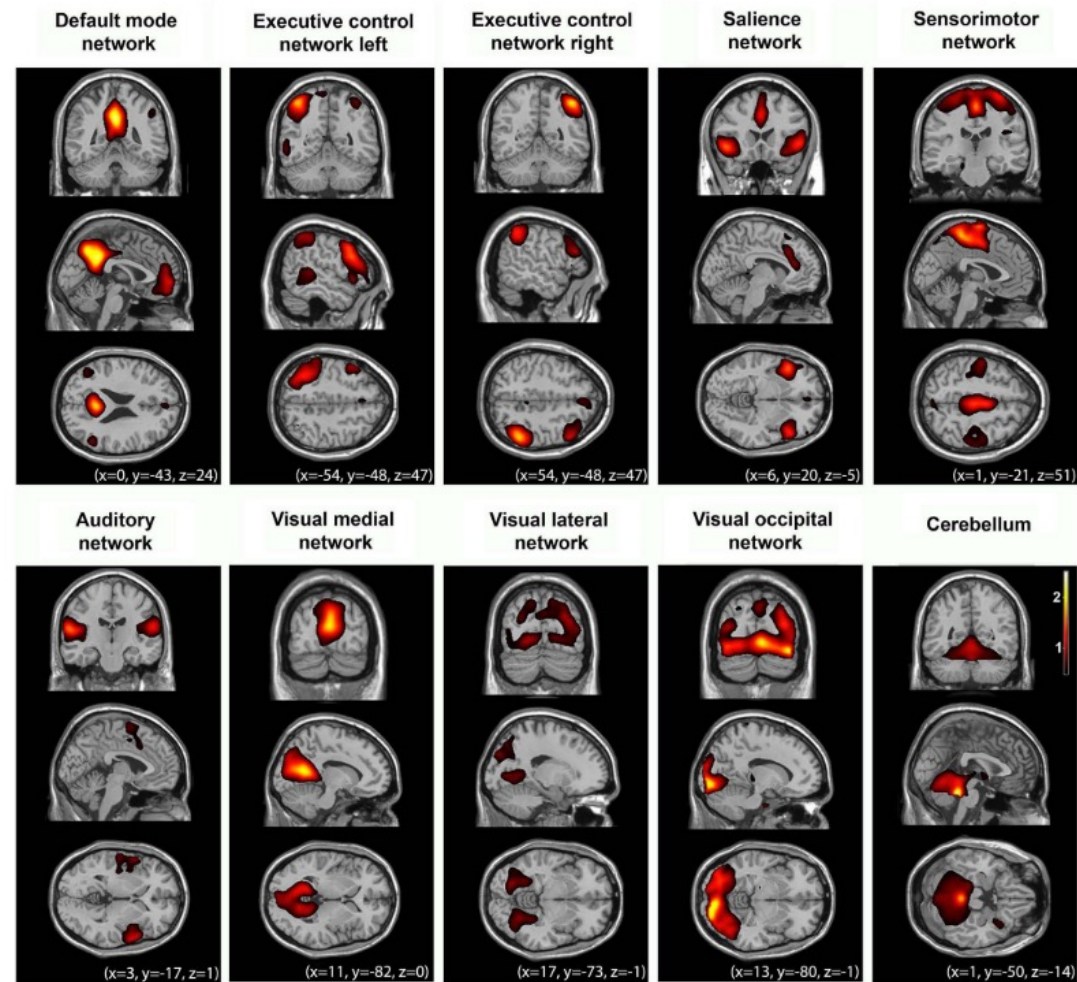
No Anticorrelations in DoC Patients



Anticorrelations predict recovery of consciousness



Resting State has Multiple Networks

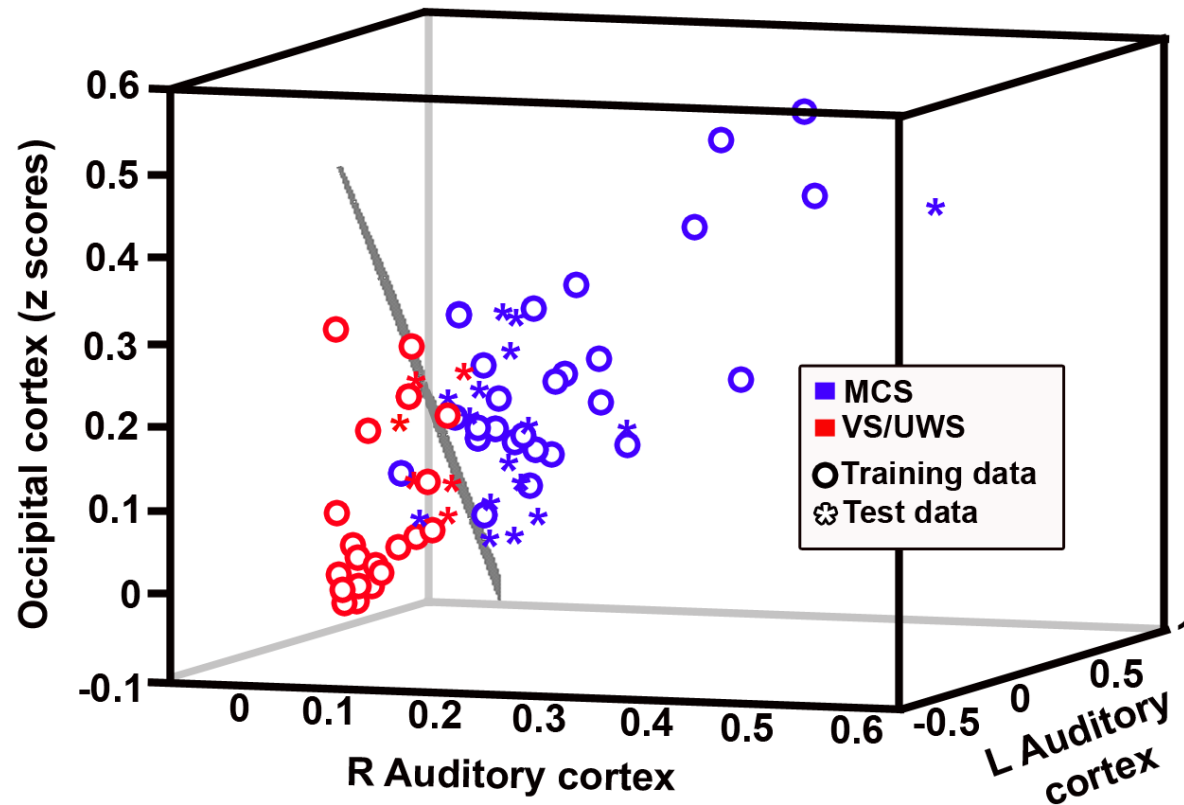


Biswal et al., *Magn Reson. Med* 1995

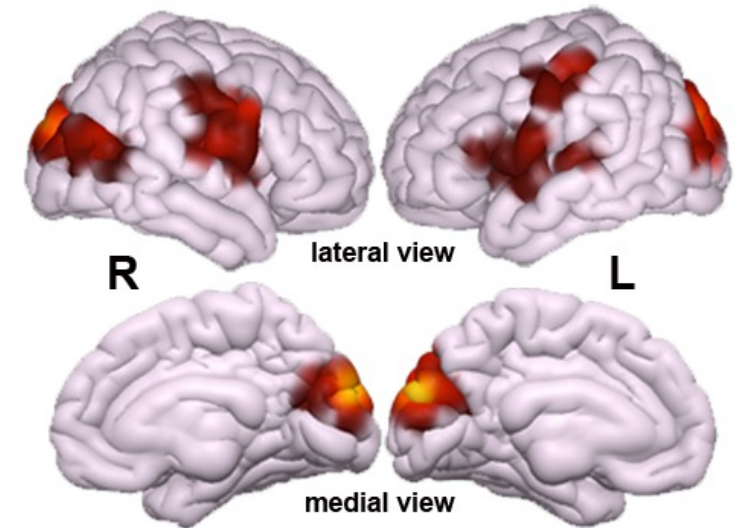
Smith et al, *PNAS* 2009

Heine et al, *Front Psych* 2012

Cross-modal connectivity classifies DoC patients



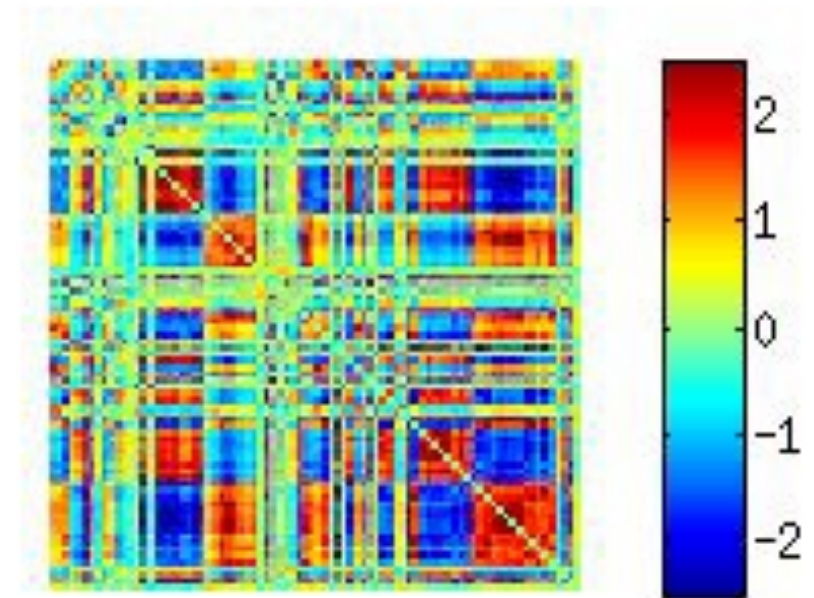
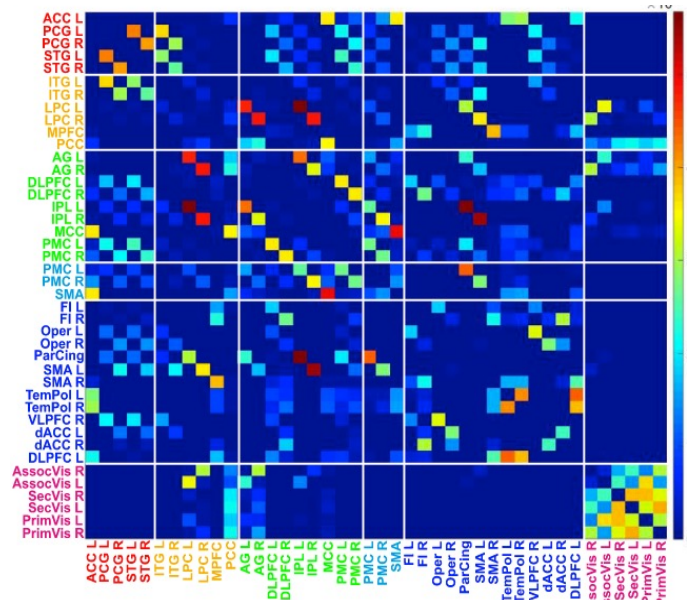
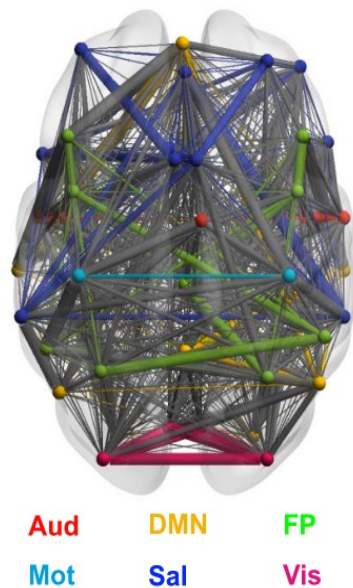
- Training set: 45 patients (26 MCS, 19 UWS)
- Test set (independent) : 22 patients (16 MCS, 6 UWS)



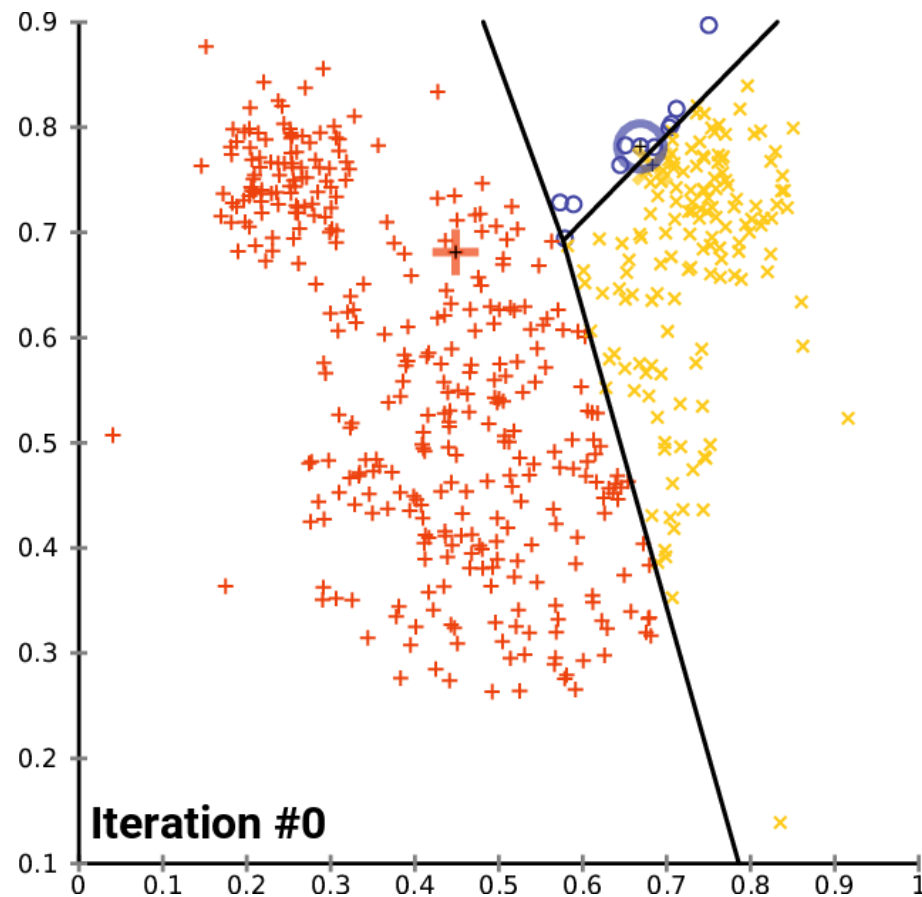
The brain as a dynamic network

100 billion neurons, ~100 trillion synaptic connections

The Connectome

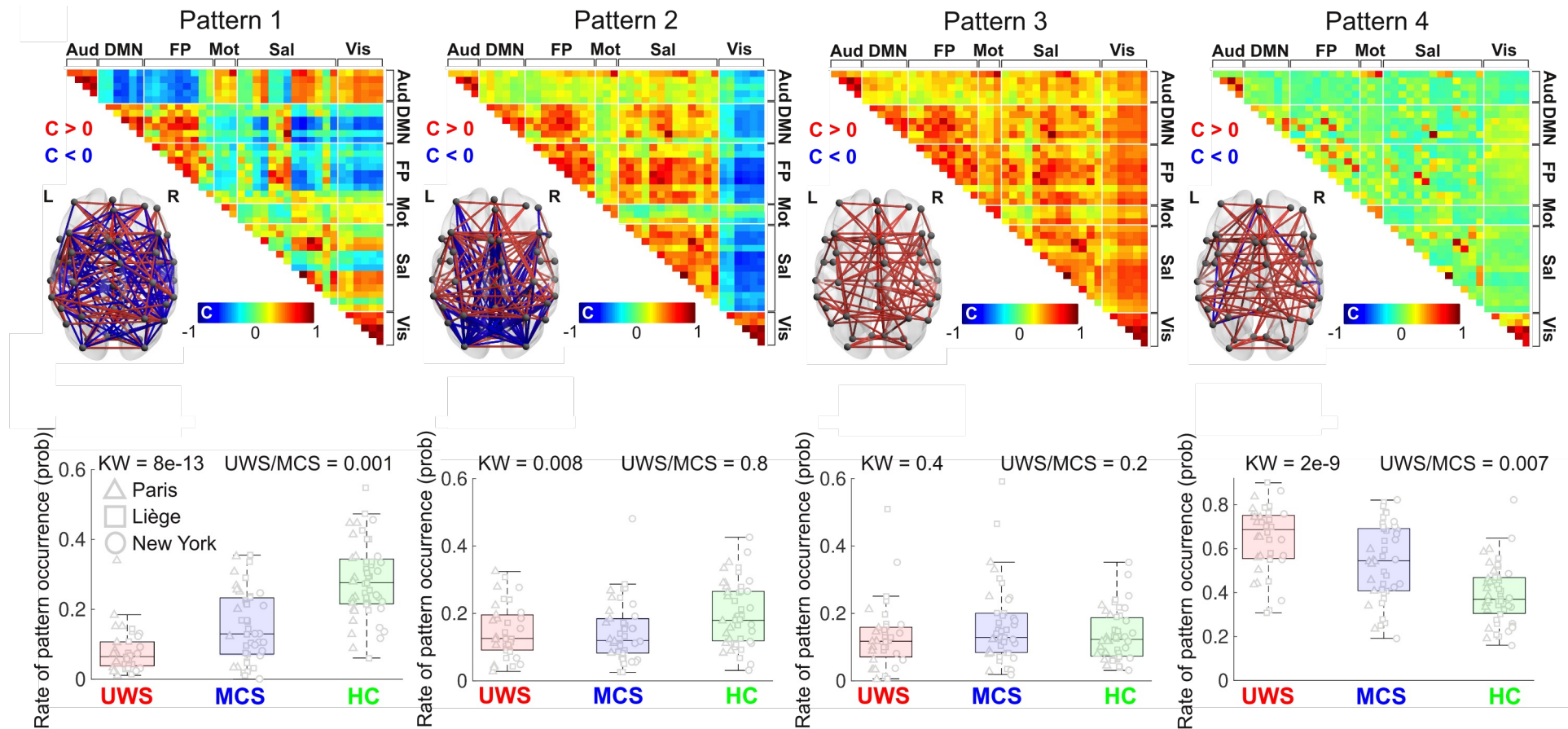


Unsupervised Clustering



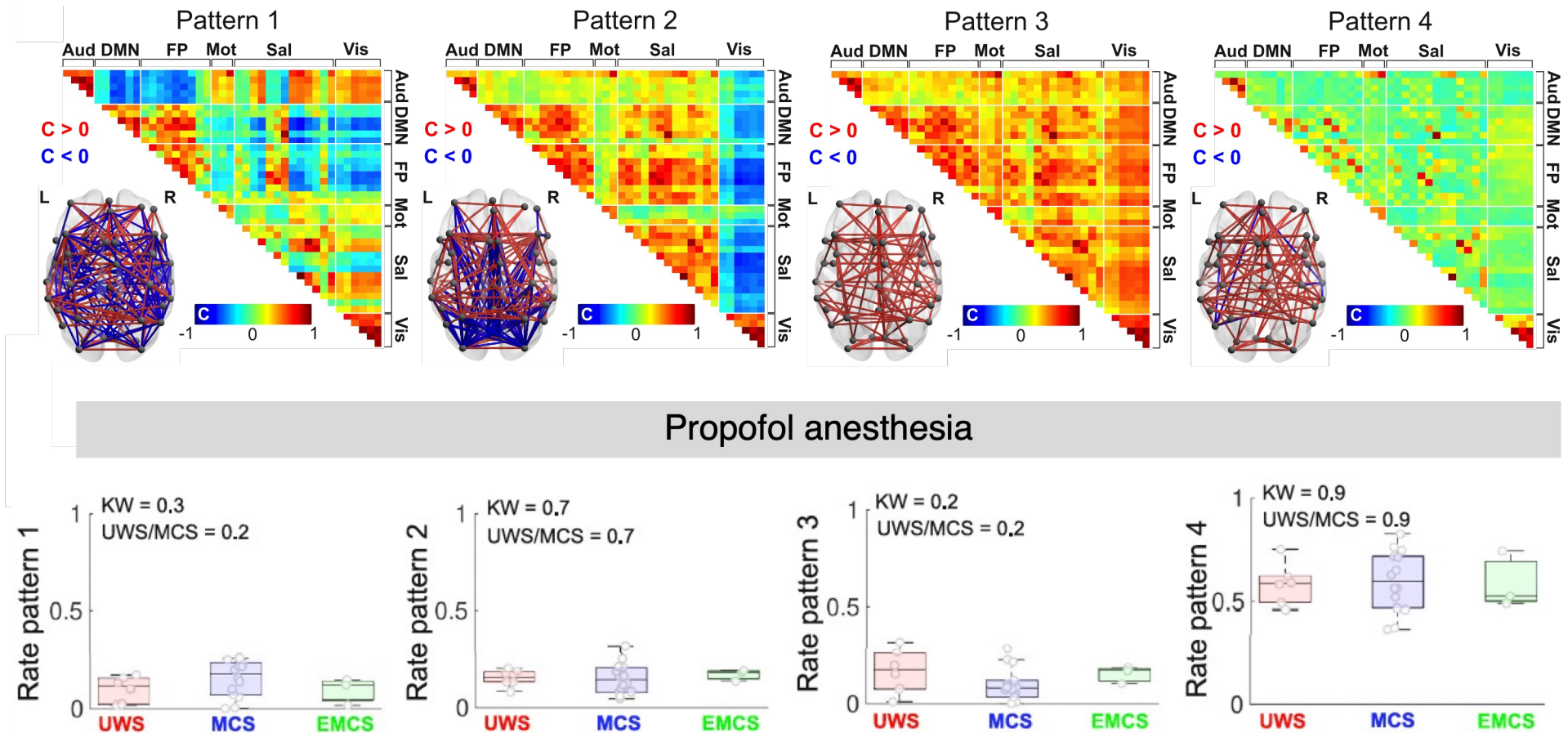
By Chire - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=59409335>

“Rich” connectivity in conscious states



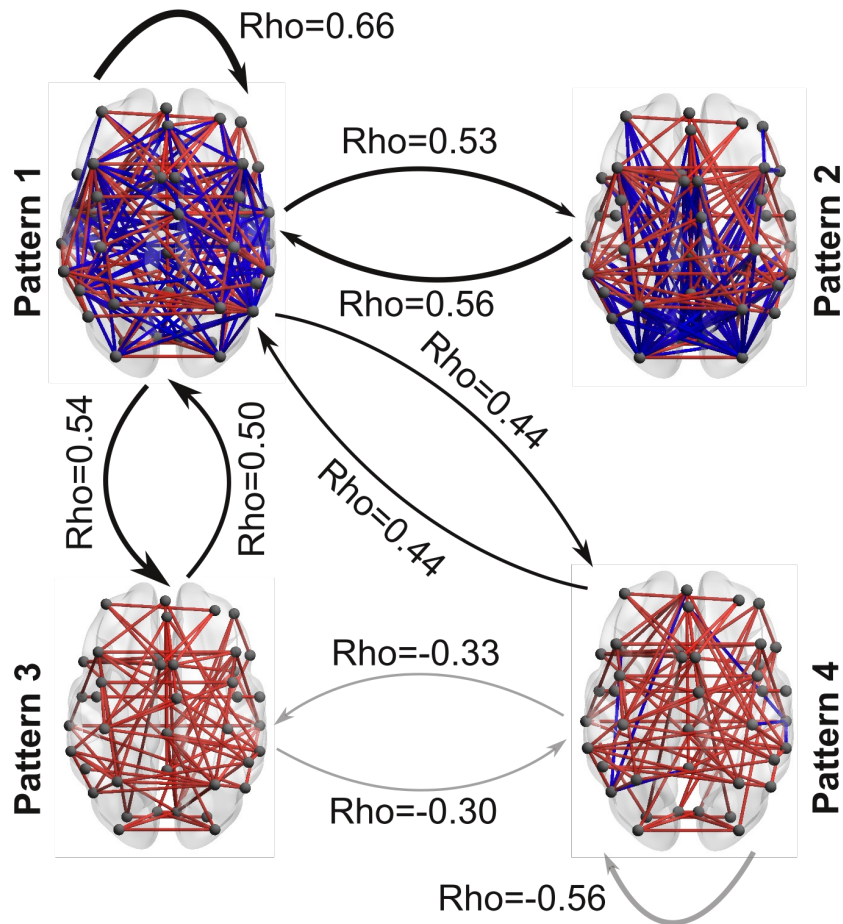
Demertzi* & Tagliazucchi*, Dehaene, Deco, Barttfeld, Raimondo, Martial, Fernández-Espejo, Rohaut, Voss, Schiff, Owen, Laureys, Naccache, Sitt.
Science Advances 2019

Simple connectivity in Unconsciousness



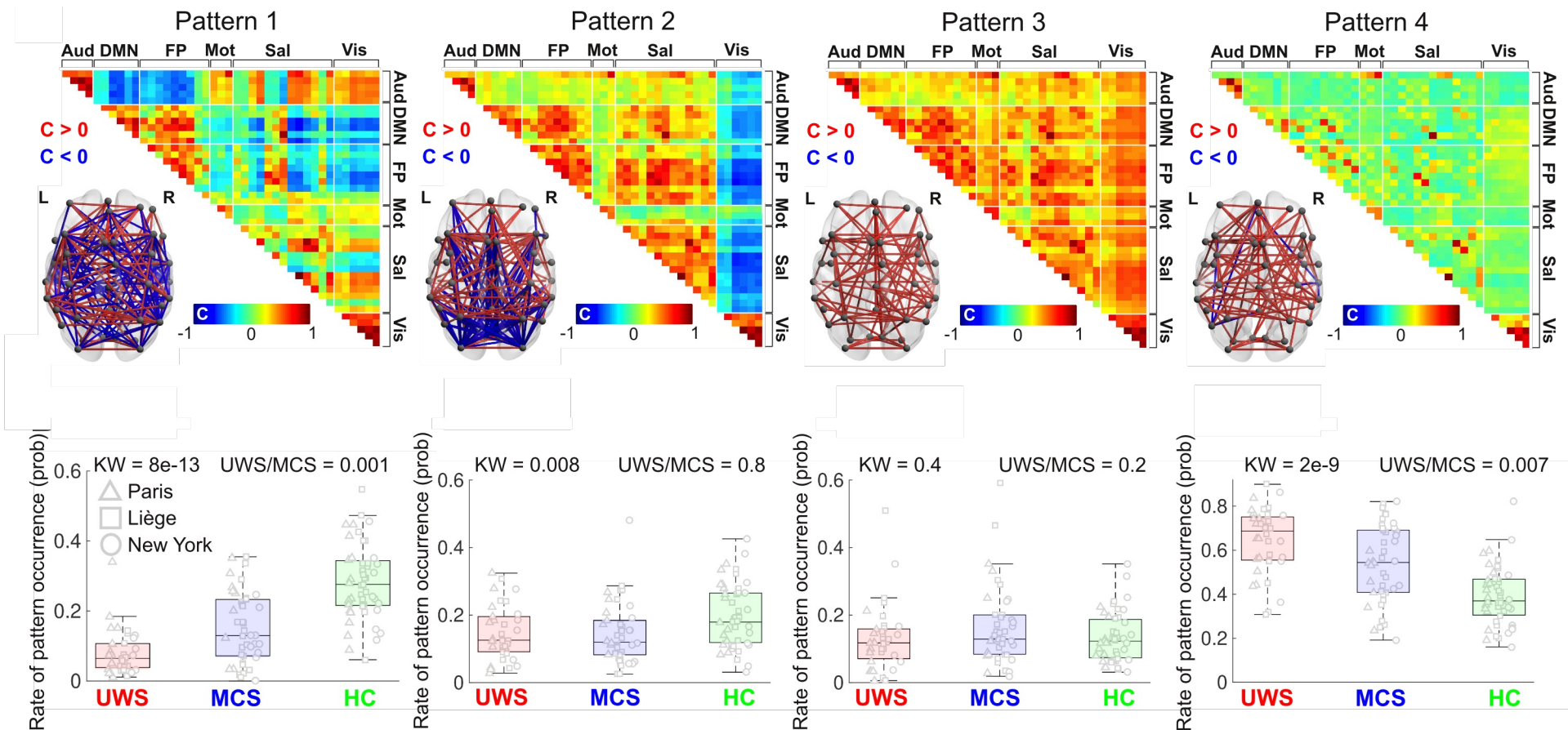
Demertzi* & Tagliazucchi*, Dehaene, Deco, Barttfeld, Raimondo, Martial, Fernández-Espejo, Rohaut, Voss, Schiff, Owen, Laureys, Naccache, Sitt.
Science Advances 2019

Higher dynamism in conscious states

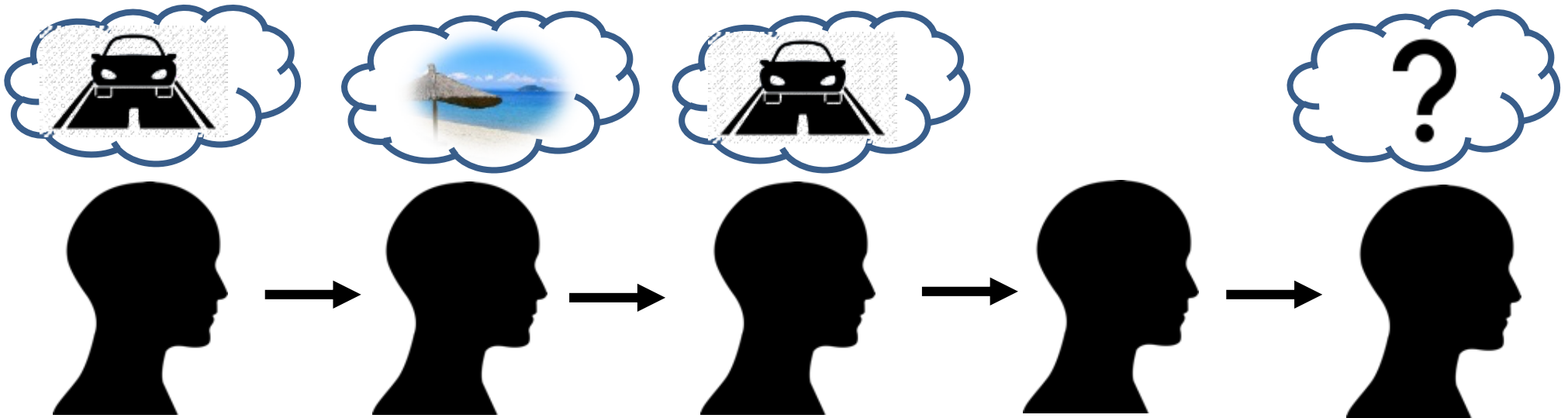


— Healthy > MCS > UWS
— UWS > MCS > Healthy

What do these patterns mean?



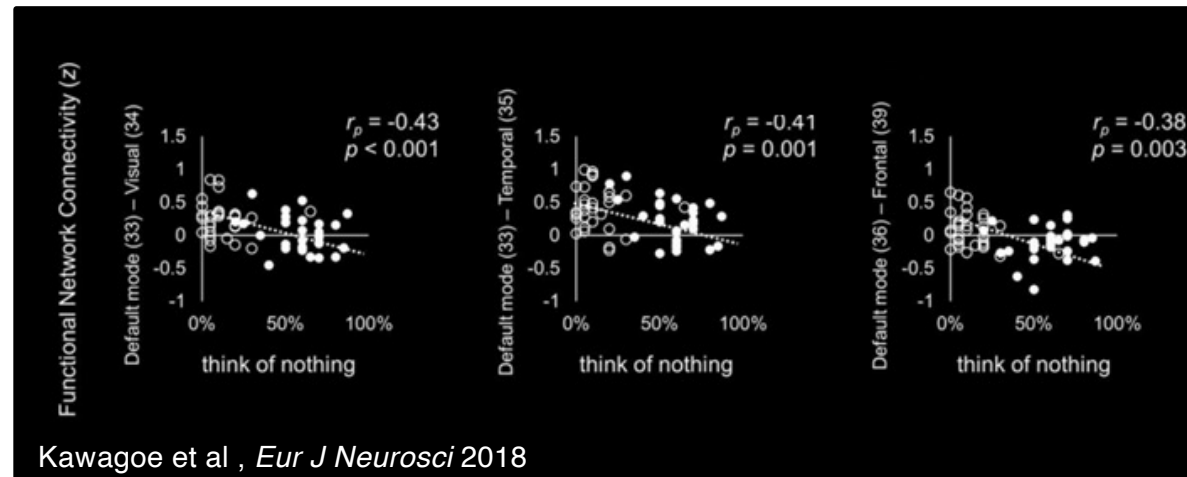
Mental states



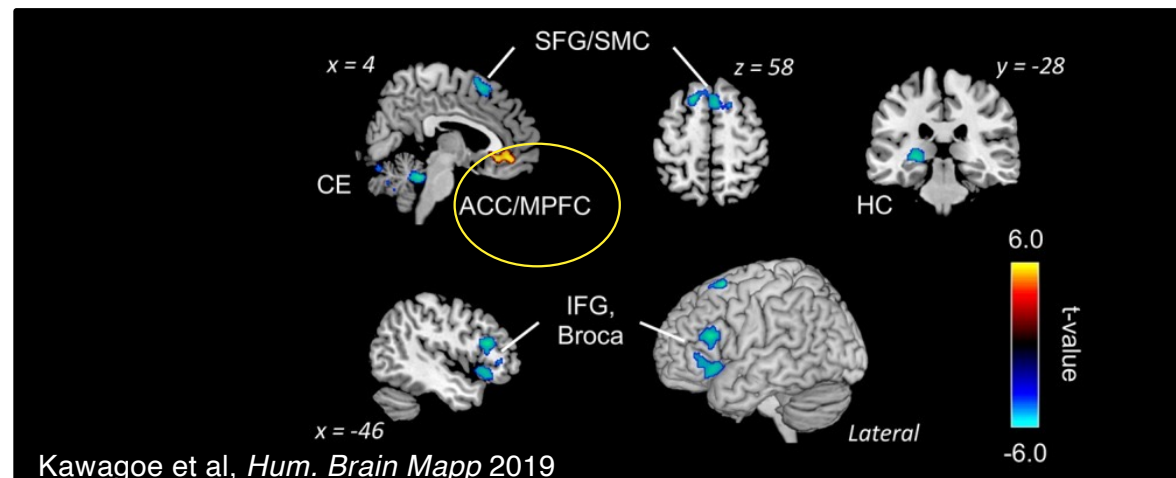
Slide courtesy: Boulakis Paris, Physiology of Cognition Lab

Voluntary Mind Blanking?

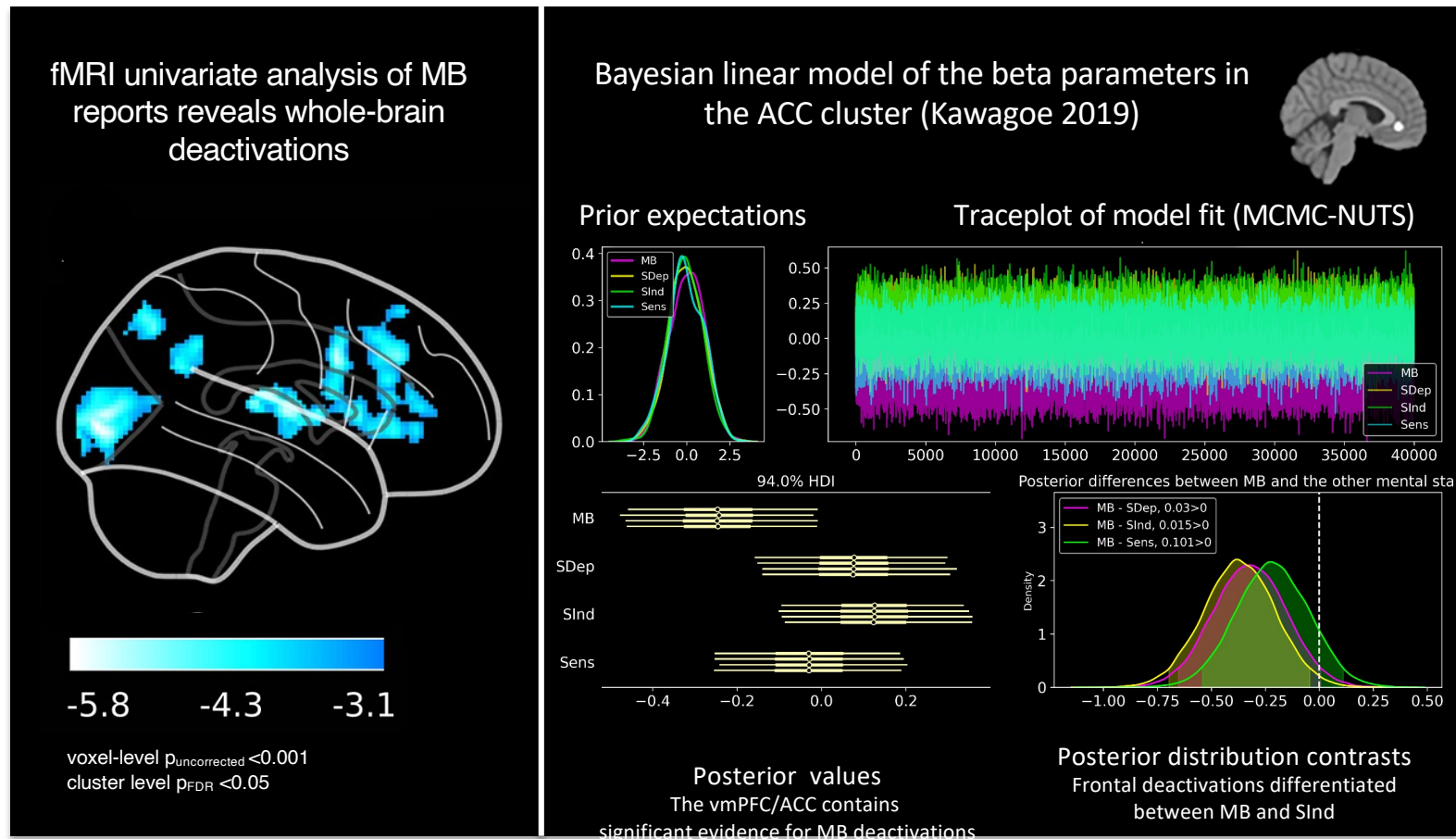
"Keep awake, fixate on the cross, and think of nothing as best you can. When you realise that you are thinking about something, disengage your attention and again try to think of nothing".



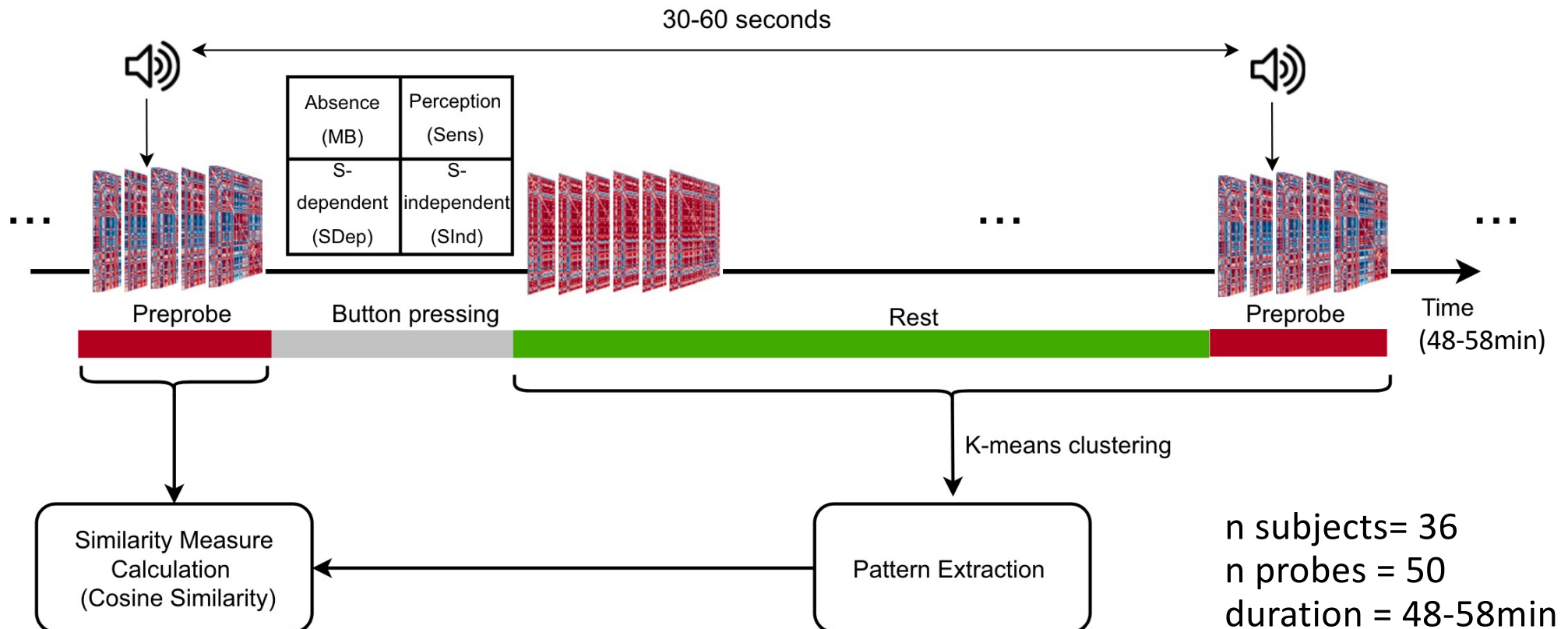
"When you realize that you are thinking about something, disengage your attention and again try to think of nothing during the scans"



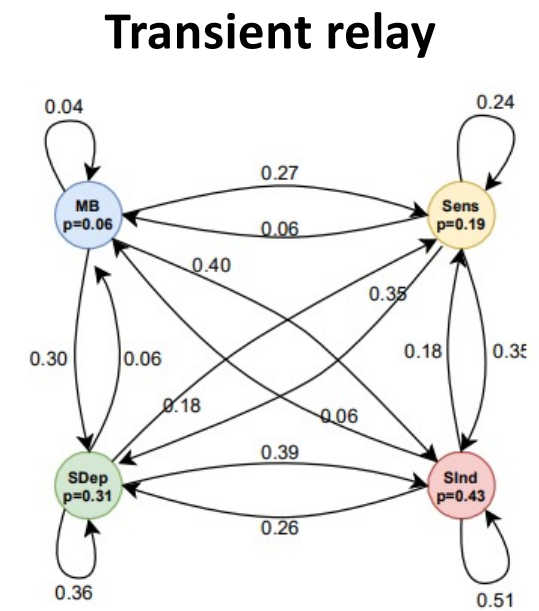
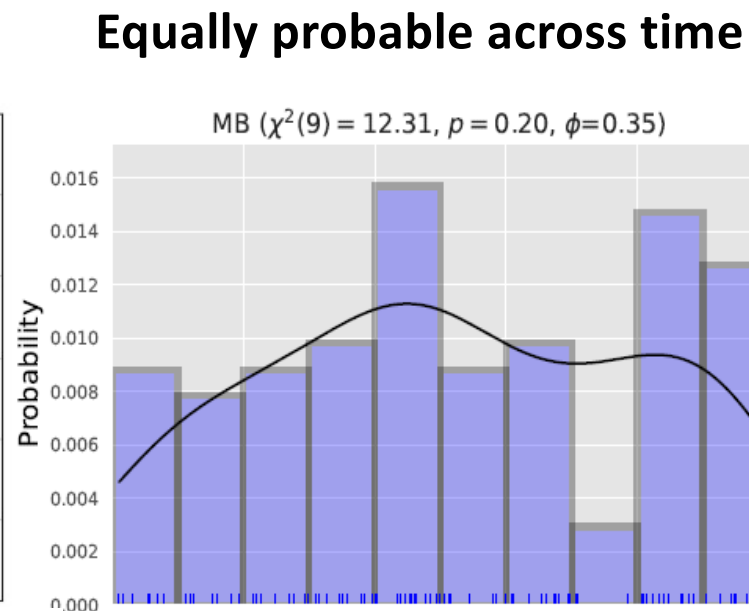
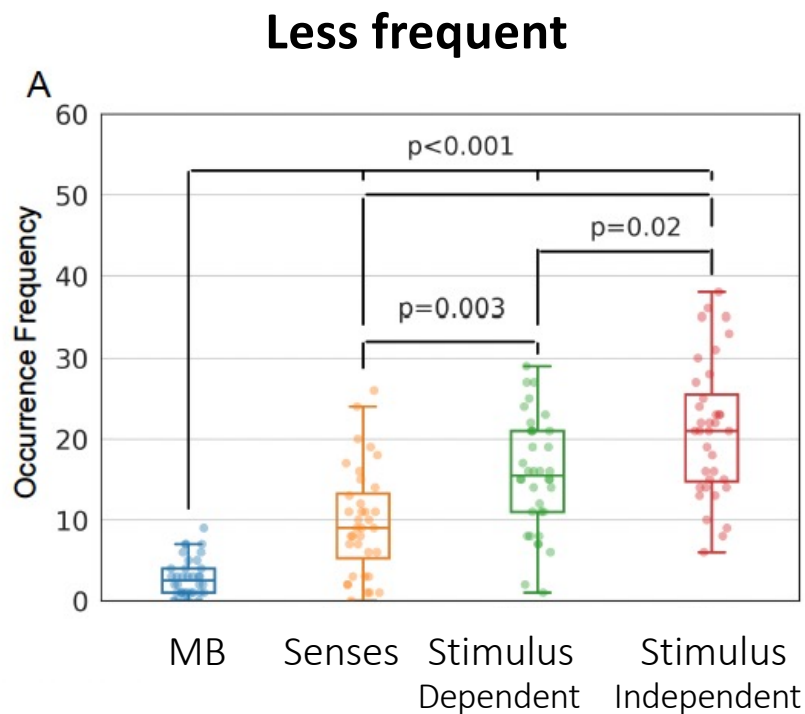
Probed Mind Blanking linked to widespread deactivations



Probing MB reports

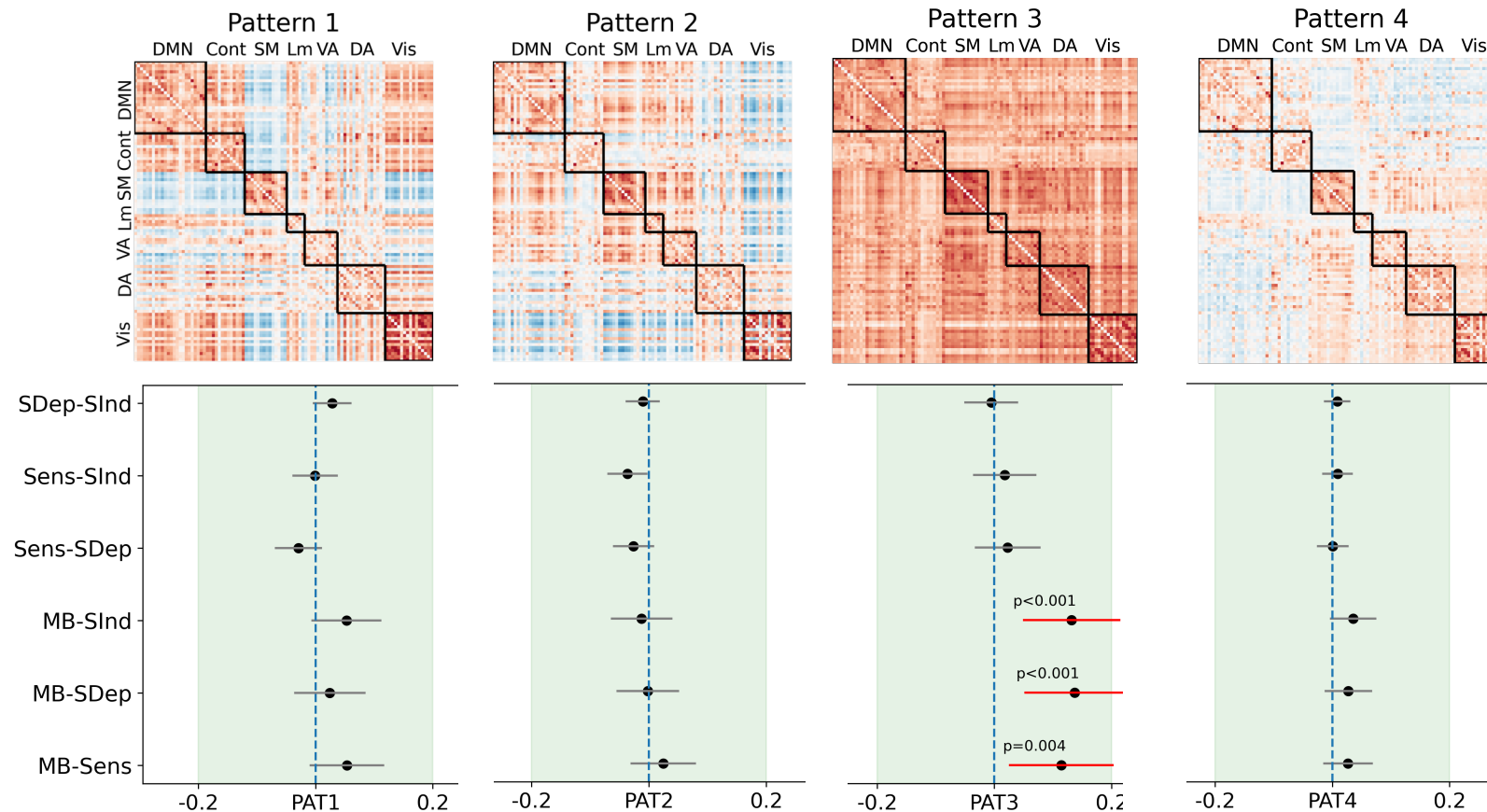


Mind Blanking characteristics

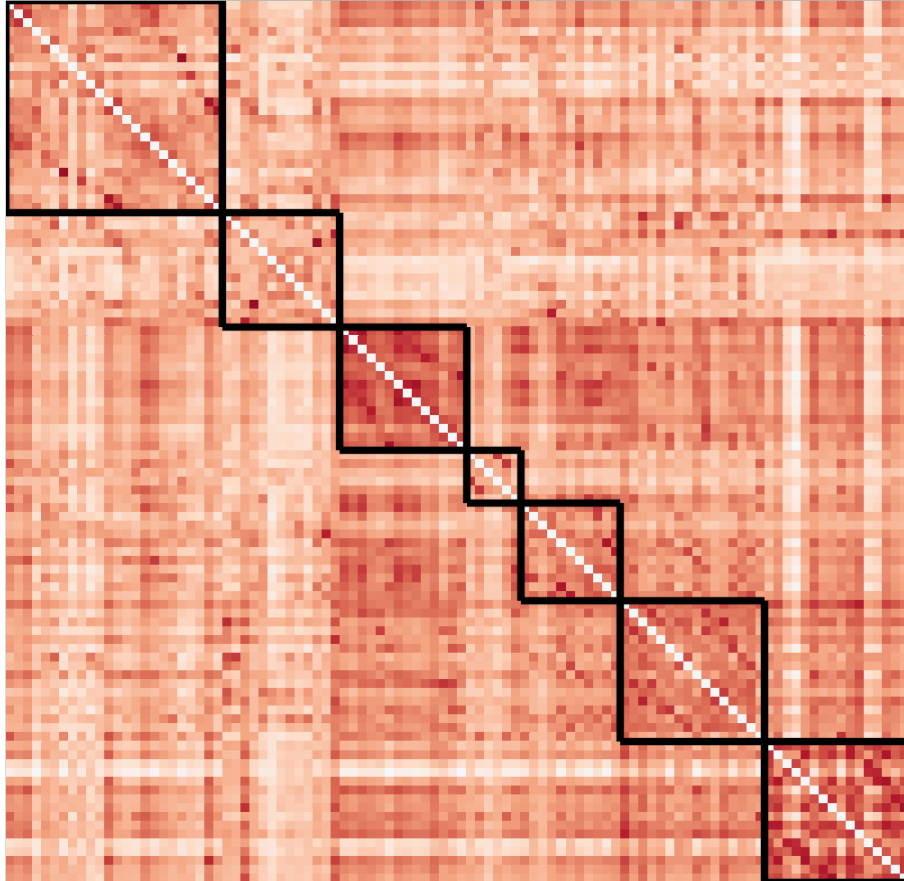


n subjects= 36
n probes = 50
duration = 48-58min

MB is linked to a hyper-connected pattern



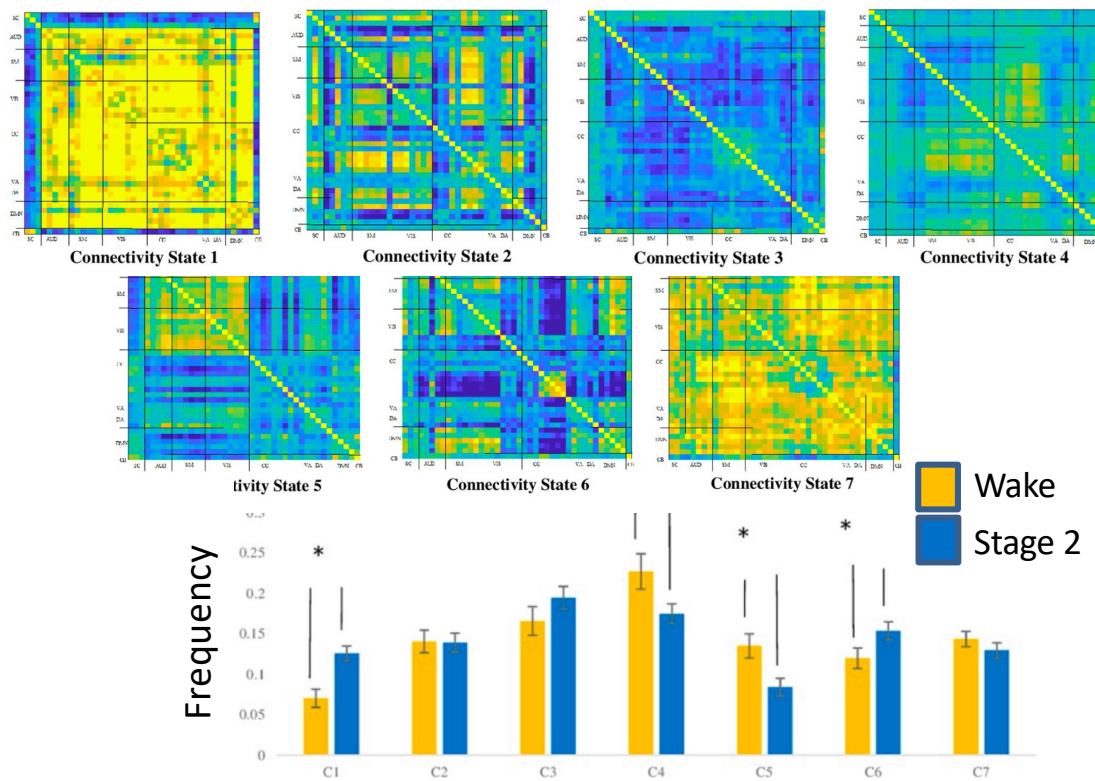
DMN Cont SM Lm VA DA Vis



**What is the
neurophysiological
substrate?**

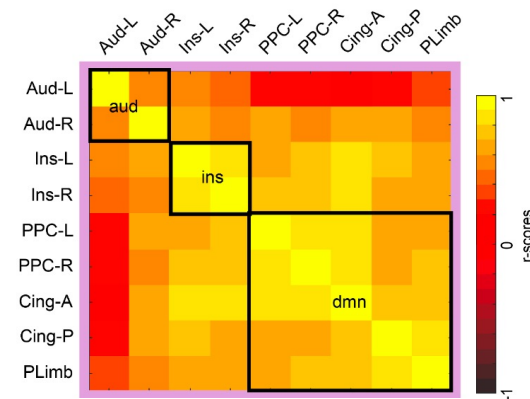
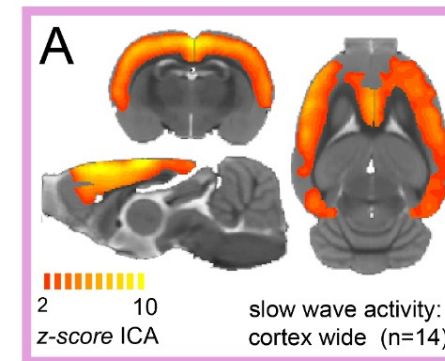
Higher connectivity in unconscious states

NREM sleep Humans



El-Baba et al, *PLOS One* 2019

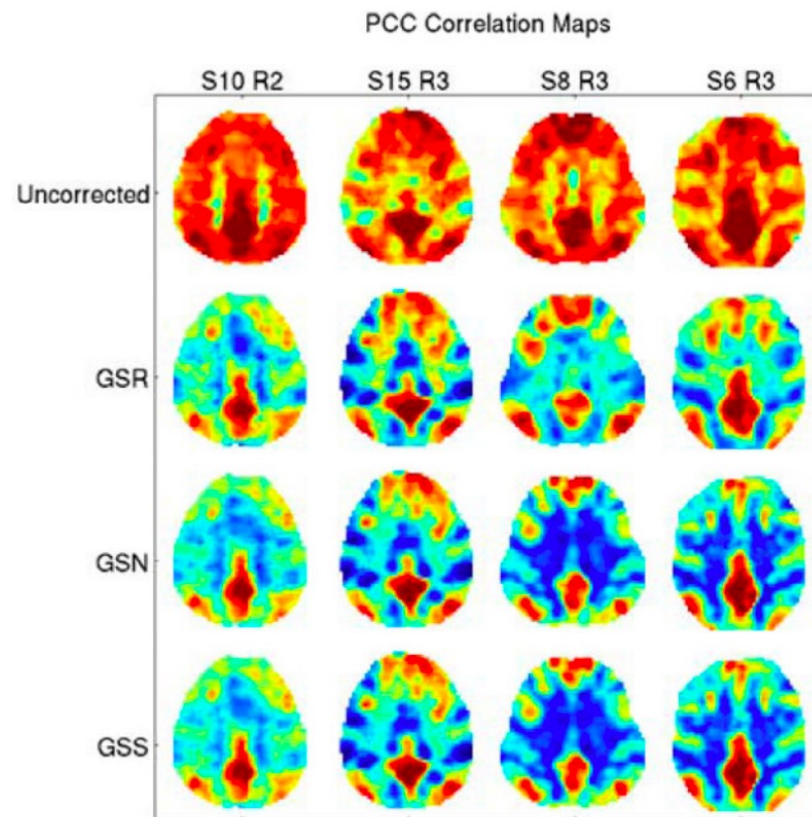
Isoflurane anesthesia Rats



Aedo-Jury et al, *eLife* 2019

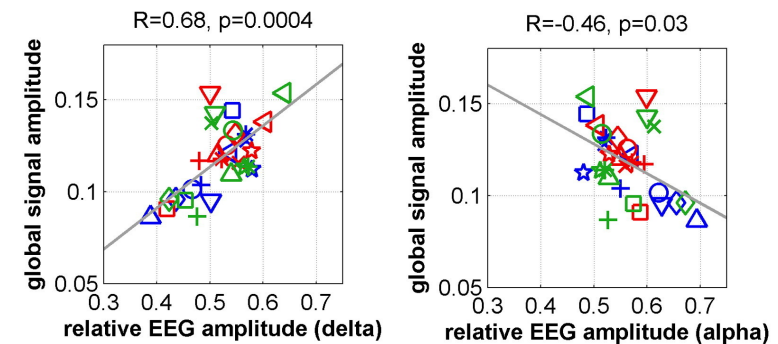
Higher Global Signal amplitude → Lower vigilance

The Global Signal

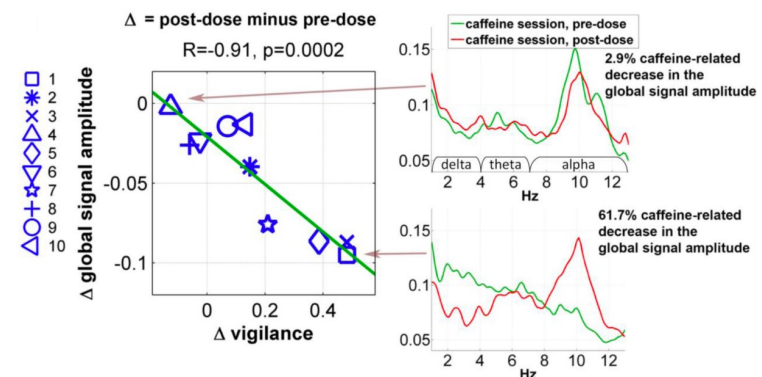


Liu et al, *NeuroImage* 2017

GS amplitude is linked to low arousal

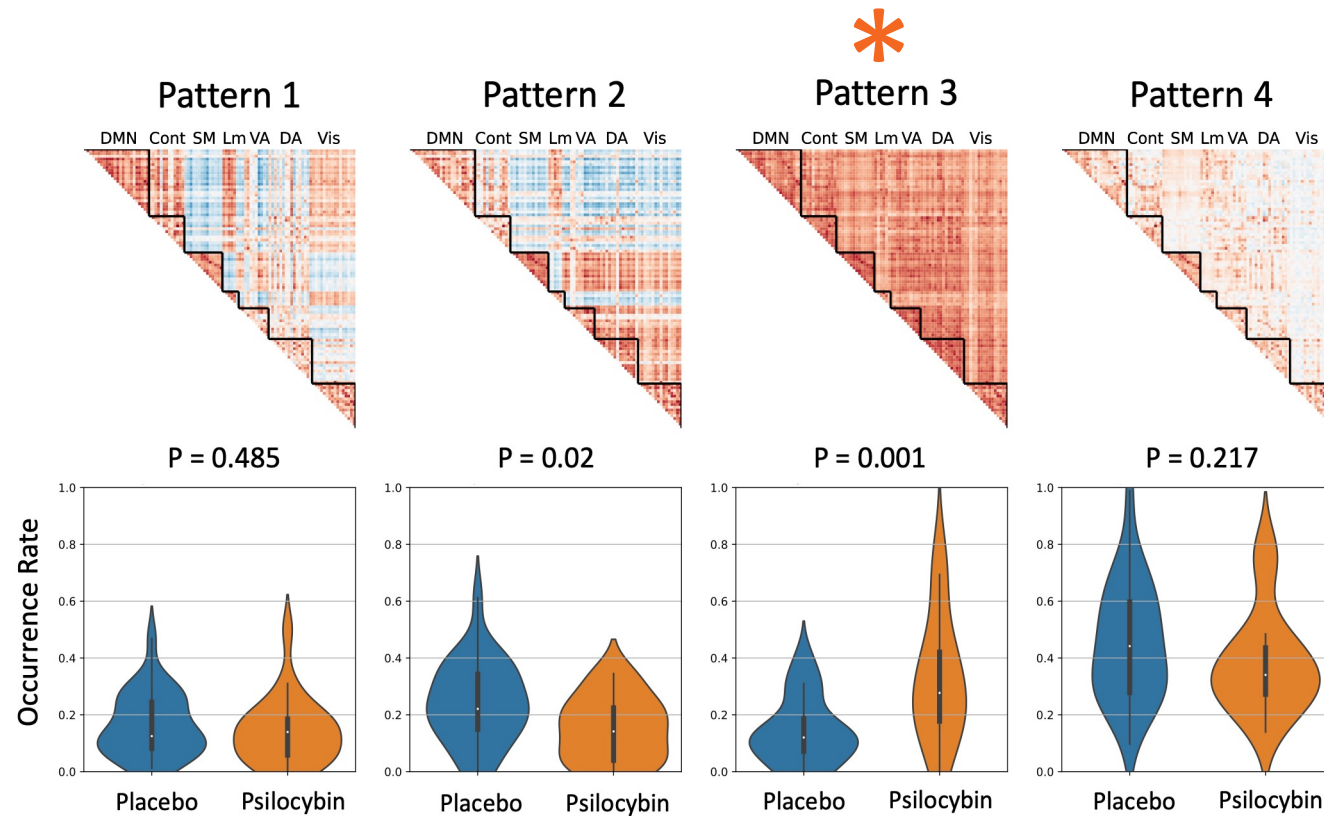


GS amplitude decreases with caffeine intake

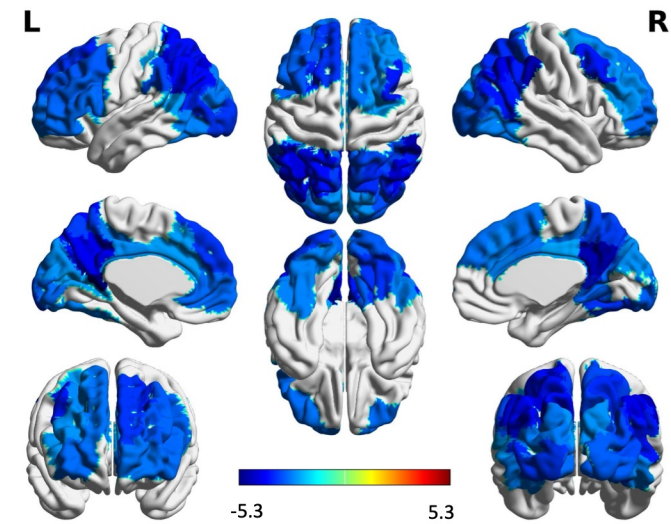


Wong et al, *Neuroimage* 2013

Lower Global Signal amplitude → Higher vigilance

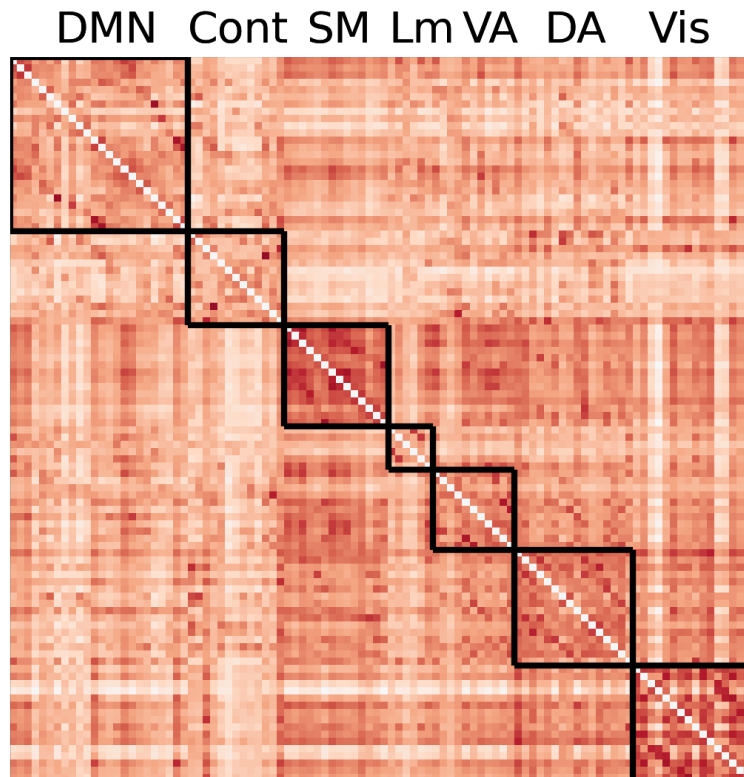


BOLD amplitude reductions

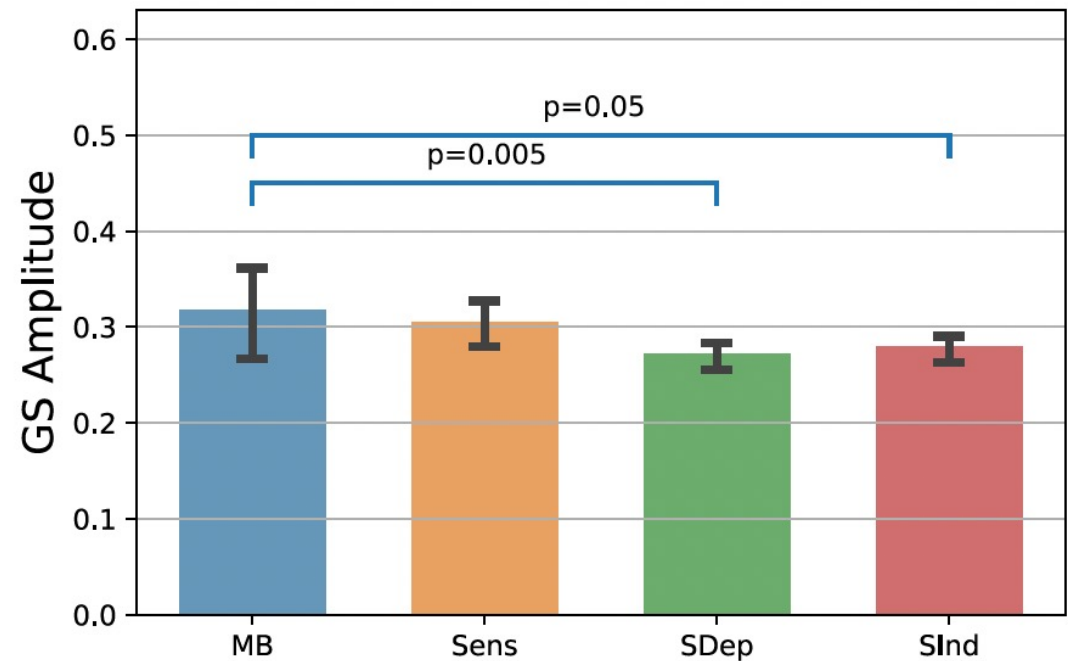


Psilocybin-Placebo

MB is mediated by low arousal levels



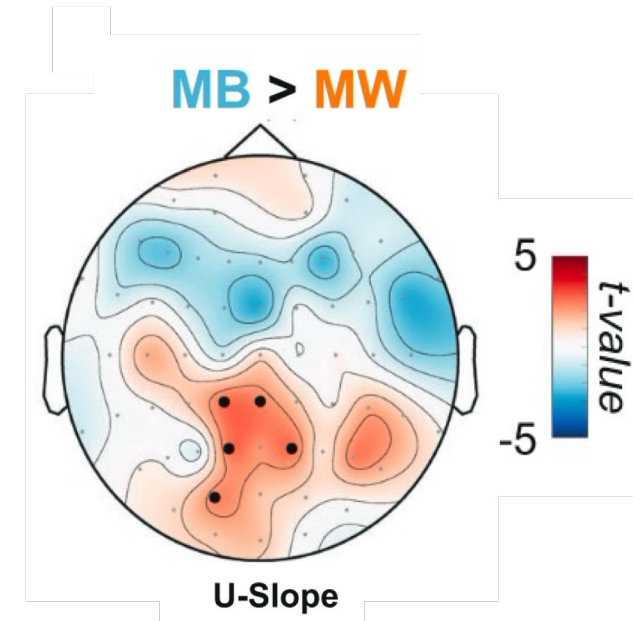
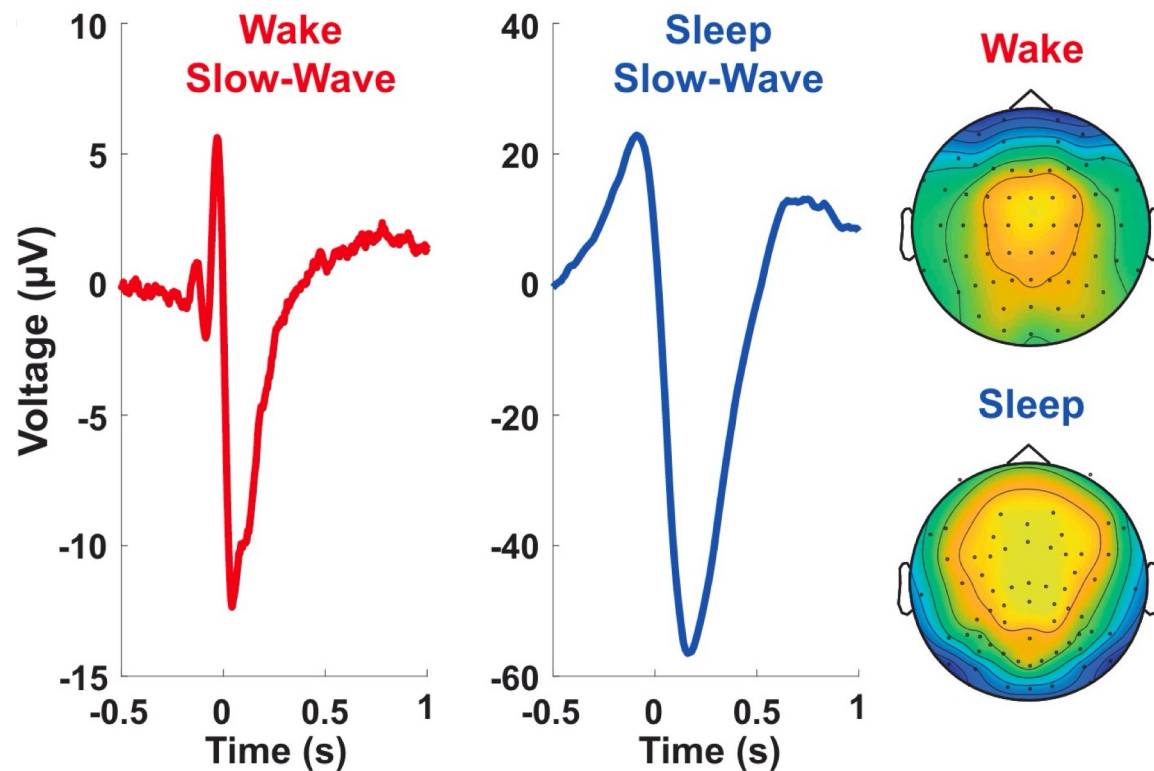
Higher Global Signal Amplitude when MB



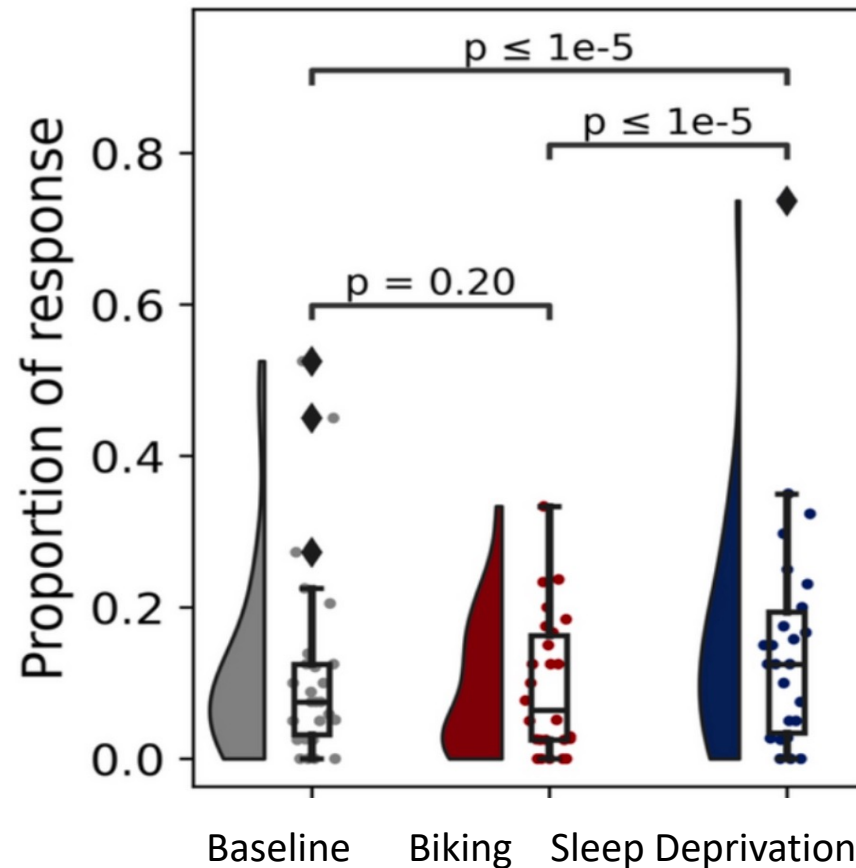
Slow wave-like activity in wakefulness

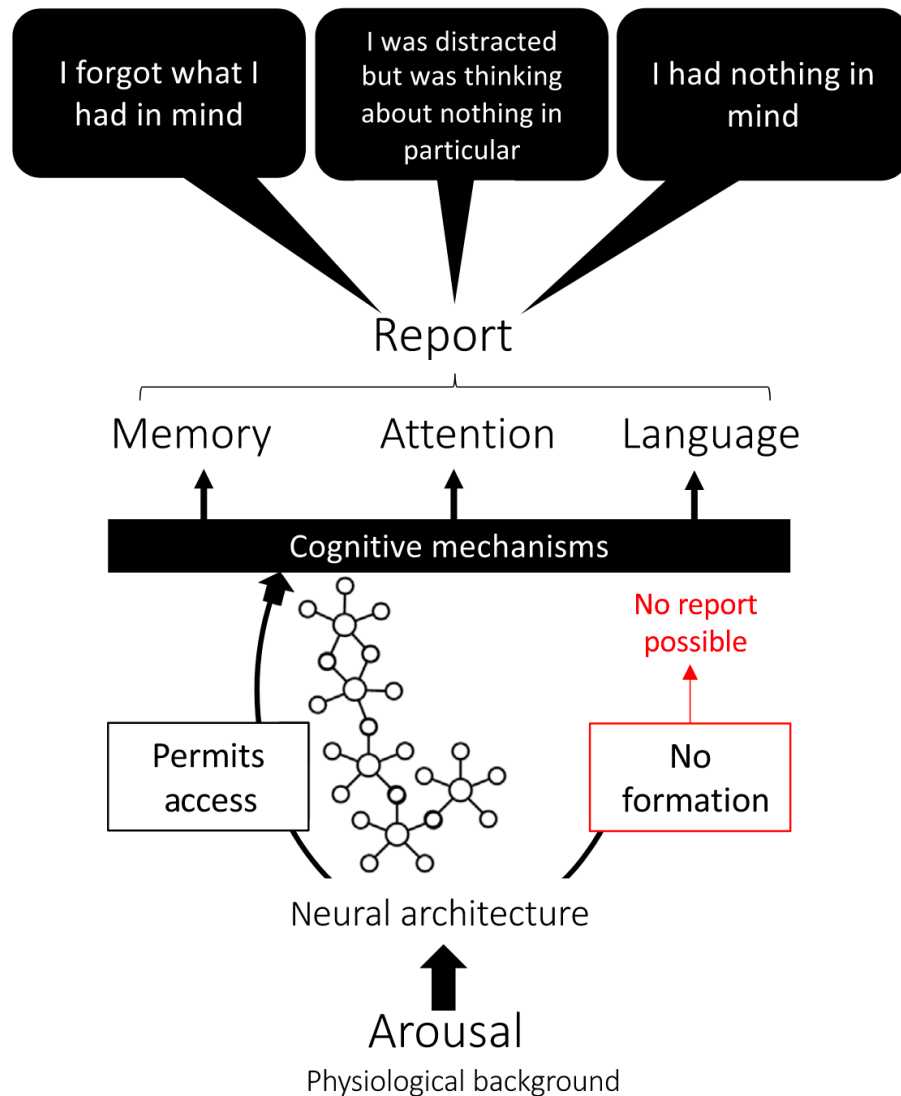
Properties of slow waves

Predictive of mental states



Altered arousal increases MB reports





Box 3. Clinical aspects of mind blanking

Reports of MB can manifest in different situations and thus shed light on the potential significance of MB in atypical and clinical contexts. MB occurrences were directly investigated in individuals with attention deficit hyperactivity disorder (ADHD) [7]. This work showed that unmedicated children with ADHD exhibited a higher number of MB reports during a sustained attention task compared to children treated with methylphenidate, children with no ADHD but with a psychiatric disorder, and a neurotypical group.

MB is also part of the clinical characterization of generalized anxiety disorder as mentioned in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5): 'Individuals with generalized anxiety disorder report subjective distress due to constant worry and related impairment in social, occupational, or other important areas of functioning. The anxiety and worry are accompanied by at least three of the following additional symptoms: restlessness or feeling keyed up or on edge, being easily fatigued, difficulty concentrating or mind going blank' [78].

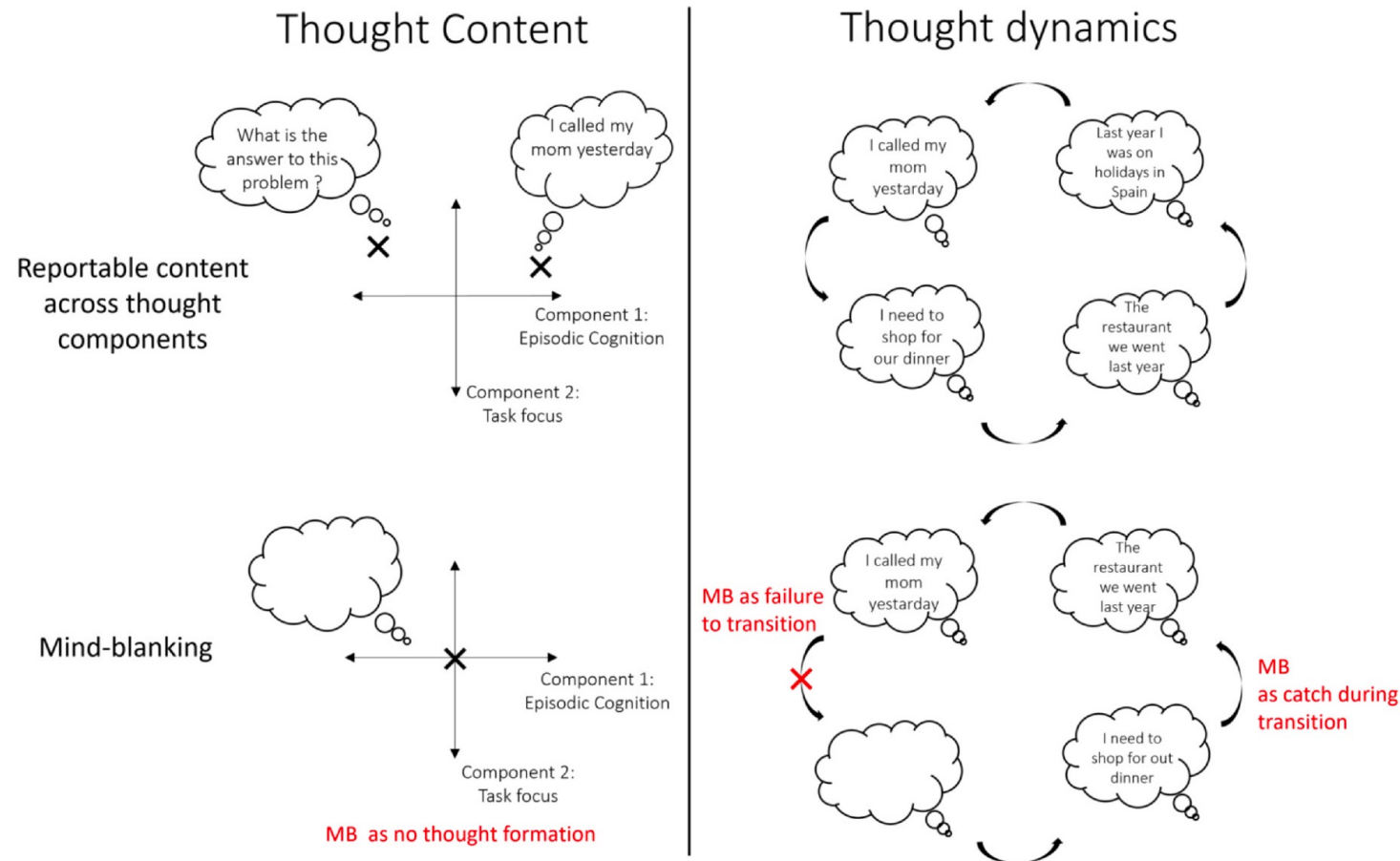
Another condition in which MB is relevant is the autoactivation deficit (AAD) syndrome. AAD is a neuropsychological syndrome resulting from a bilateral damage to the basal ganglia and is characterized by acute apathy and a loss of self-driven behavior that is partially reversible with external stimulation [79]. Patients with AAD also express the feeling that their mind is empty when they are not stimulated, hence echoing the mind blank reported in healthy people.

Kleine-Levin Syndrome (KLS), also known as the 'Sleeping Beauty syndrome', is another rare neurological disorder that primarily affects primarily teenage males and which is characterized by recurring episodes of excessive sleepiness, up to 20 h per day. The recurrent episodes of hypersomnia are usually accompanied by behavioral and cognitive disturbances. Although people with KLS behave typically between episodes, they may not be able to remember everything that happened during the episodes, leading to reports that resemble MB reports.

Another rare sleep disorder is idiopathic hypersomnia. Patients with idiopathic hypersomnia suffer from excessive daytime sleepiness despite casual or increased night-time sleep duration, and many suffer from long but unrefreshing naps [80]. Some of these patients may report experiencing a specific night 'blackout' when sleeping, namely an absence of consciousness encompassing not only the absence of dreams but also the feeling of an absence of thoughts and conscious experiences during the night [46].

Finally, during absence seizures children appear to briefly lose responsiveness (5–30 s) while they remain altogether wakeful¹. This is manifested as sudden blank stares, pauses in ongoing activity, and a temporary interruption in responsiveness with their surroundings, and features generalized spike-wave bursts at the low frequency of the EEG, accompanied by normal background brain activity. After the seizure ends, individuals may not always be aware that they were absent or had a seizure, although in some cases they might notice a gap in their memory or a brief disruption in their ongoing activities.

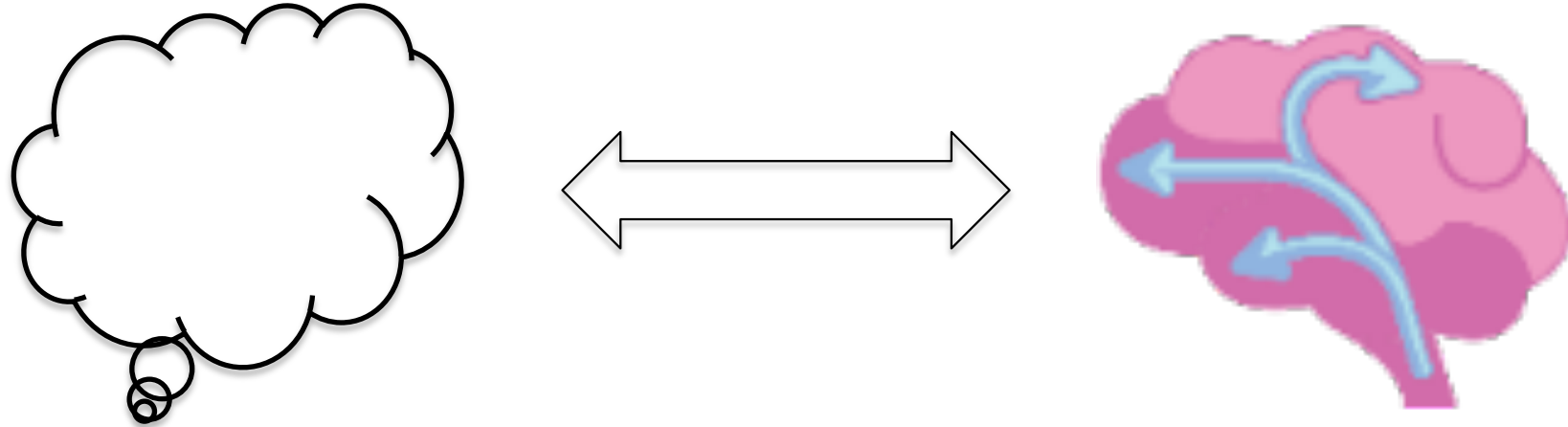
Different mechanisms of MB



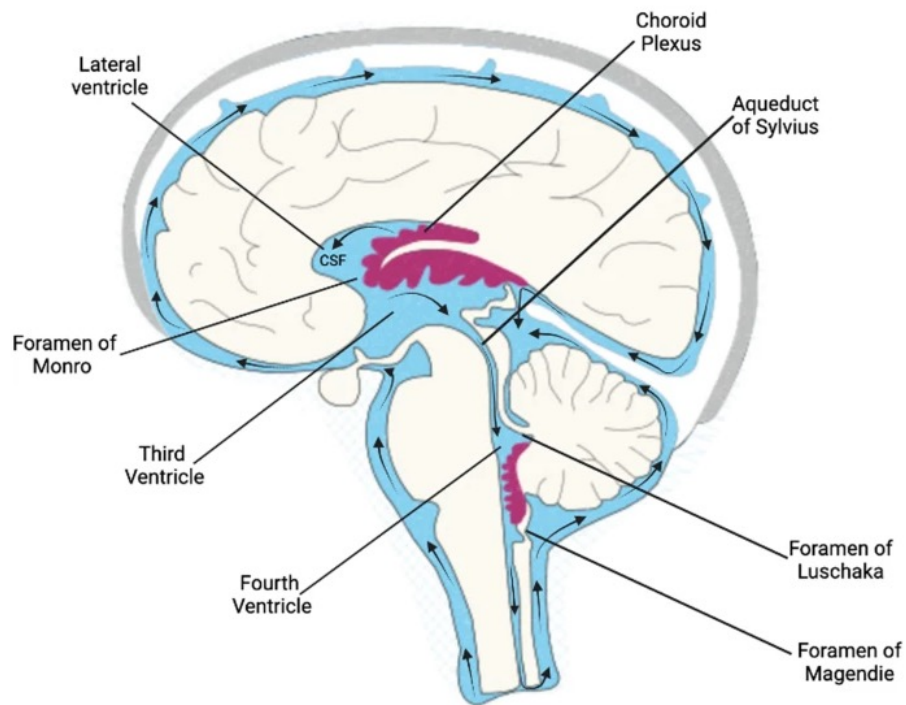


**Why do we
mind blank?**

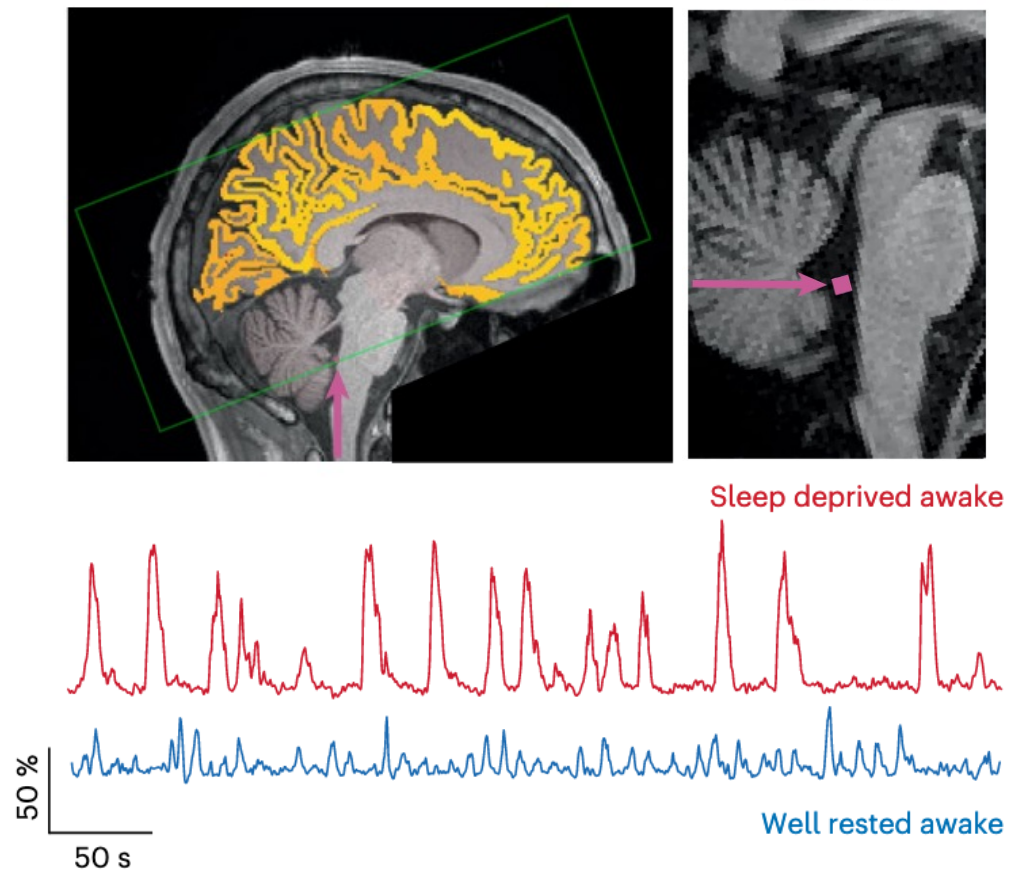
Empty Mind – Busy Brain



Low arousal is linked to higher CSF movement

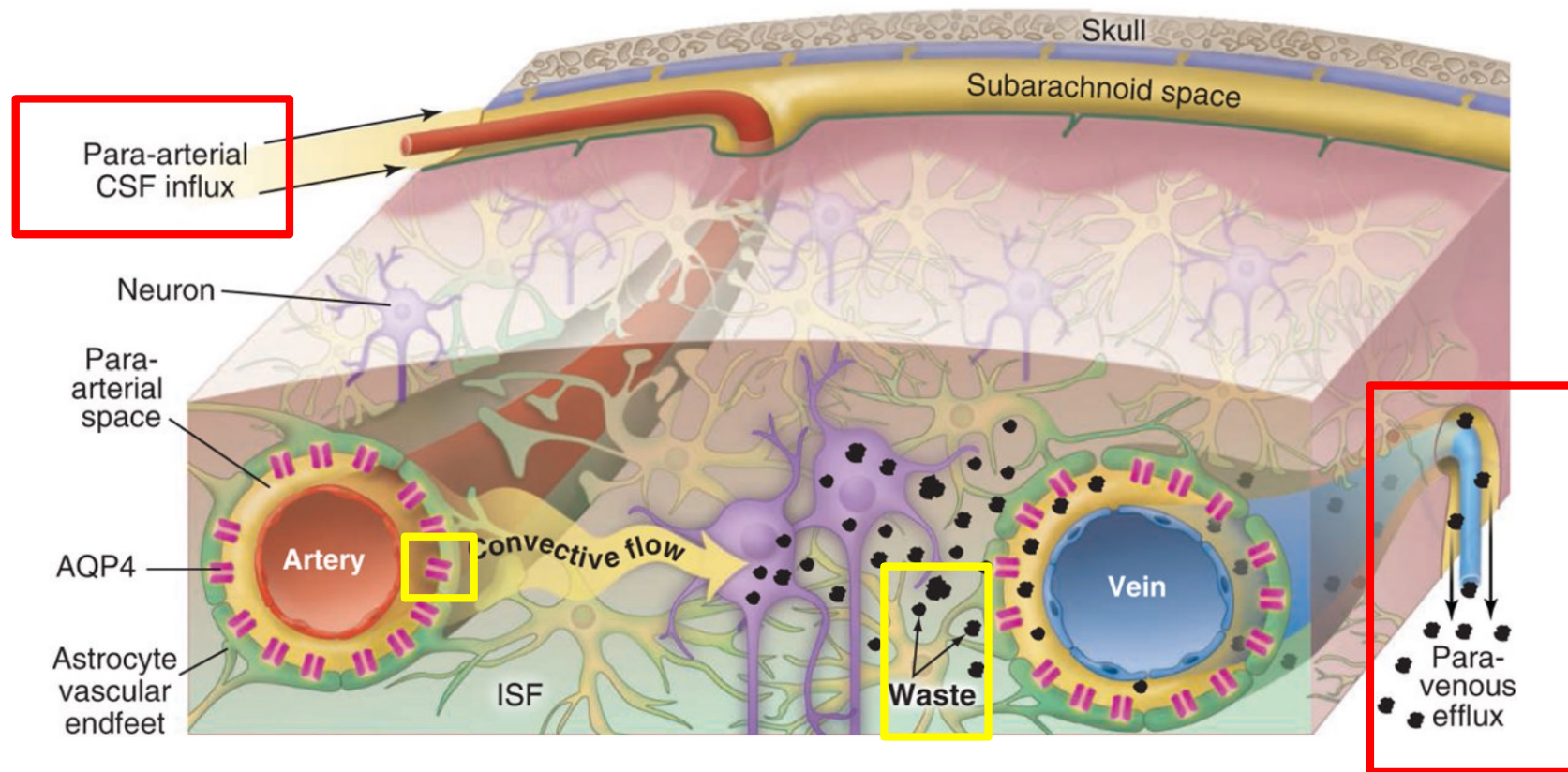


Bitanirwe, Lizano & Woo. *Molecular Psychiatry* (2022)



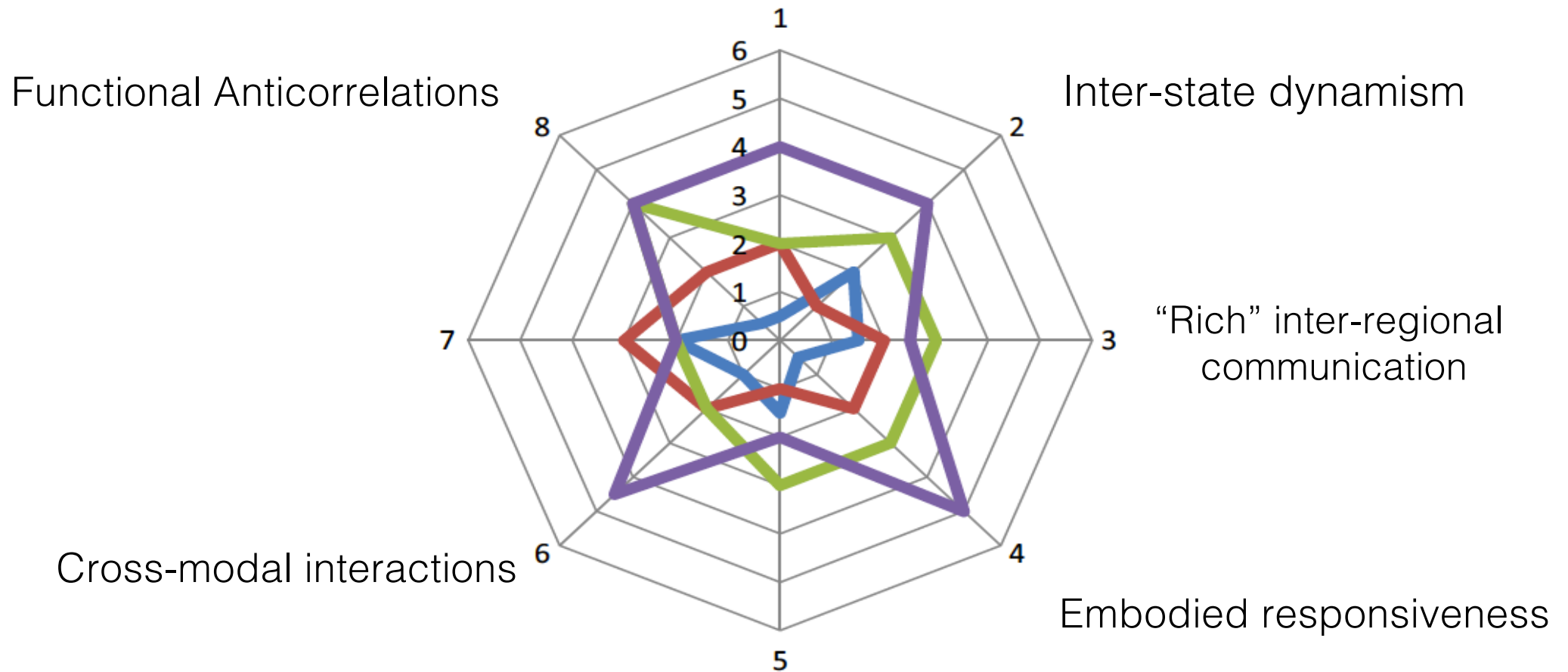
Yang et al., *Nature Neuroscience*, 2025

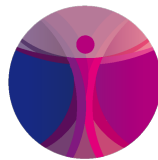
Glymphatic clearance



Nedergaard, *Science*, 2013
Demertzi & Andillon, *in prep*

Consciousness is multidimensional





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