Symposium

Empirical and philosophical challenges for current theories of consciousness

Neural correlates of mind blanking in the human brain
Challenges for consciousness theories

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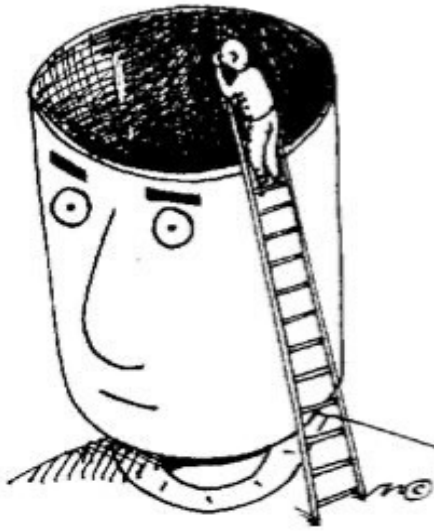
6ο Πανελλήνιο Συνέδριο Γνωσιακής Επιστήμης

Ξυλόκαστρο
22 Σεπτεμβρίου 2023

Limits of Reportability



Clinical Physiological Typical

- wakefulness +

The resting brain

Brain ~2% body's weight

Evoked changes <5%

80% for neuronal signaling

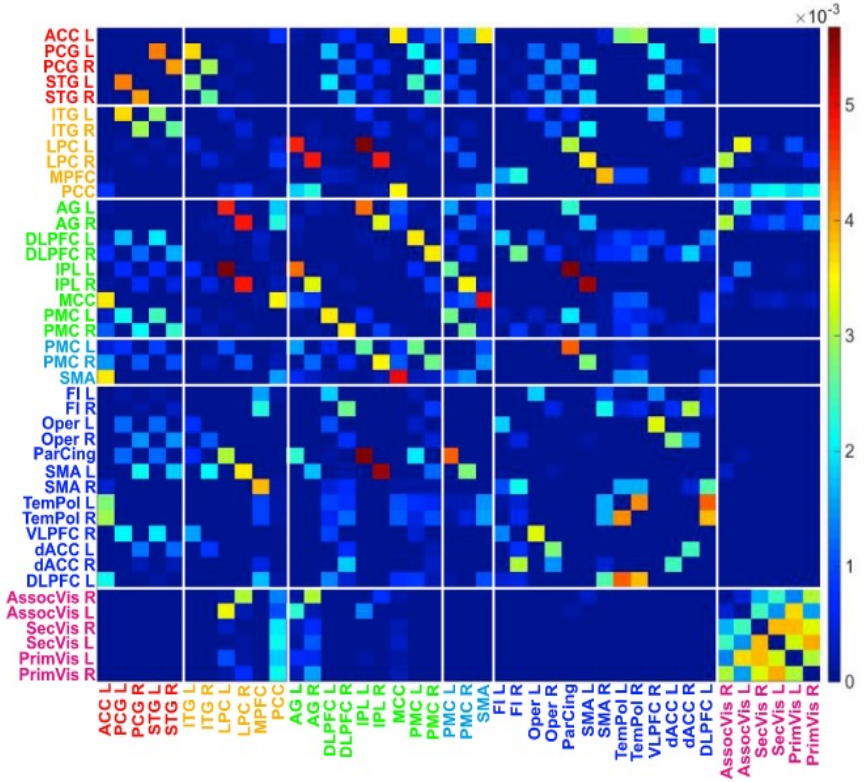
"While conscious awareness is […] energetically inexpensive, it is dependent upon a very complex, dynamically organized state of the brain that is achieved at great expense"

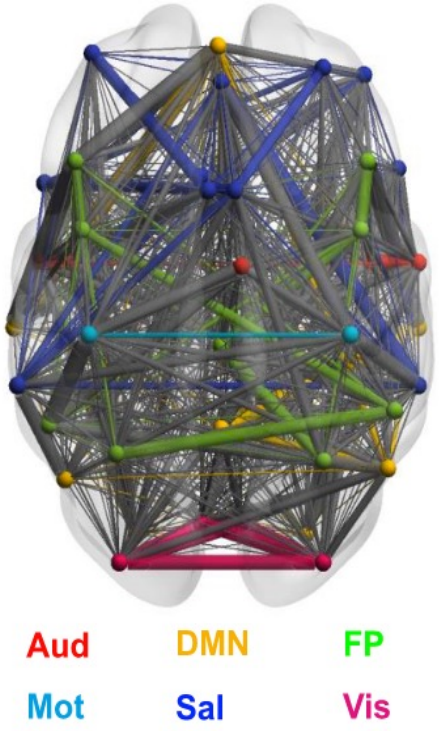
(Raichle M. *Science* 2006)

The brain as a network

100 billion neurons, ~100 trillion synaptic connections

The Connectome





A matrix representing all possible pairwise anatomical connections between neural elements of the brain

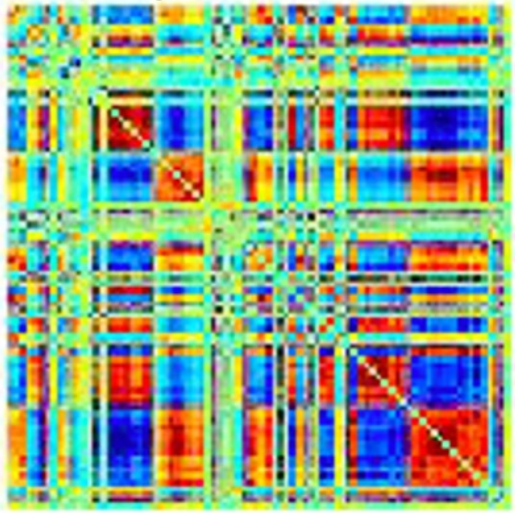
Sporns, Tononi, & Koetter. *PLoS Comput. Biol.* 2005

Fornito, Zalesky, Bullmore. Ch 1: An Introduction to Brain Networks. *Fundamentals of Brain Network Analysis, Academic Press* 2016

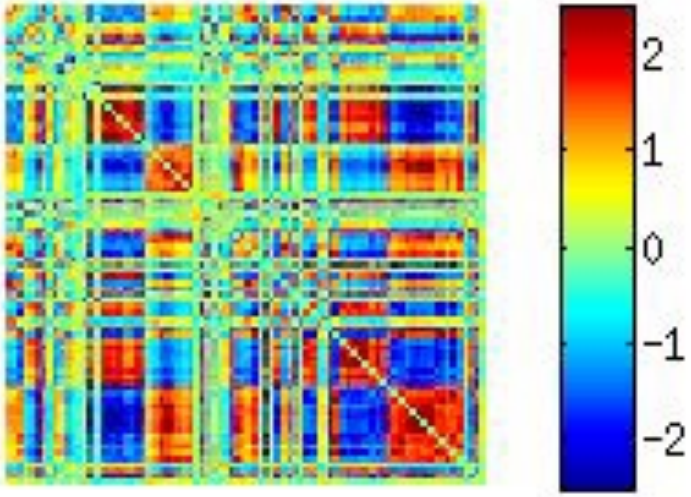
Image from: Demertzi & Tagliazucchi, Dehaene, Deco, Barttfeld, Raimondo […] et al, *Science Advances* 2019

Brain dynamics and cognition

Averaged connectome



Time-varying connectome



Typical wakefulness

Performance, emotion and cognition

Alavash et al, *Neuroimage*, 2016; Shine et al *Neuron*, 2016; Friston *Neuroimage*, 1997; Thompson et al, *Hum Brain Mapp,* 2013

Unconsciousness

Rigid spatiotemporal organization, less metastable dynamics

- sleep (Tagliazucchi et al, *PNAS* 2013; Wang et al, *PNAS* 2016; Wilson et al., *Neuroimage* 2015; Chow et al, *PNAS* 2013)
- anesthesia
  - humans (Tagliazucchi et al, *J. R. Soc. Interface* 2016; Kafashan et al, *Front Neural Circuits*, 2016; Amico et al, *PLoS One* 2014)
  - animals (Barttfeld et al, *PNAS* 2014; Grandjean et al, *Neuroimage* 2017; Liang et al, *Neuroimage* 2015)

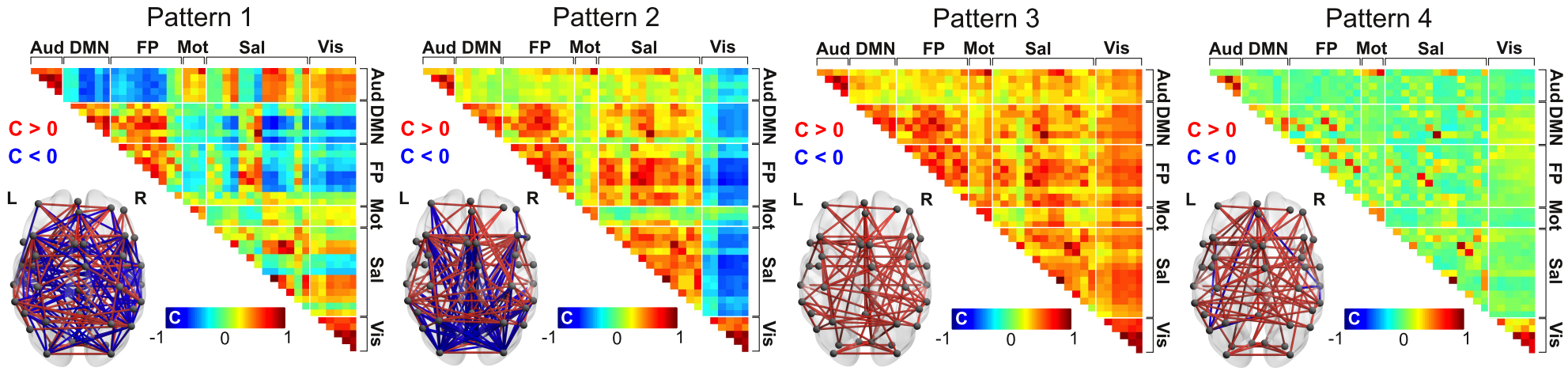
The brain cannot map the complexity of internal and external world

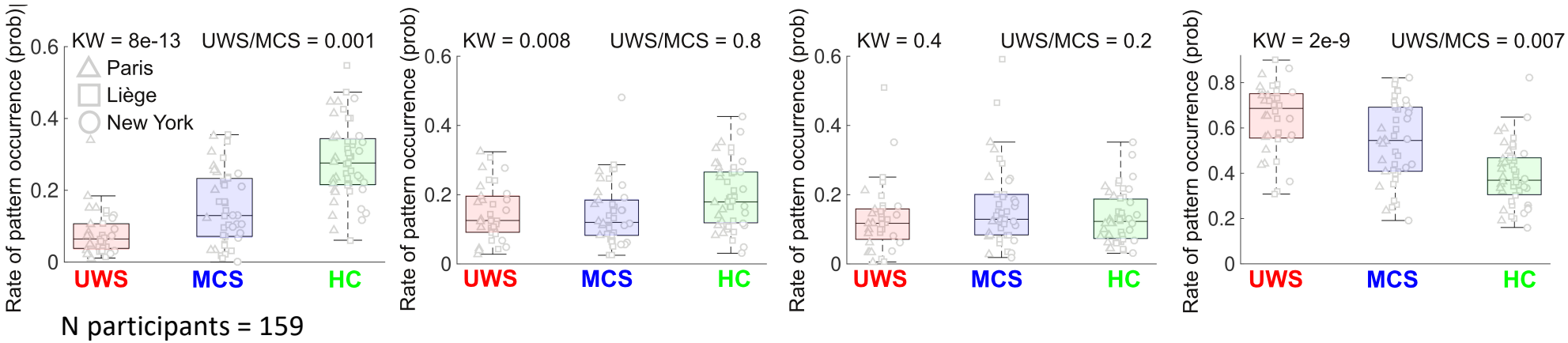
(Dehaene et al, *Trends Cog Sci, 2006;* Tononi et al, *Nat Rev Neurosci.* 2016)

Complex patterns in communicating states


Prof. E Tagliazucchi

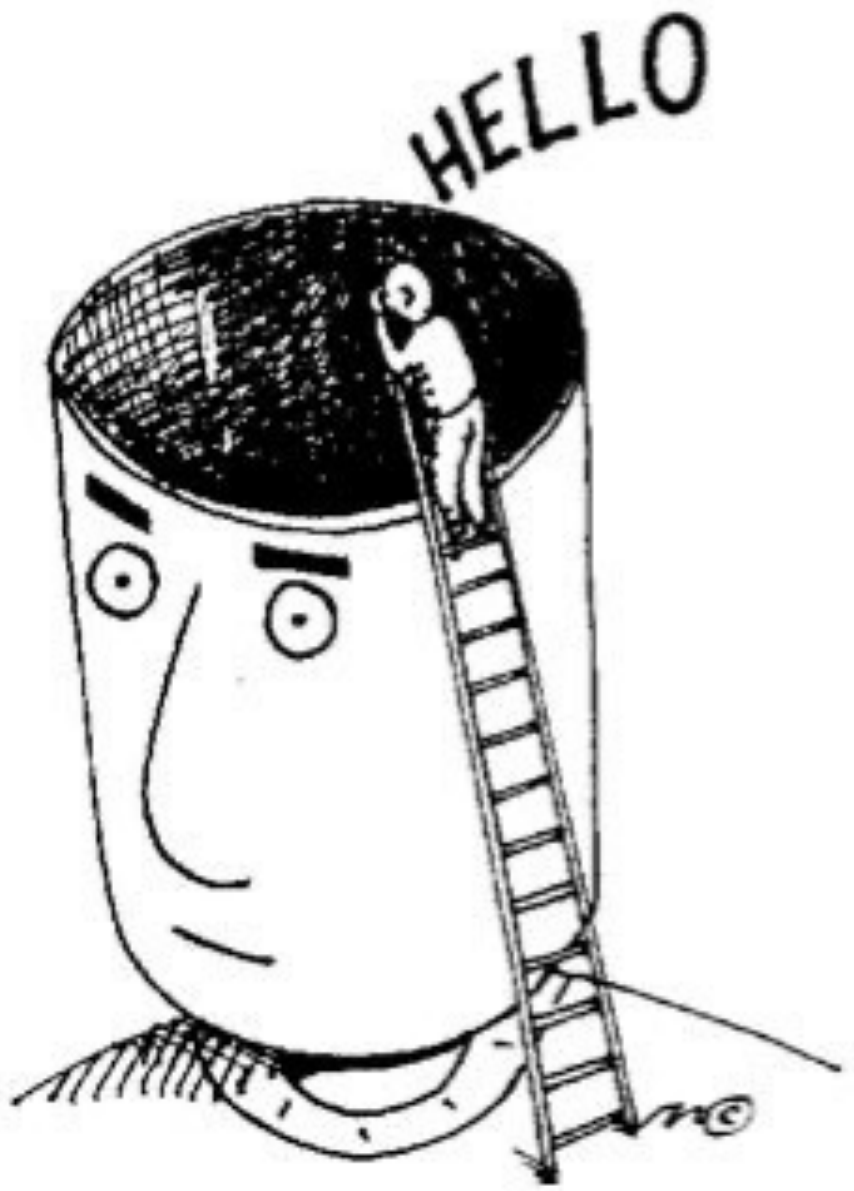

Prof. J Sitt



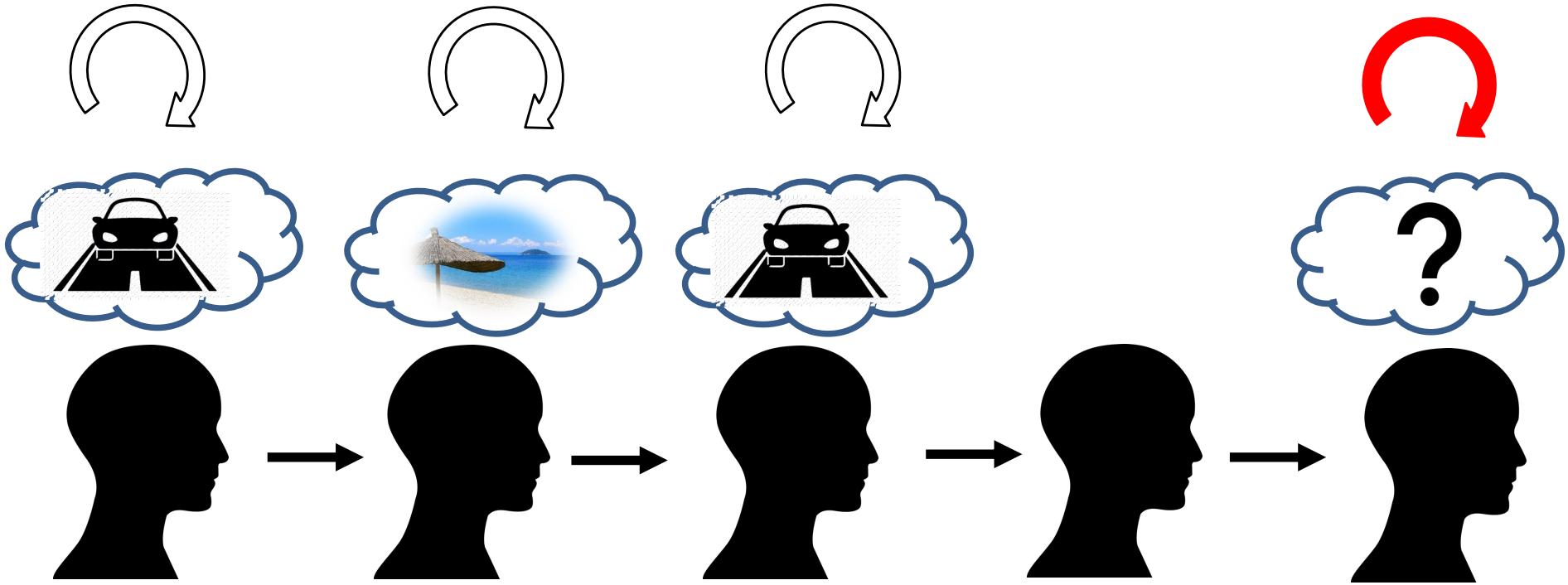


N participants = 159

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


HELLO

Mental states

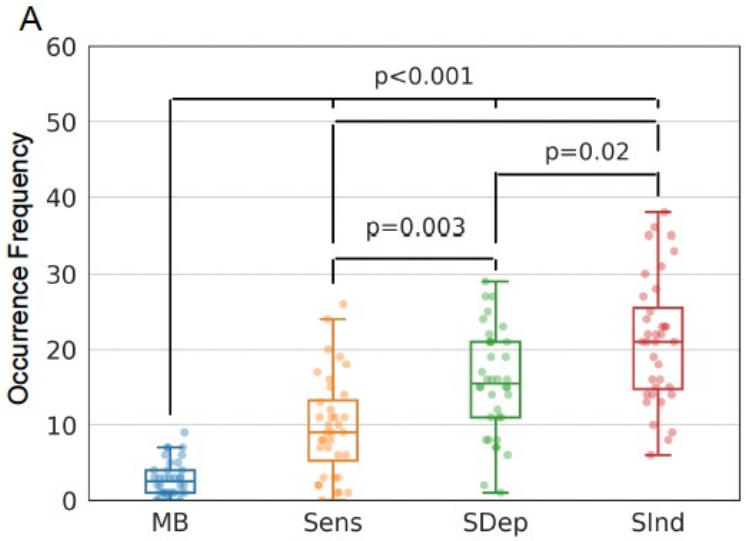


Slide courtesy: Boulakis Paris, Physiology of Cognition Lab

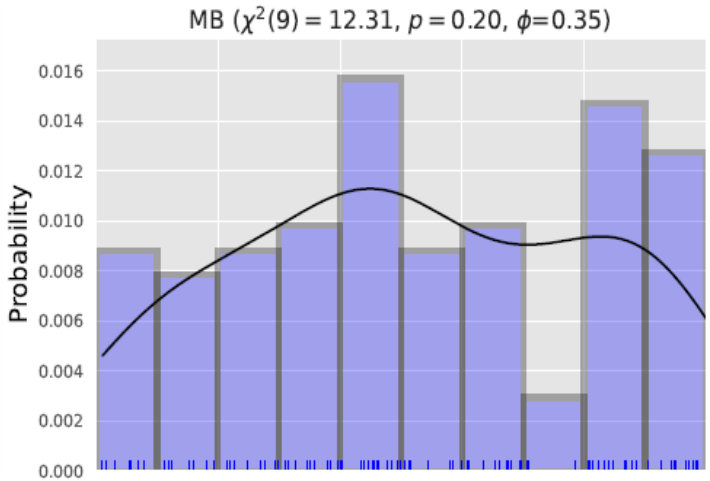
Christoff et al, *Nat Rev Neurosci* 2016

Mind Blanking has a distinct behavioral profile

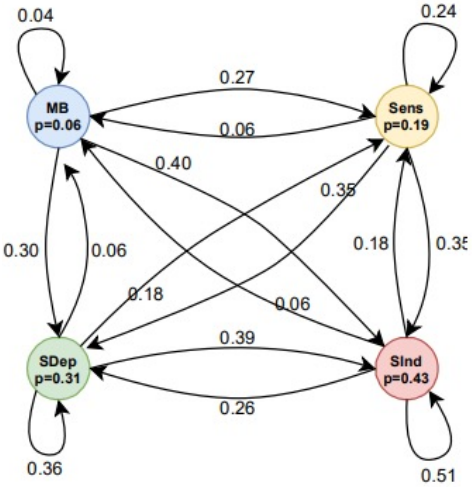
Less frequent



Equally probable across time



Transient relay

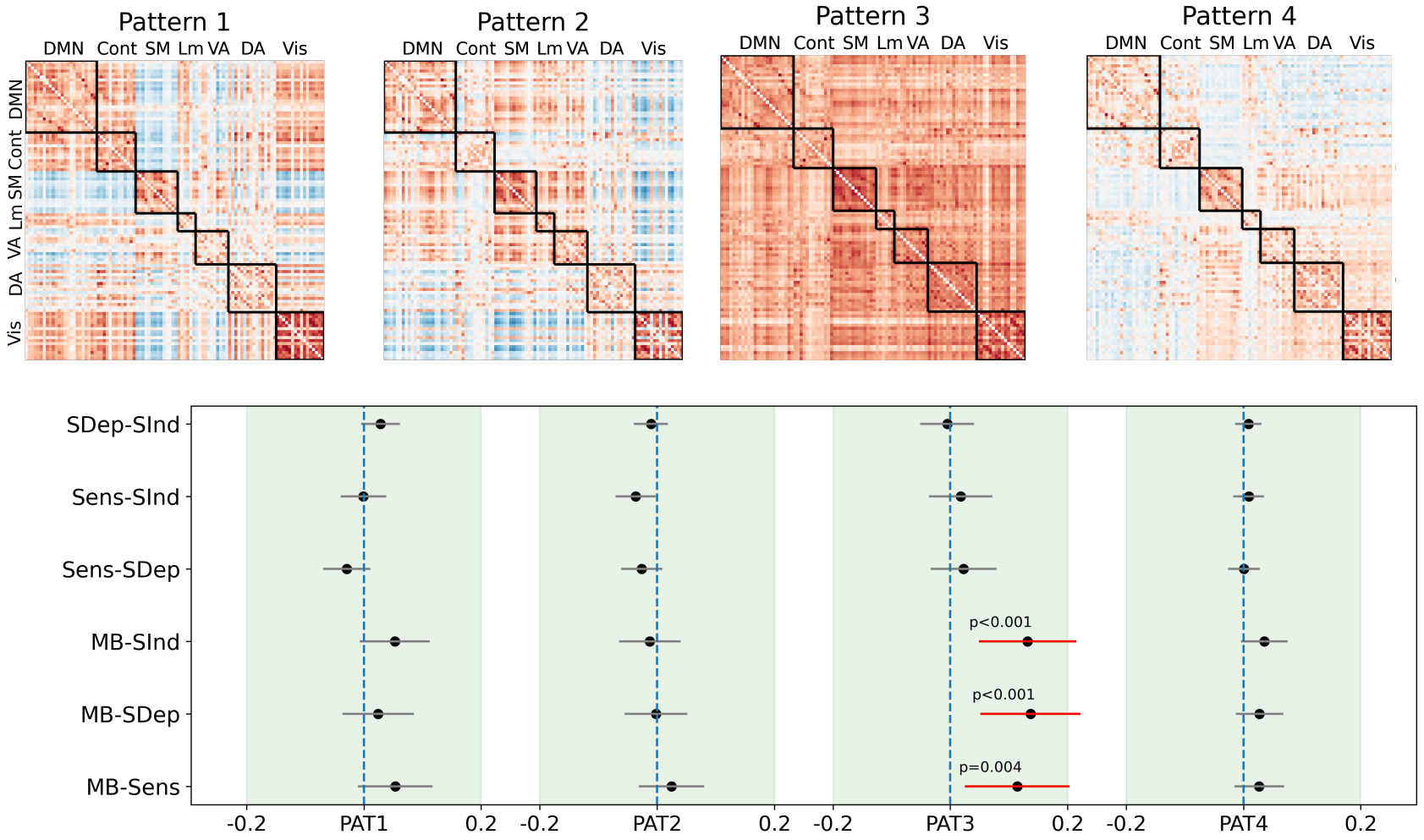


N participants = 36

Mortaheb, Van Calster, Raimondo, Klados, Boulakis, Georgoulaa, Majerus, Van De Ville*, Demertzi*. *PNAS* 2022

Van Calster, D'Argembeau, Salmon, Peters, Majerus*, J Cogn Neurosci* 2017

MB is linked to a hyper-connected state



Mortaheb, Van Calster, Raimondo, Klados, Boulakis, Georgoulaa, Majerus, Van De Ville*, Demertzi*. *PNAS* 2022

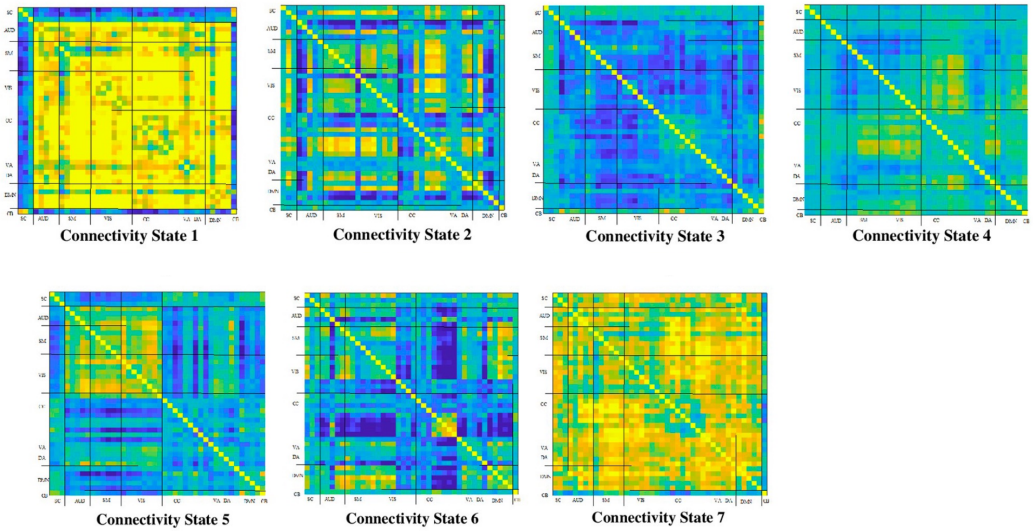
Van Calster, D'Argembeau, Salmon, Peters, Majerus, *J Cogn Neurosci* 2017

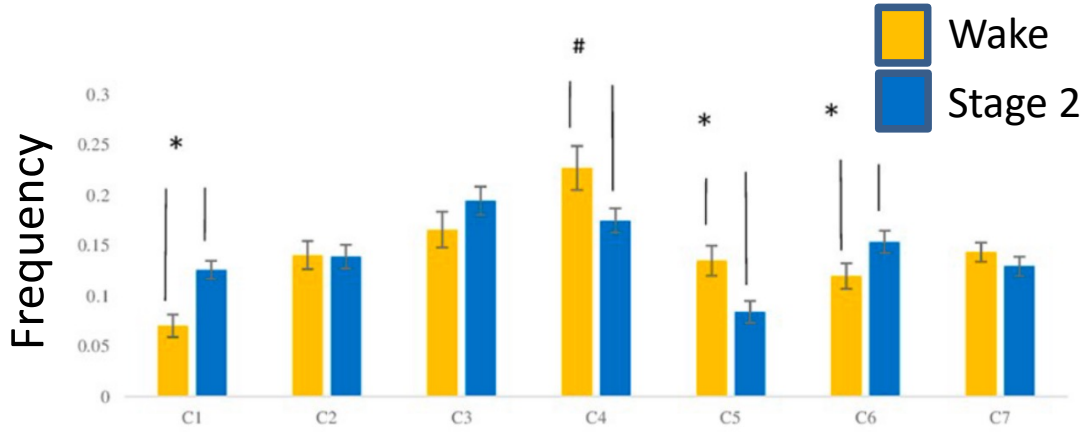
Higher connectivity due to what?

Slow wave activity in unconscious states

NREM sleep

Humans

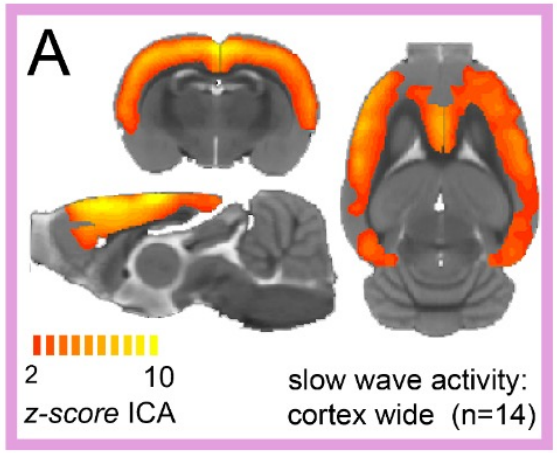


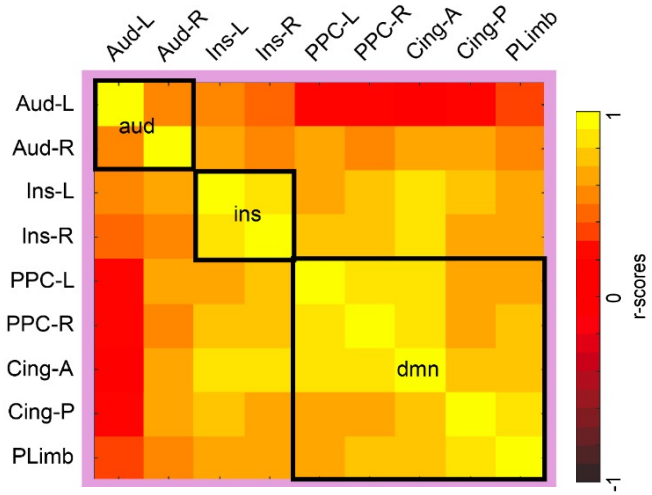


El-Baba et al, *PLOS One* 2019

Isoflurane anesthesia

Rats



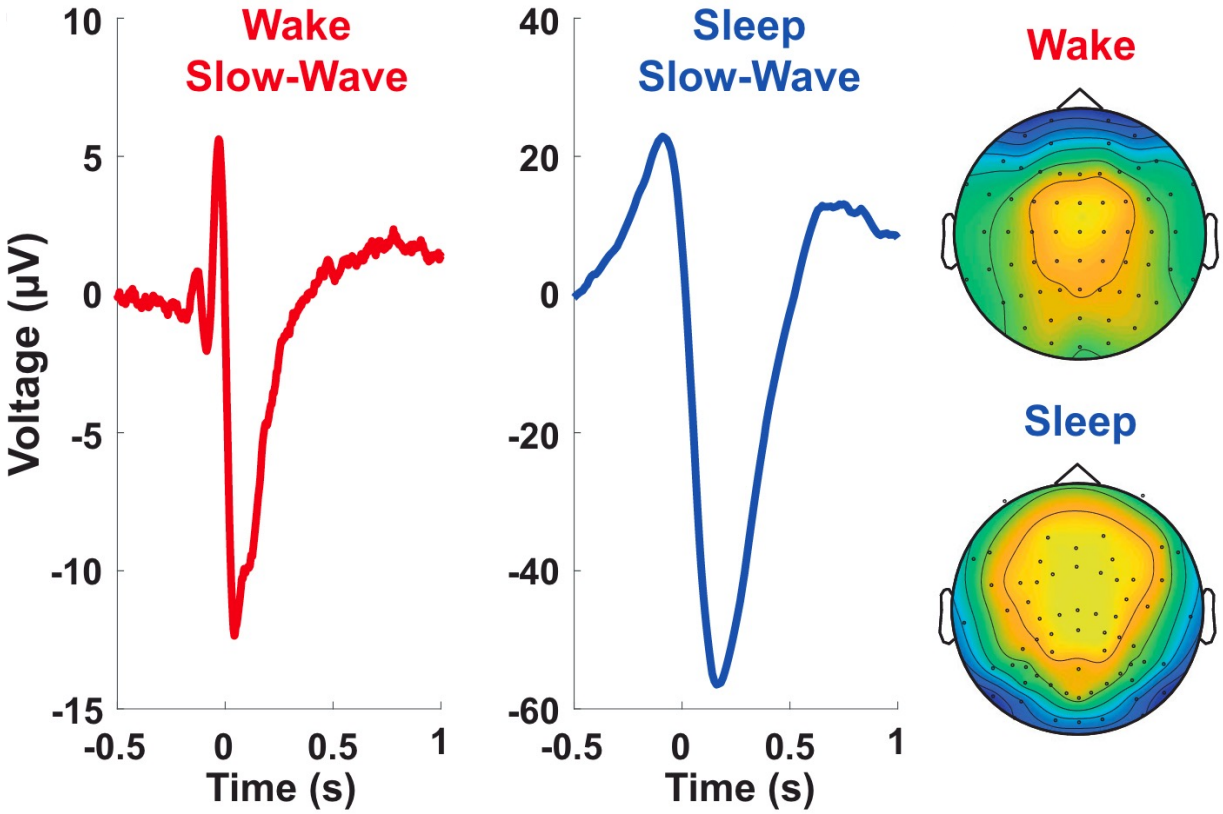


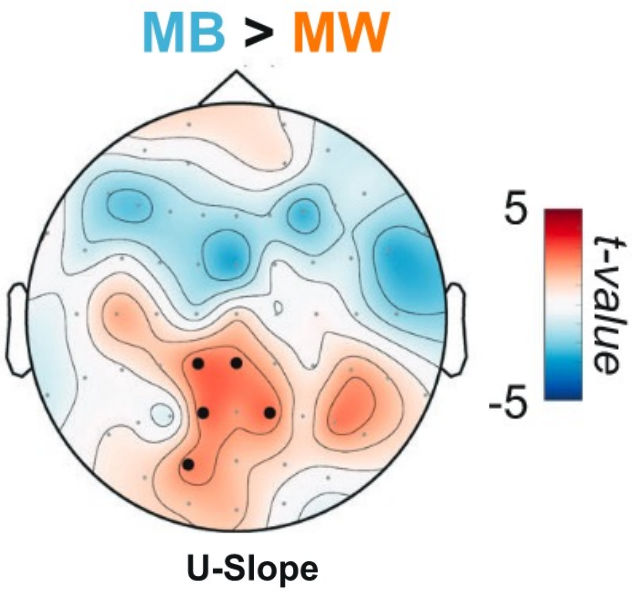
Aedo-Jury et al, *eLife* 2019

Slow wave activity in wakefulness “local sleeps”

Properties of slow waves

Predictive of mental states





Andrillon et al, *Nat Communications* 2021

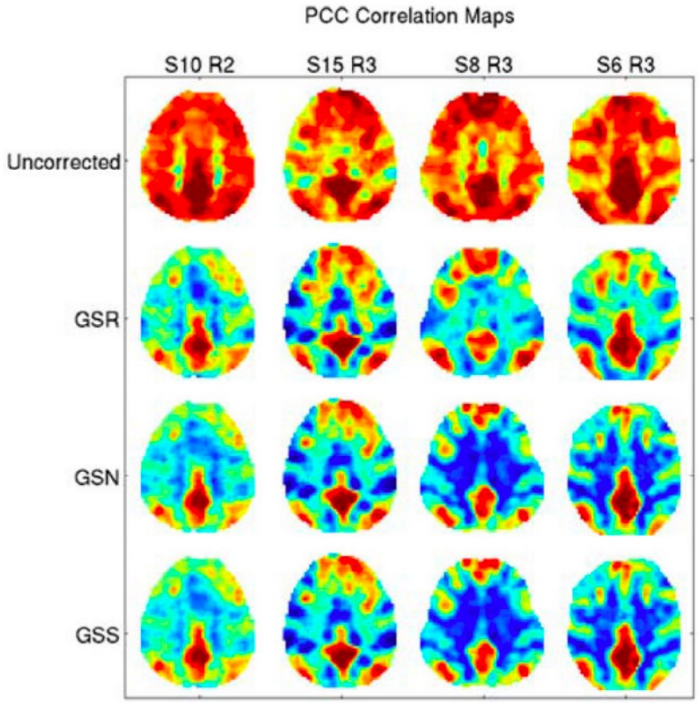
MB due to lower cortical arousal?

Global signal

Average voxel timeseries

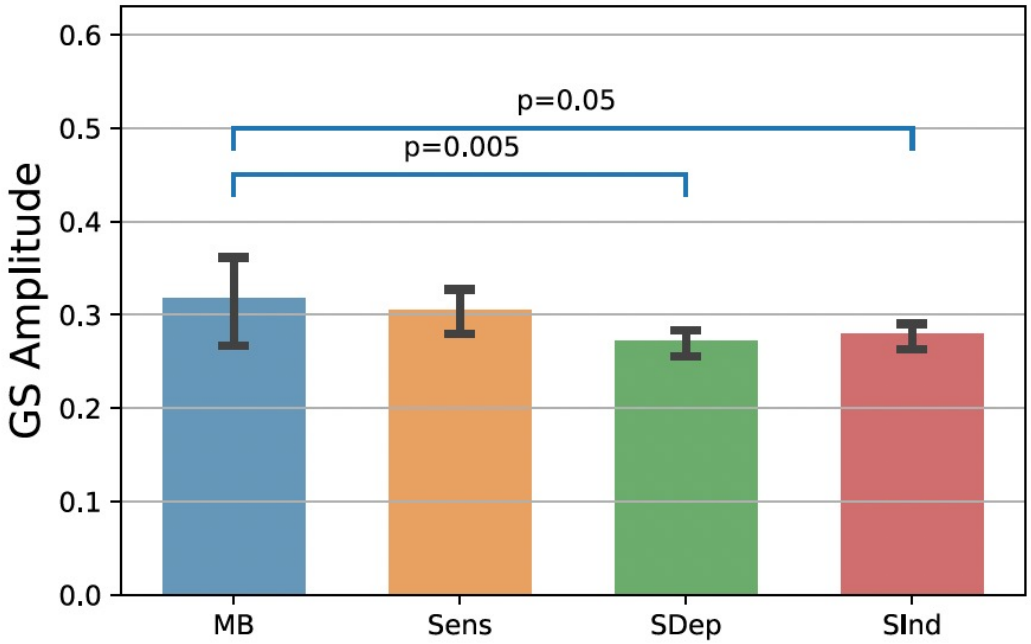
Zarahn, Aguirre, D'Esposito, NeuroImage 1997

("Global flow'' in PET, Friston et al., 1990)



Liu et al, *NeuroImage* 2017

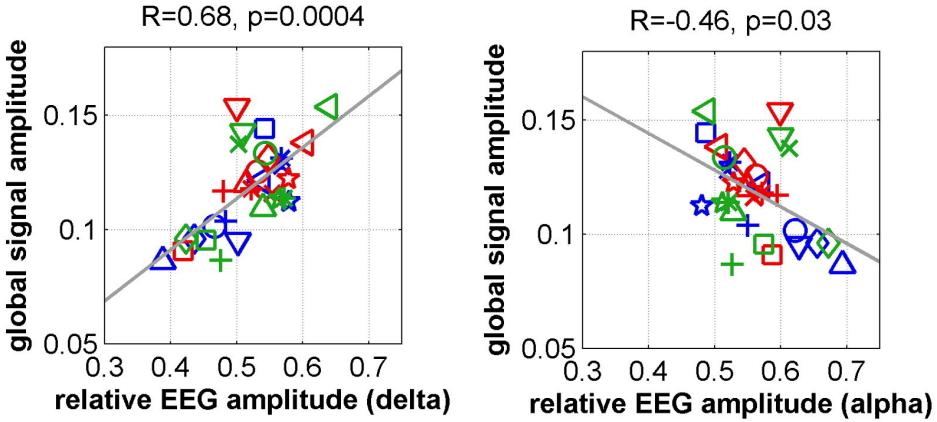
Higher Global Signal Amplitude
around MB reports



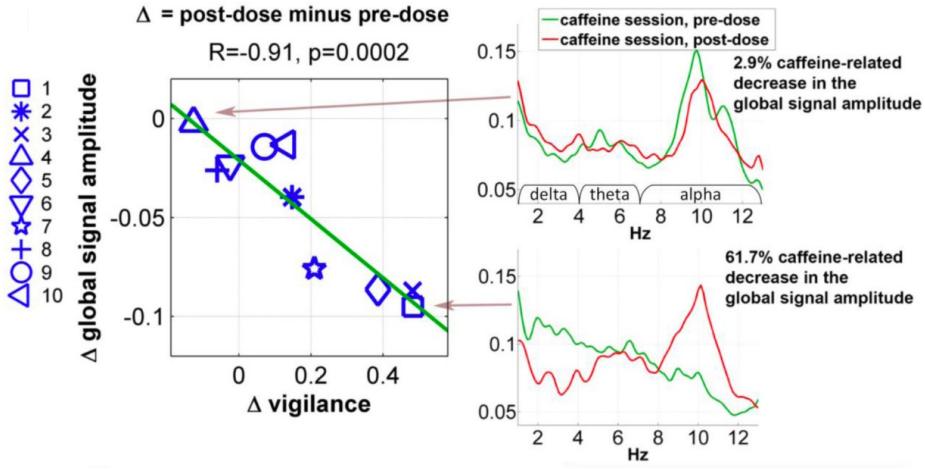
Mortaheb et al, *PNAS* 2022

Global Signal amplitude reflects levels of arousal

GS amplitude is linked to low arousal

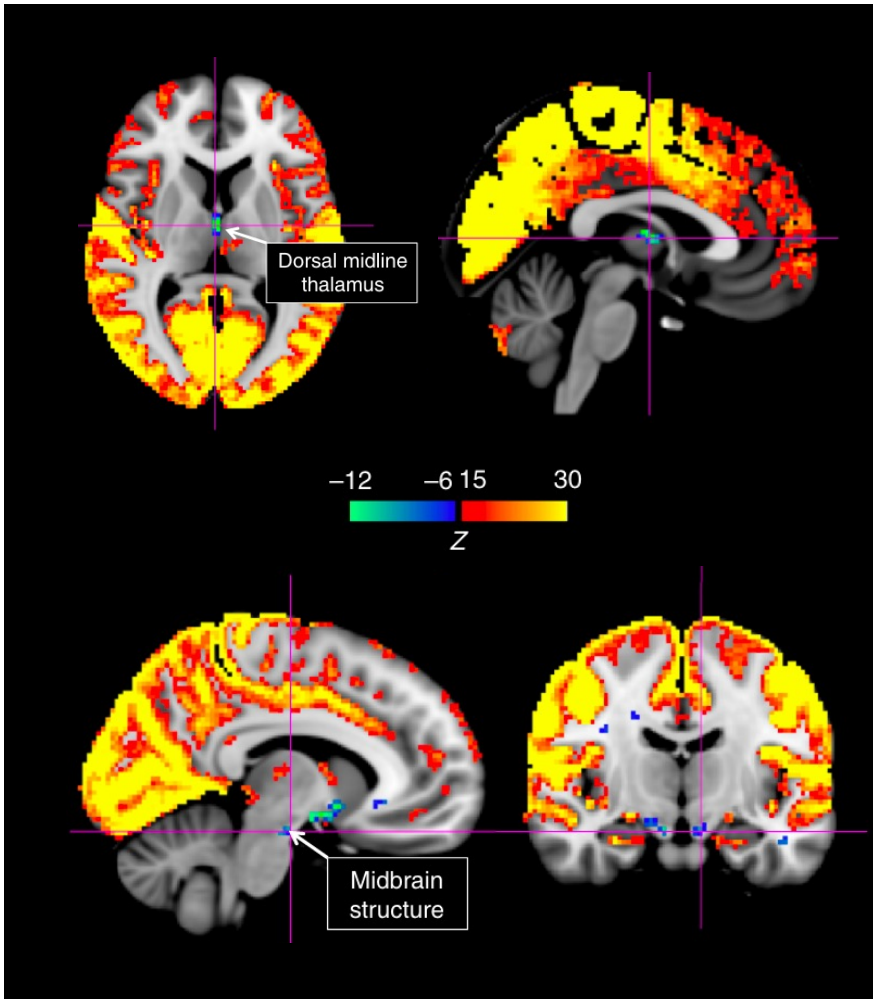


GS amplitude decreases with caffeine intake



Wong et al, *Neuroimage* 2013

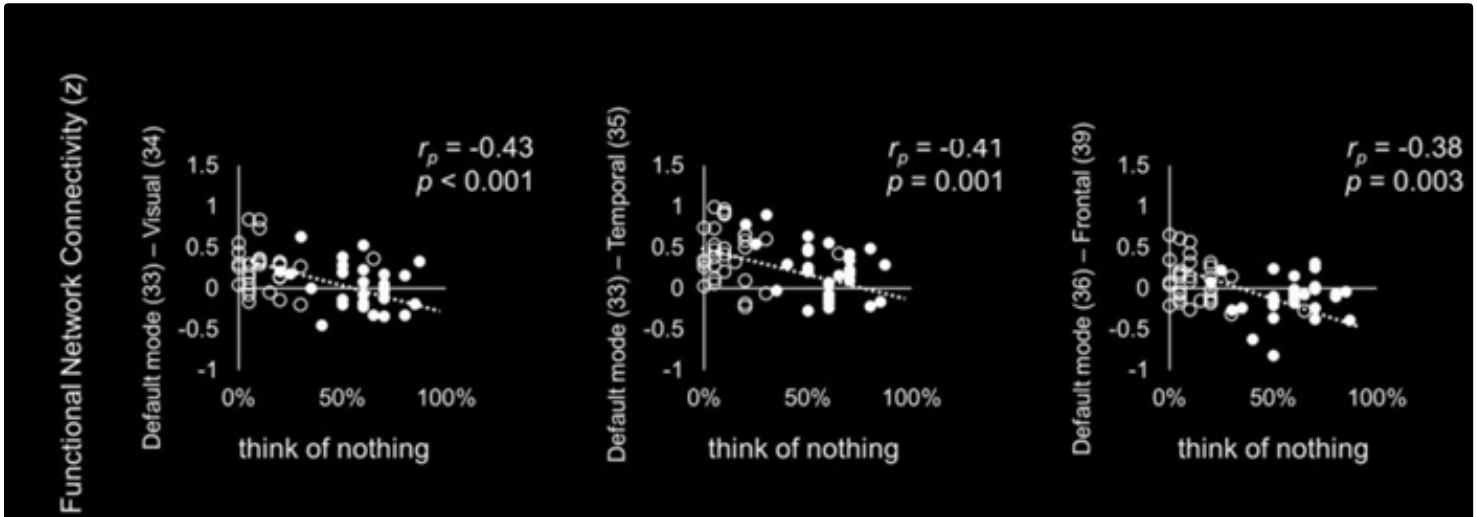
GS amplitude linked to signal decreases in subcortical structures of arousal



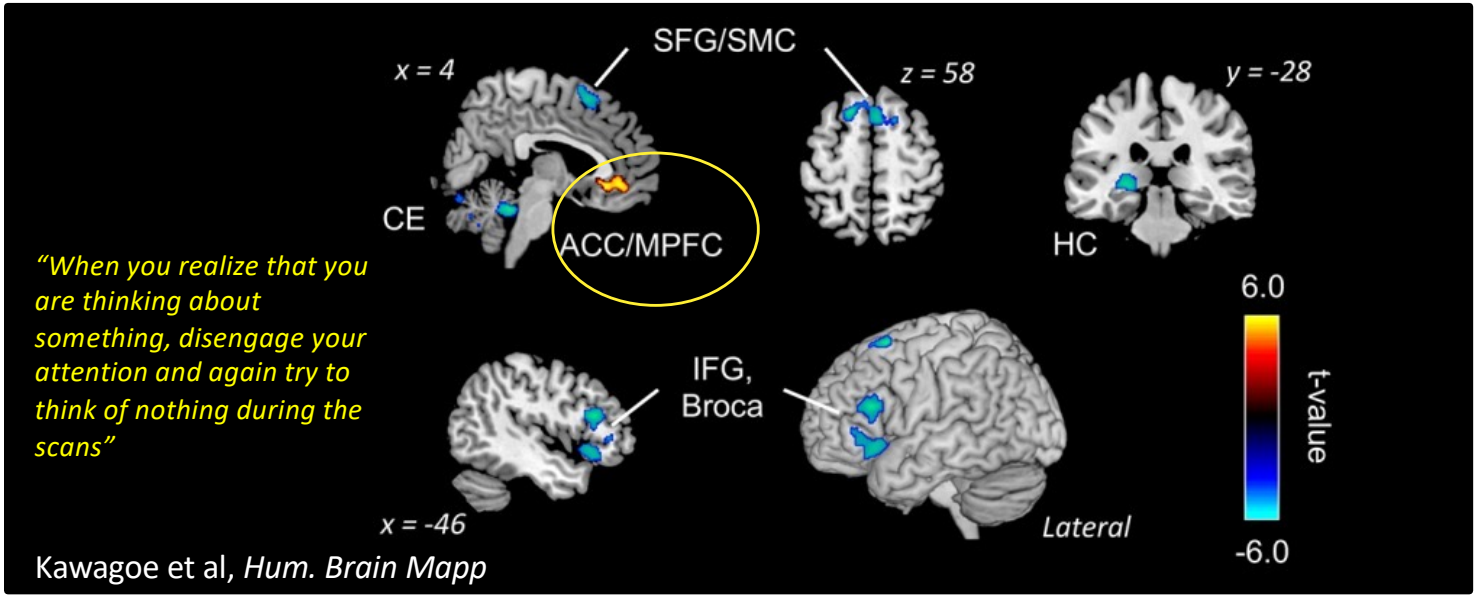
Liu et al, *Nat Communications* 2018

Induced MB

Result of reduced inner speech?



Kawagoe et al , *Eur J Neurosci* 2018



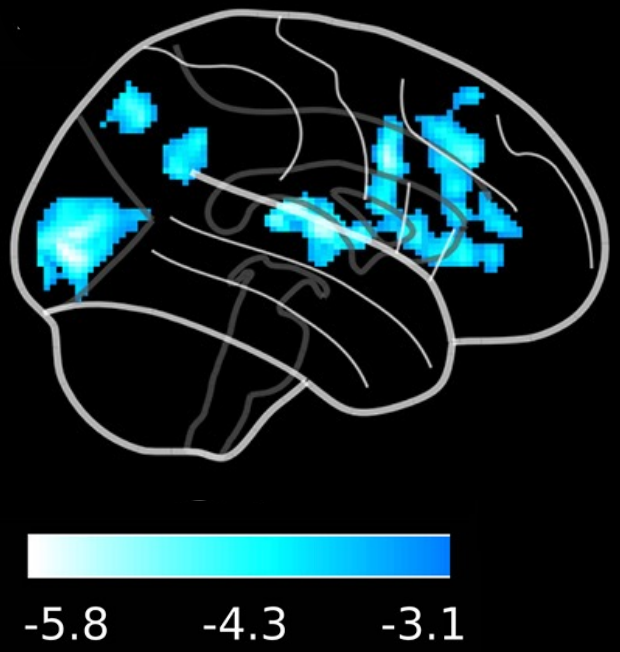
"When you realize that you are thinking about something, disengage your attention and again try to think of nothing during the scans"

Kawagoe et al, *Hum. Brain Mapp*

Spontaneous MB

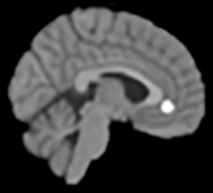
Result of wide regional disengagement?

FMRI univariate analysis of MB reports reveals whole-brain deactivations

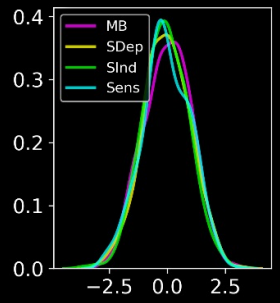


voxel-level $p_{uncorrected}$ <0.001
cluster level p_{FDR} <0.05

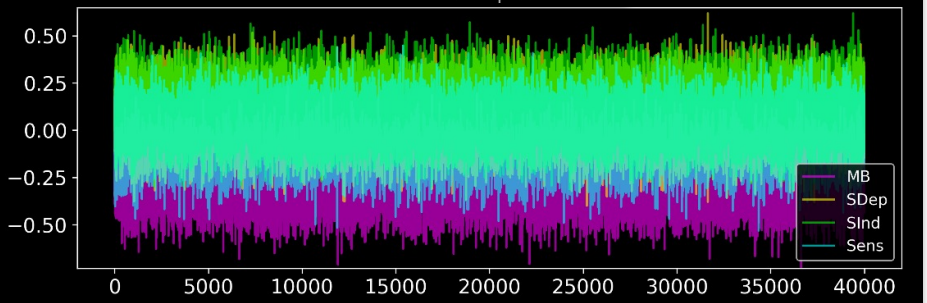
Bayesian linear model of the beta parameters in the ACC cluster (Kawagoe 2019)

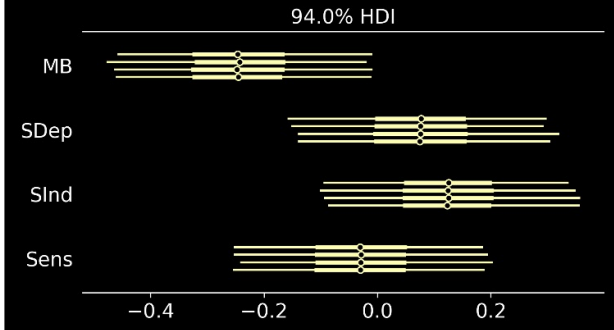


Prior expectations



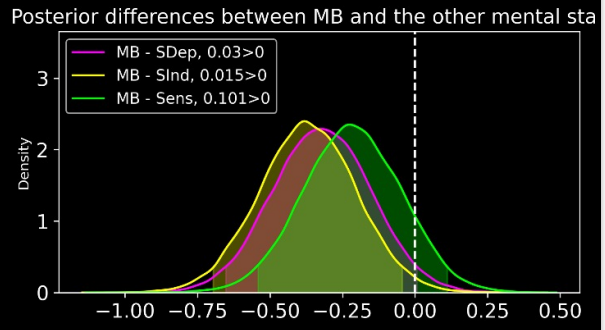
Traceplot of model fit (MCMC-NUTS)





Posterior values

The vmPFC/ACC contains significant evidence for MB deactivations

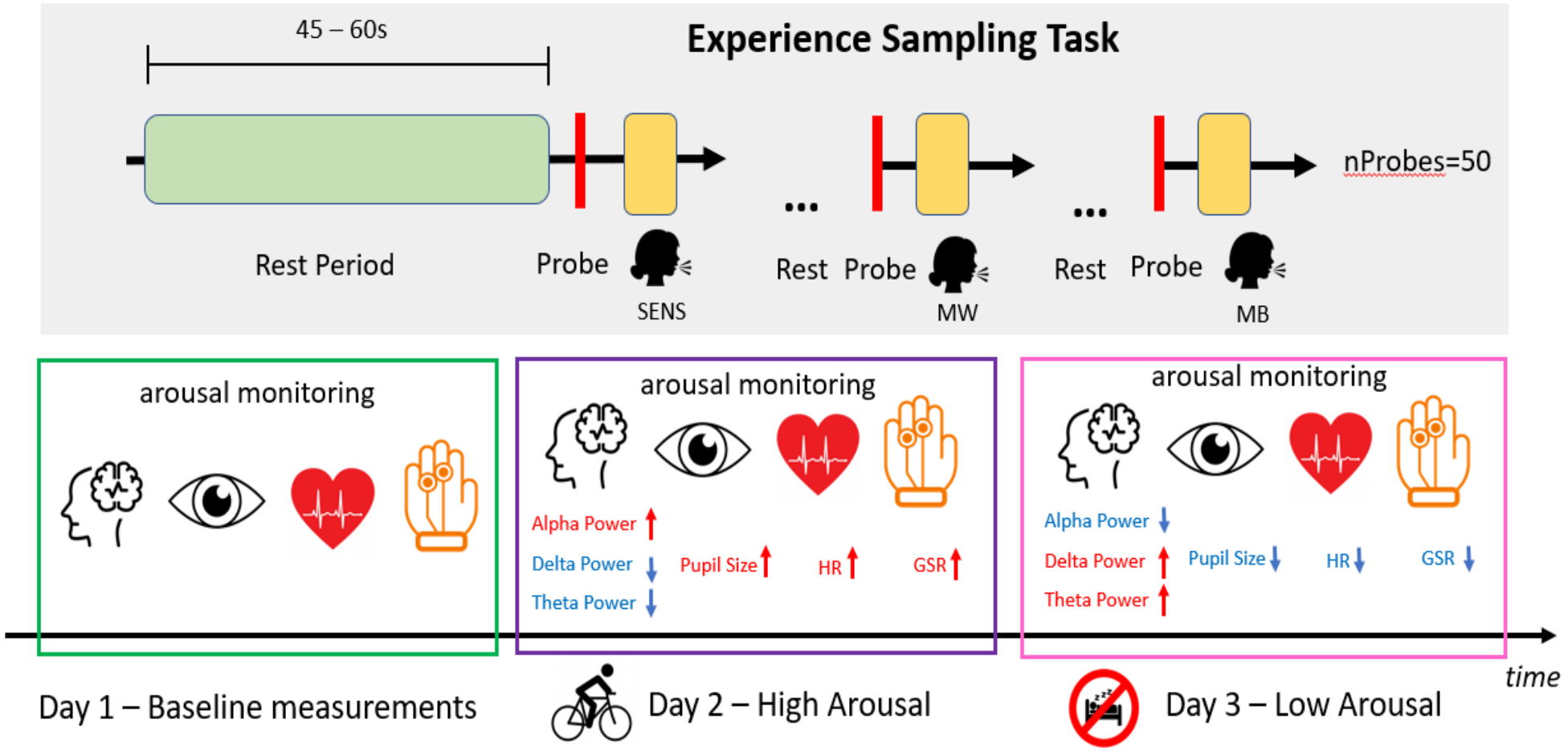


Posterior distribution contrasts

Frontal deactivations differentiated between MB and SInd

Boulakis, Mortaheb, Van Calster, Majerus, Demertzi, JNeurosci *in press*

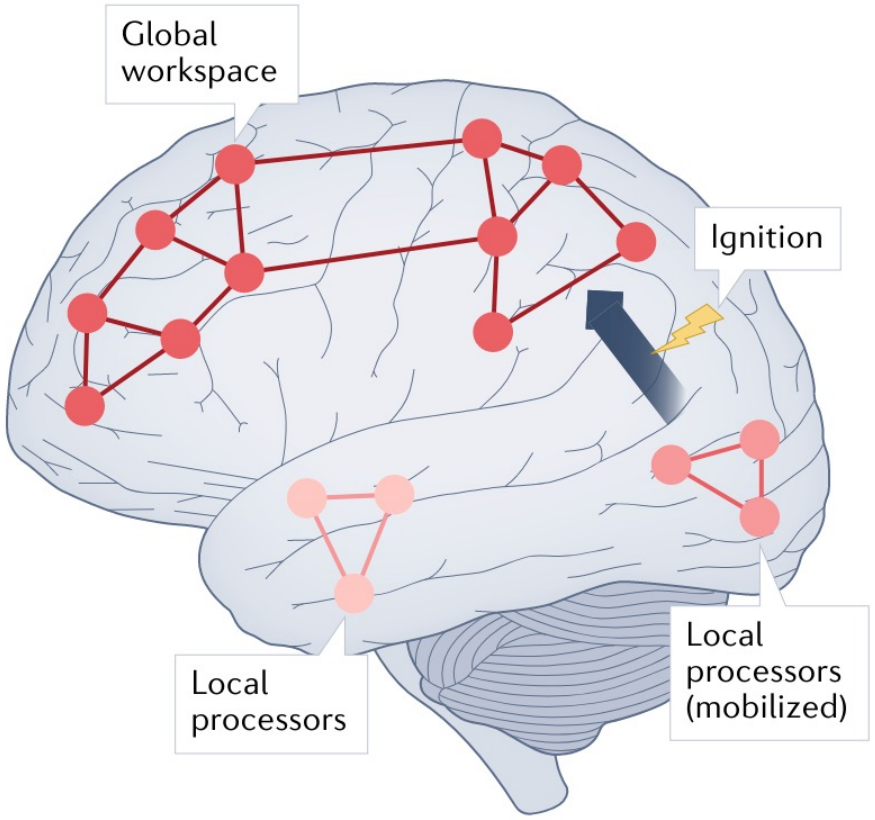
Hypothesis:
Mental state reportability has an embodied component



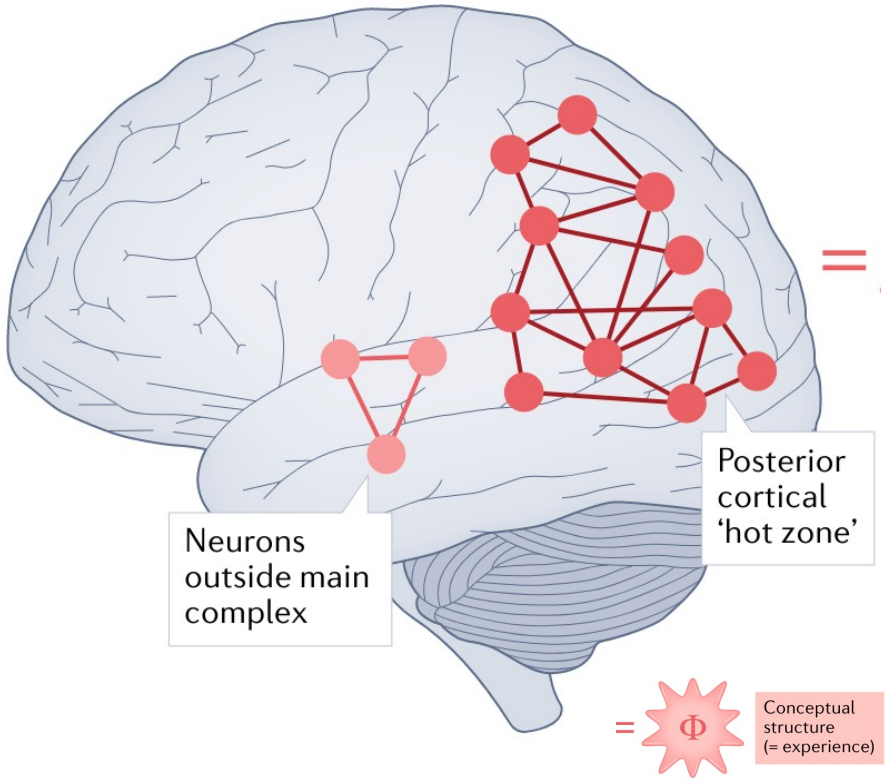
Boulakis, Raimondo, Mortaheb, Schmidt, Demertzi. *Scientific Reports* (accepted as Registered Report Stage 1)

Non-reportable Awareness?

Challenges for Theories of Consciousness



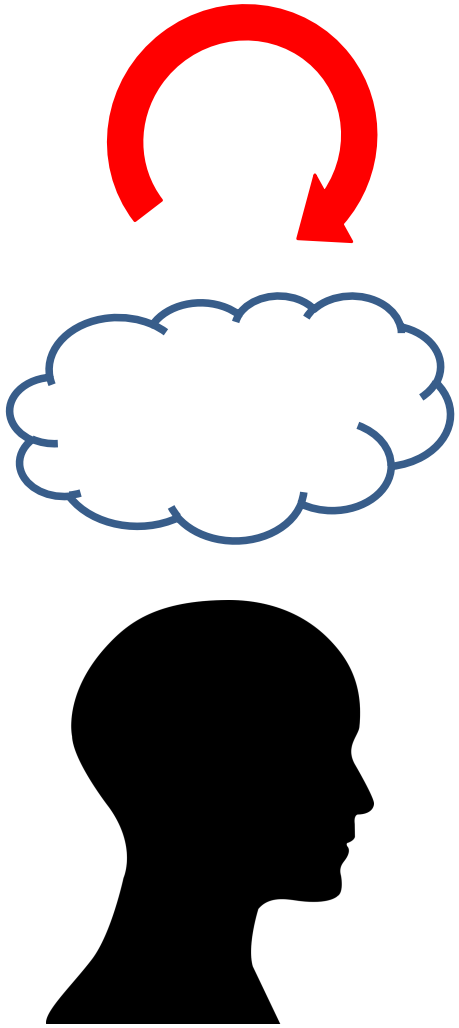
Global Neuronal Workspace Theory



Integrated information theory

Seth & Bayne *Nat Rev Neurosci* 2022

Take-home messages



- MB retains the stream of consciousness
- MB interrupts content monitoring
- MB's neuronal profile mediated by arousal
- MB challenges consciousness models

Thank you!

Physiology of Cognition

CRC-In Vivo Imaging Center GIGA Institute
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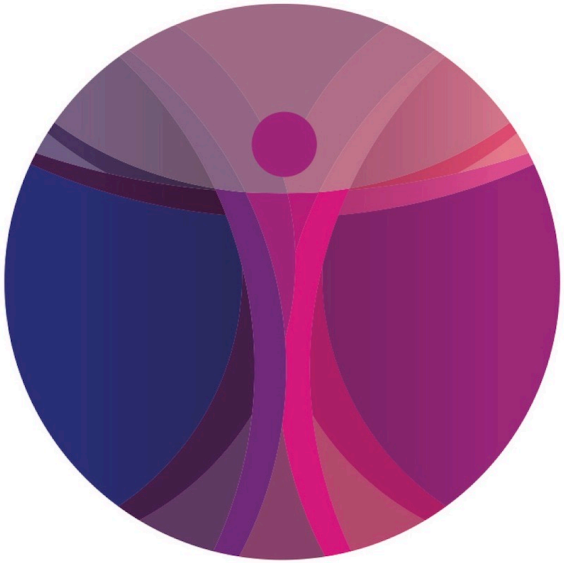

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The Neural Architecture of Consciousness

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