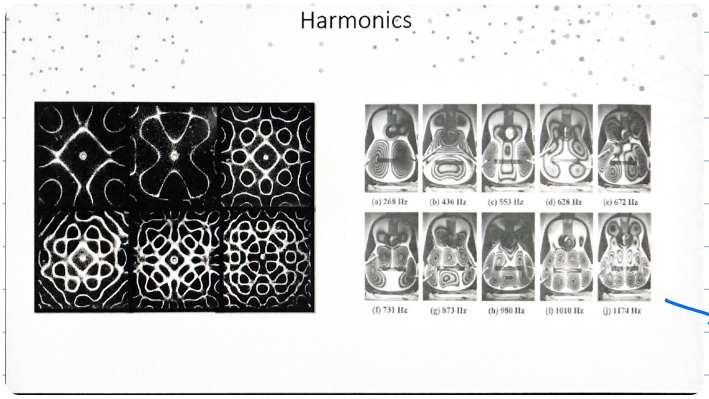
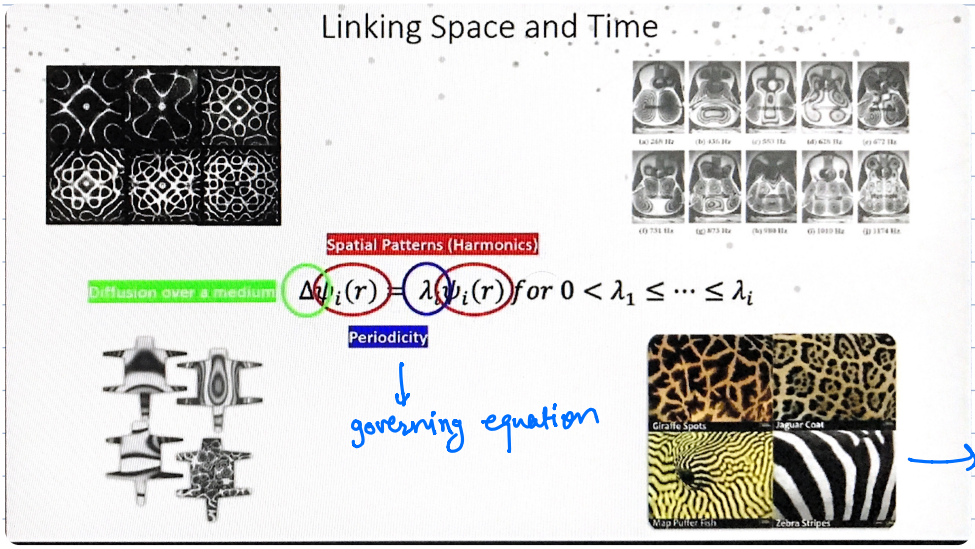
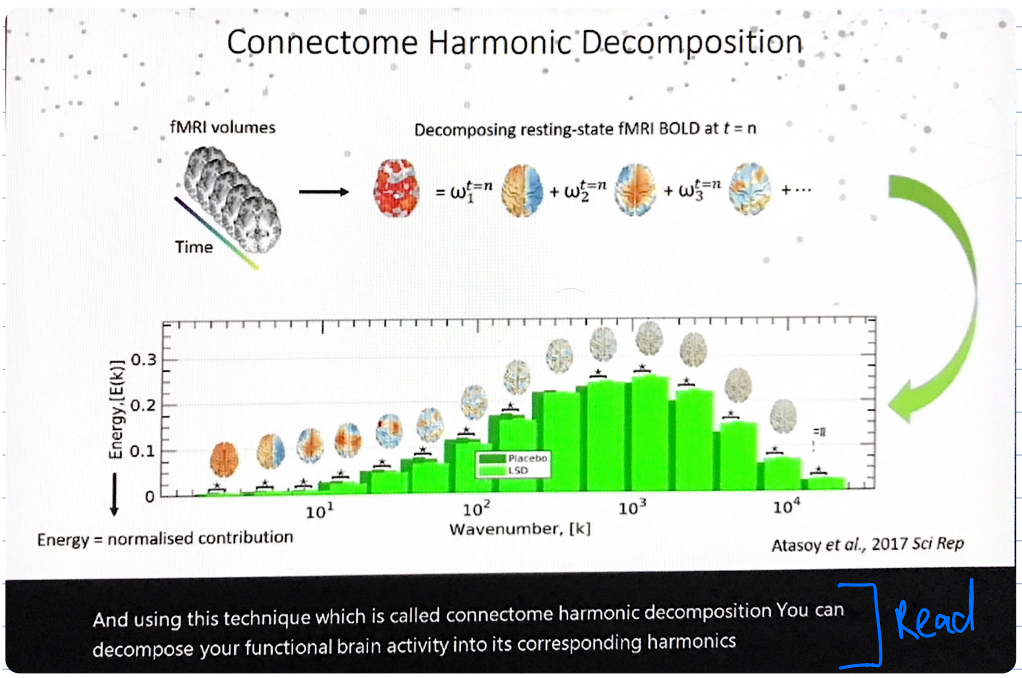
1) Connectome Harmonic Signatures of Consciousness
— Andrea I Luppi
(University of Cambridge)



→ complex pattern as freq. is increased



→ Now, we can also explain it to be cause of these things (Murray 1998)

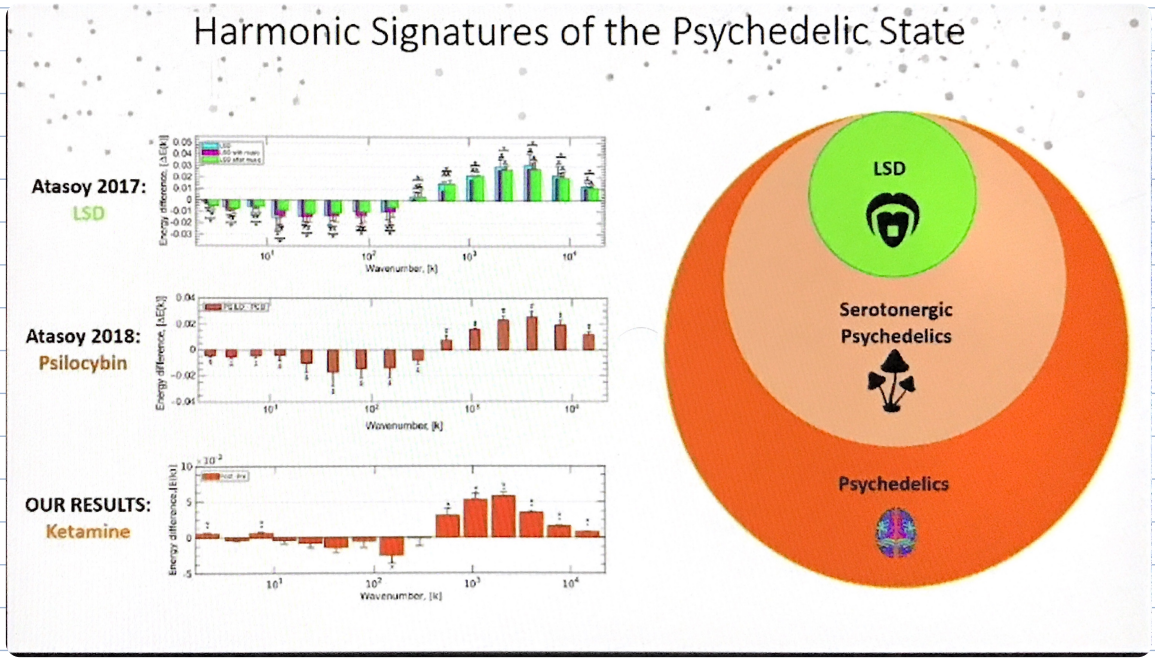


Read

They applied it on LSD & psilocybin ⇒ found that

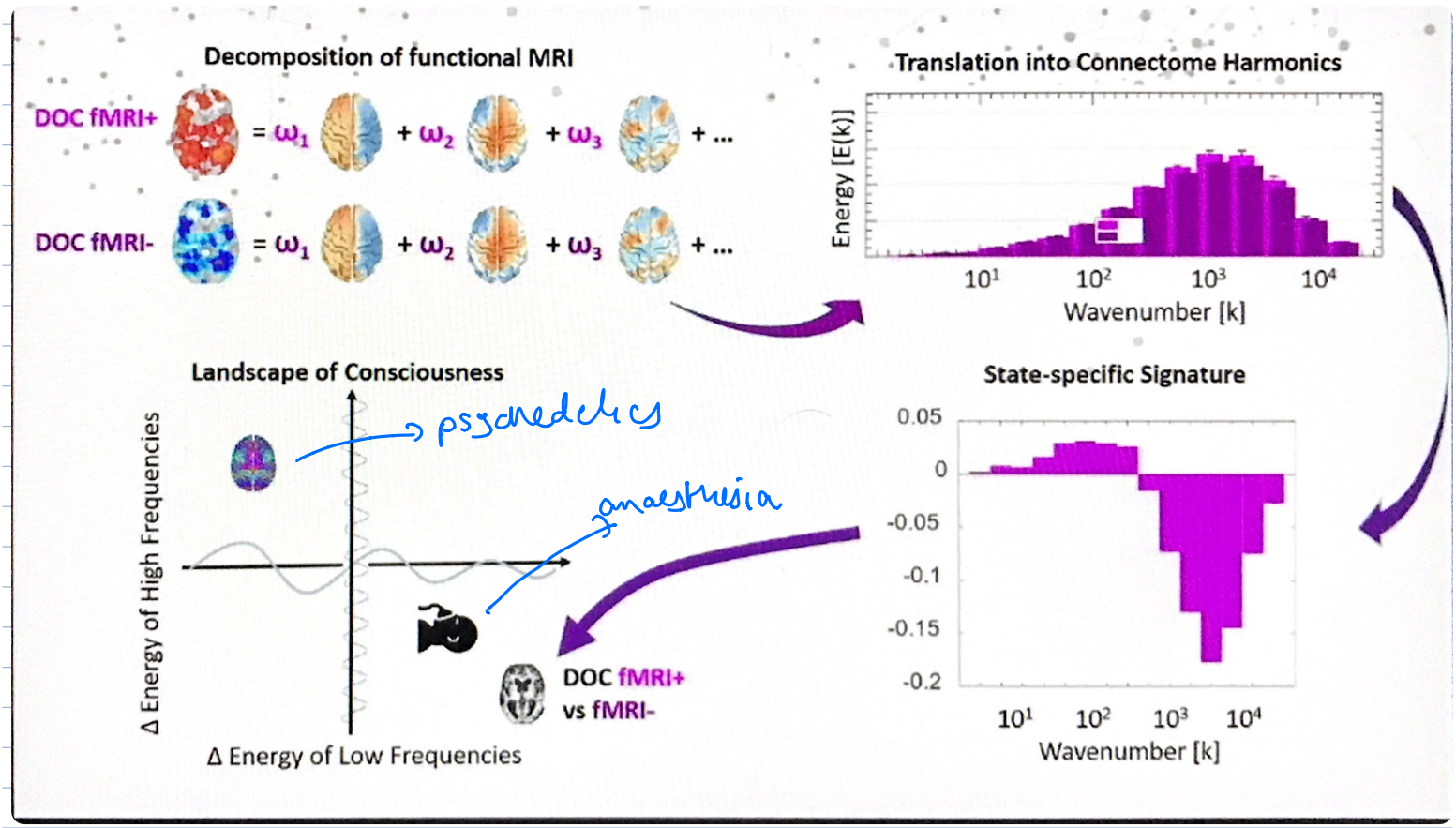
- energy of low freq. harmonics ↓
- " " high " " ↑

⇒ same happened with Ketamine ⇒ In general this happens with psychedelics



↳ opposite happens with anaesthesia (not including ketamine afc)

→ Using this knowledge we can make a landscape of consciousness



Connectome Harmonic Signatures of Consciousness

Luppi A.I. [a], Vohryzek J. [b,c], Atasoy S. [b,c], Mediano P.M. [a], Craig M. M. [a], Pappas I. [a,d], Adapa R. [a], Finoia P. [a], Williams G. B. [a], Allanson J. [a], Pickard J. D. [a], Menon D. K. [a], Kringelbach M. L. [b,c], & Stamatakis E.A. [a]

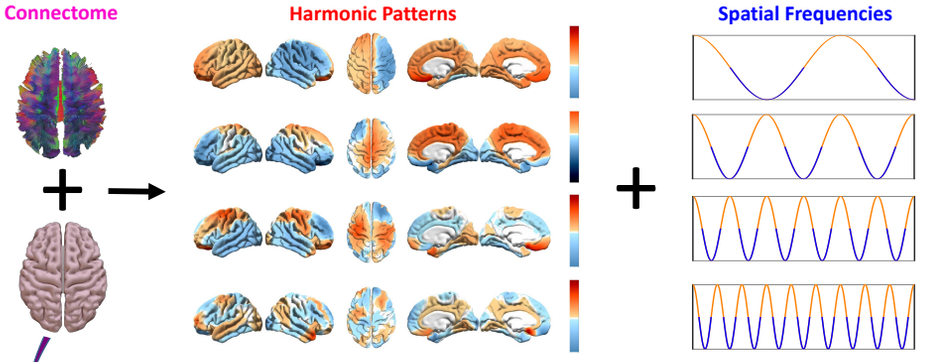
[a] University of Cambridge, Cambridge, UK; [b] University of Oxford, Oxford, UK; [c] Aarhus University, Aarhus, Denmark; [d] University of California – Berkeley, CA, USA.

Background

Connectome Harmonics are a framework to decompose cortical activation patterns into oscillatory modes of different frequency, based on the underlying structural connectivity of the brain[1]. Connectome Harmonic analysis can identify consistent signatures of altered states of consciousness induced by the psychedelics LSD[2] and psilocybin[3]. We hypothesised that this harmonic signature should generalise to non-serotonergic psychedelics, and that loss of consciousness should have the opposite signature.

Connectome Harmonics

Eigendecomposition of the Laplacian $\Delta\psi_i(r) = \lambda_i\psi_i(r) \; for \; 0 < \lambda_1 \leq \cdots \leq \lambda_i$

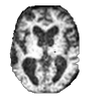


Participants and Data

Data : resting-state fMRI (TR = 2s)

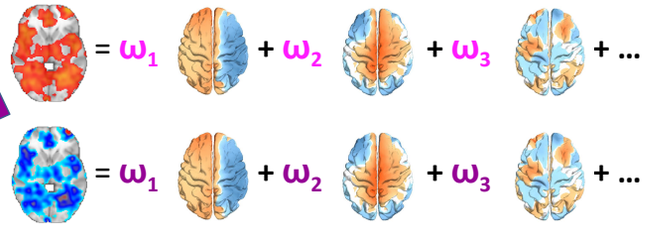
Sub-anaesthetic Ketamine
N = 20
Placebo-controlled

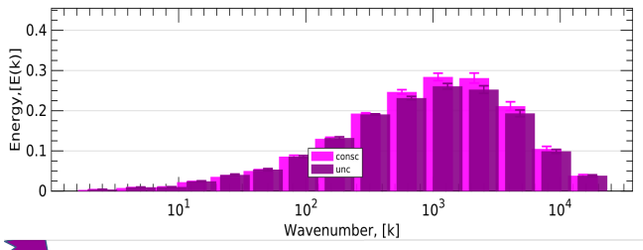
Propofol
N=15
Awake, Mild, LOBR, Recovery



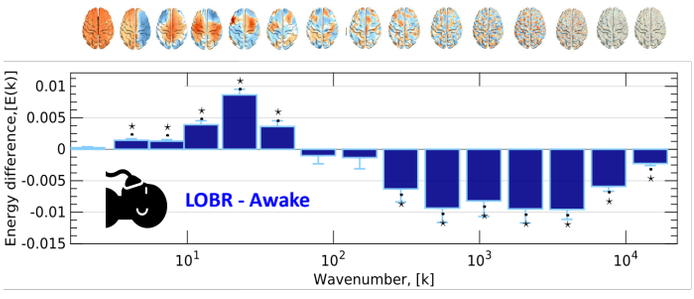
DoC Patients[4]
N=22
8 fMRI+ vs 14 fMRI-

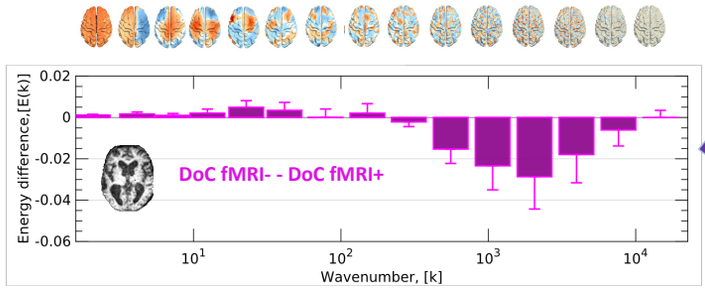
Harmonic Signatures of Consciousness



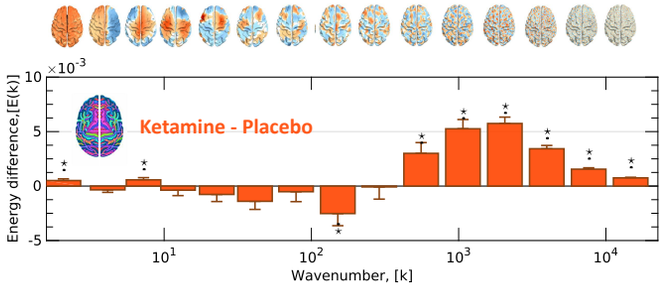


Common signature of unconsciousness: reduced energy over high-frequency harmonics

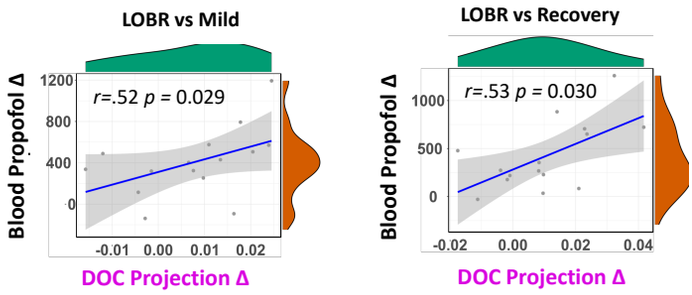




Opposite harmonic signatures for psychedelics and loss of consciousness



Generalisation: DoC brain pattern predicts anaesthetic dose



Conclusions

We identified a general connectome harmonic signature of psychedelics: high energy over the high-frequency harmonics, and decreased energy over the low-frequency harmonics.
The harmonic signature of loss of consciousness (propofol anaesthesia and disorders of consciousness) is the opposite of psychedelics.
This framework can be applied to any mental state, to map the landscape of conscious states.

References

[1]Atasoy, S., Donnelly, I., & Pearson, J. (2016). Human brain networks function in connectome-specific harmonic waves. *Nature Communications* 7:10340. DOI: 10.1038/ncomms10340

[2]Atasoy, S., Roseman, L., Kaelen, M., Kringelbach, M. L., Deco, G., & Carhart-Harris, R. L. (2017). Connectome-harmonic decomposition of human brain activity reveals dynamical repertoire re-organization under LSD. *Scientific Reports*, *7*(1), 1–18. https://doi.org/10.1038/s41598-017-17546-0

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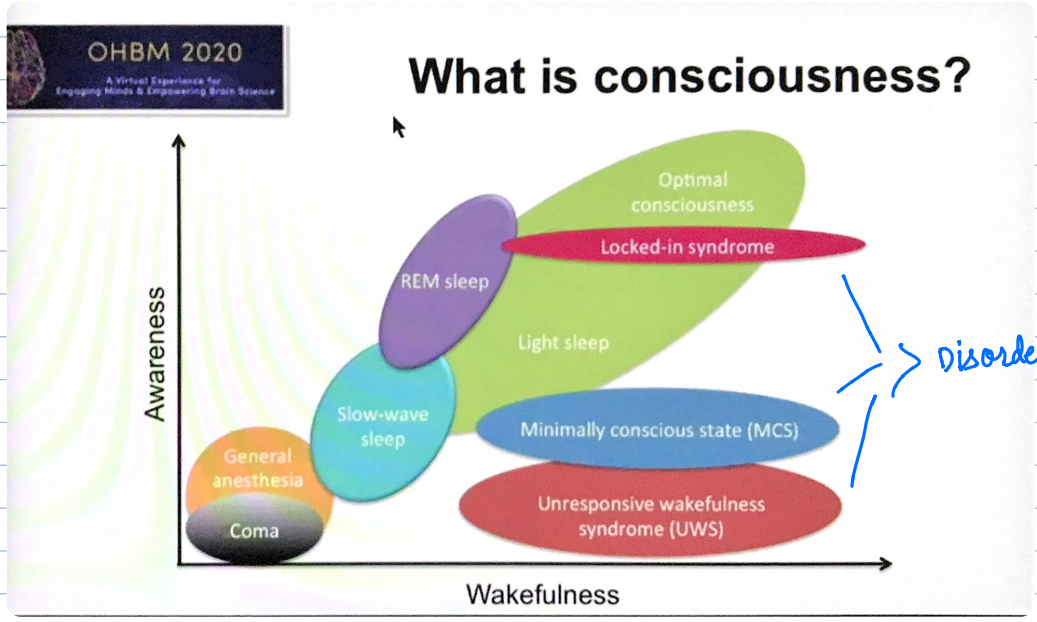
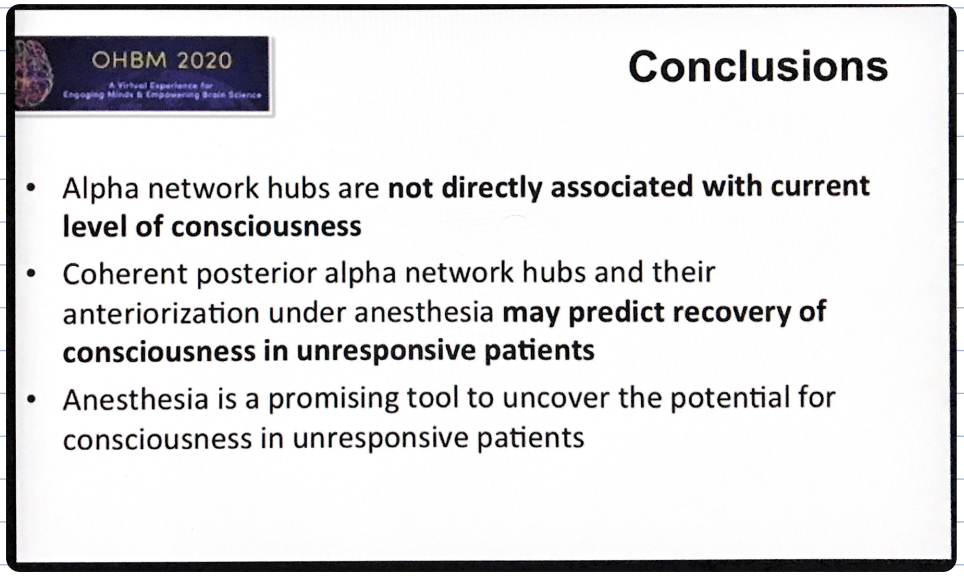
2) Reconfiguration of Network Hubs Under Anaesthesia may predict recovery of consciousness
— Catherine Duclos (McGill)



> Disorders of consciousness

Problem → people in MCS are diagnosed to be in UWS
⇒ they don't get required amount of treatment



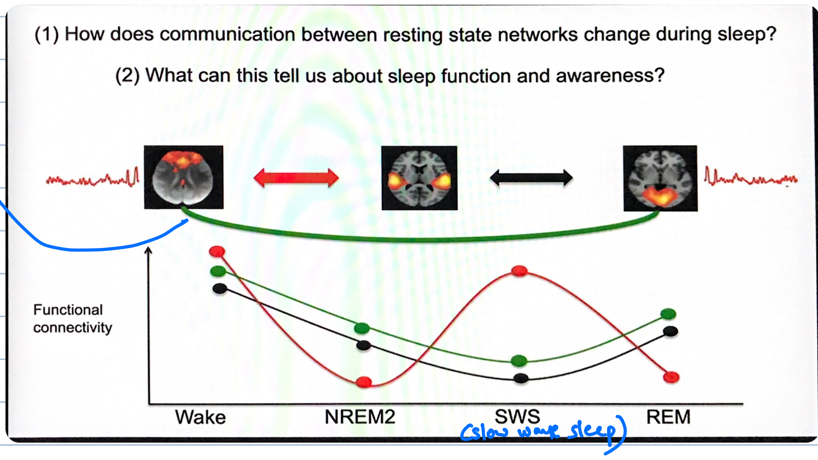
3) Ketamine's influence on global rs functional connectivity & individual variation in neuro-behavioral relationships
— Flora Moujaes

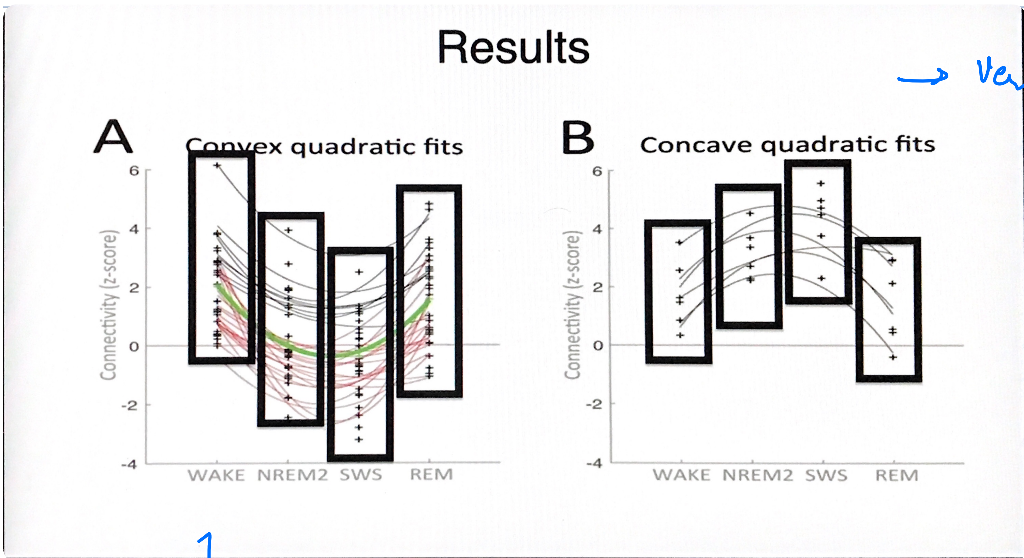
- Ketamine can reverse the loss of synapses caused by stress
- Ketamine increases global brain connectivity

4) Slow Sleep wave is an altered, not a reduced state of consciousness
: Resting state network functional connectivity in sleep - Evan Houldin
uOttawa
sleep research lab

sleep < why / what

→ Distant region with similar activity ⇒ assumption they are communicating with each other to carry out some function





→ Verified fMRI dynamics match EEG dynamics

↓ we can see that the regions which were communicating more during wake, communicate less during NREM

⇒ Function of sleep may be to homeostatically counterbalance wake life communicat^n pattern ⇒ so that our brains are not overly biased towards some pattern of communicat^n

so NREM
- What : Network communicat^n changes opposite to wake
- Why : isolat^n is safer, altered awareness

The Royal
Mental Health - Care & Research
Santé mentale - Soins et recherche

uOttawa

Non-REM Sleep Network Connectivity Represents an Altered, Not a Reduced State of Consciousness

Evan Houldin[1,2], Zhuo Fang[1,3], Laura Ray[1,4], Bobby Stojanoski[1], Adrian Owen[1,5], Stuart Fogel[1,3-7]

INTRODUCTION

Resting state network (RSN) functional connectivity (FC) has been evaluated for a number of compromised and non-wakefulness states, including sedation [1], the vegetative state [2] and sleep [3]. These studies suggest that reduced states of conscious awareness are associated with a reduction in the magnitude of RSN FC, particularly for "higher-order" RSNs such as the default mode network (DMN, [4]). Further, higher-order RSNs have been associated with executive cognitive functions such as task shifting [5]. Thus, RSN FC configurations provide a useful tool for profiling both consciousness and higher-order cognitive activity. However, RSN FC in sleep is the least well understood, due to the paucity of fMRI data acquired during rapid eye movement (REM) and slow wave sleep (SWS). These sleep stages are accompanied by dramatic changes to the electrophysiological milieu of the brain. Nonetheless, it remains to be determined how these systems-level changes are reflected changes to RSN FC, and, by association, alterations of higher-order cognitive activity and consciousness.

METHODS

Simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) was recorded from 36 sleeping subjects (with no prior deprivation). RSN FC matrices were generated for 14 canonical RSNs, for each sleep stage (NREM2, SWS, and REM), as well as wake. Next, 1st-, 2nd- and 3rd- order polynomials were fit to the FC edge data across all stages. It was hypothesized that 2nd-order (i.e., quadratic) fits would best-fit the FC data for most edges, indicating a progressive deviation away from wakefulness FC during NREM, with a return to wake-like FC during REM. Next, angular distances were evaluated in order to determine the dissimilarity between each of the sleep stages and wakefulness. Finally, all FC changes were tested to determine whether NREM sleep manifested; (A) a reduction or (B) an increase in the magnitude of wakefulness FC, or; (C) a reversal of the polarity of wakefulness FC.

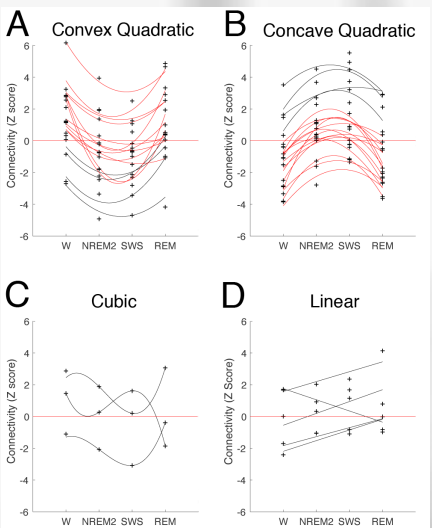


Figure 1: Significant polynomial fits to functional connectivity (FC) data across wakefulness and sleep stages. Plus symbols indicate group-average FC values for a given edge, for a given stage. Units are Fisher r-to-z-transformed full-correlation values, taking into account autocorrelation. FC edges that change in the direction opposite to wakefulness polarity during NREM and return towards wakefulness FC during REM are indicated with red lines. FC edges best described by: (A) convex quadratic fits (N=16; 12 red). (B) Concave quadratic fits (N=18; 14 red). (C) Cubic fits (N=3). (D) Linear fits (N=5). W=wakefulness, REM=rapid eye movement, NREM2=non-REM stage 2, SWS=slow wave sleep.

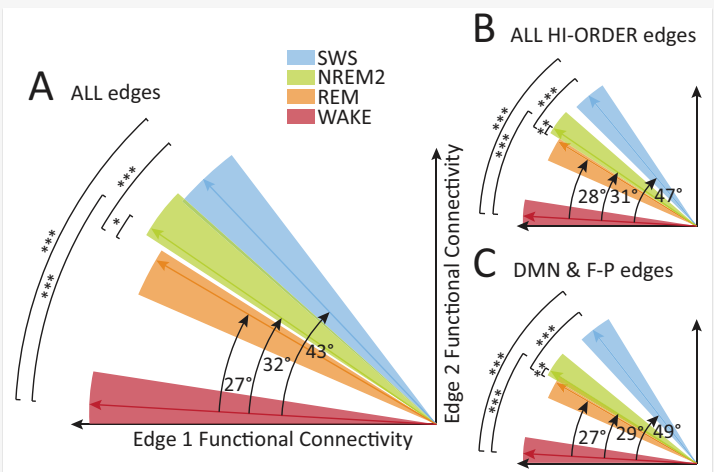


Figure 2: Representative cartoon of the angular distances between vectors representing resting state network (RSN) functional connectivity (FC) in different sleep-wake stages. Vectors exist in multidimensional space, with the number of dimensions dependent on the number of FC edges that are in a given category (e.g., each vector exists in 91 dimensional space for the category "ALL edges"). However, only two dimensions are represented here, for illustrative purposes. Indicated angles are the degree-equivalent of the angular distances between the mean vectors for each stage (indicated as colored arrows), with the mean wakefulness vector always used as the reference point. Angles between sleep stages are not indicated, however, the statistical significance of these differences is indicated by asterisks (note that angles between any pair of vectors actually exists in separate dimensional planes and is only represented in the same plane for illustrative purposes). Colored triangles indicate the spread of vectors for each stage, again for illustrative purposes, as they are actually spread across multidimensional space. (A) ALL edges (N=91 dimensions). (B) ALL HIGHER-ORDER resting state network edges (N=70). (C) Default mode network (DMN) & Fronto-Parietal network (F-P) edges (N=46). REM=rapid eye movement, NREM2=non-REM stage 2, SWS=slow wave sleep.

RESULTS

The results yielded, as far as we know, the largest set of REM fMRI data collected in a single study (non-sleep deprived subjects or otherwise). Consistent with our hypothesis, the majority of FC edges that were found to be modulated by sleep were best described by quadratic fits (Fig 1). Further, changes were highly directional: i.e., towards opposite connectivity in NREM and back towards wake connectivity in REM. This directional change went as far as reversing FC and strengthening it in the opposite direction. Further, although the quadratic edges represented a subset of the total number of FC edges, the angular distance results (Fig 2A) support the conclusion that overall whole-brain RSN FC changes reflect this pattern, such that FC is driven furthest from wake during SWS and is closest to wake during REM sleep. These results held for subsets of FC edges involving RSNs previously found to be associated with higher-order cognition (Fig 2B) and consciousness (Fig 2C). Finally, we found that the majority of significant stage transitions between wakefulness and NREM are either increases, or reversals of FC, rather than reductions of FC.

DISCUSSION

This study demonstrated for the first time that RSN FC appears to be modulated in accordance with changes in electrophysiology across wakefulness and sleep. It further suggested that NREM, and SWS in particular, progressively modulates RSN FC in a directional fashion, opposite to that of wakefulness, implying a wakefulness/NREM homeostatic function. Significantly, the angular distance and stage transition results together support the interpretation that NREM, and SWS in particular, manifests an altered state of higher- order cognition and conscious awareness. Importantly, the more nuanced description of stage transitions (i.e., including FC reversals), helps to contrast the present findings with previous descriptions of non-REM as a reduced state.

Affiliations

1. Brain & Mind Institute, Western University, Canada
2. Department of Neuroscience, Western University, Canada
3. University of Ottawa Brain & Mind Research Institute, Canada
4. University of Ottawa Institute for Mental Health Research, Canada
5. Department of Psychology, Western University, Canada
6. School of Psychology, University of Ottawa, Ottawa, Canada
7. The Royal's Institute of Mental Health Research, University of Ottawa, Canada

References

1. Boly, M. (2009), Human Brain Mapping, 30 (8): 2393-2400
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Canada Excellence Research Chair
Natural Science and Engineering Research Council of Canada

5) The impact of sleep deprivation on cortical functional integration & cognitive performances — Dr Nathan Cross (Concordia University)

AIMS

MISSING: Impact of increased brain connectivity on cognition during tasks

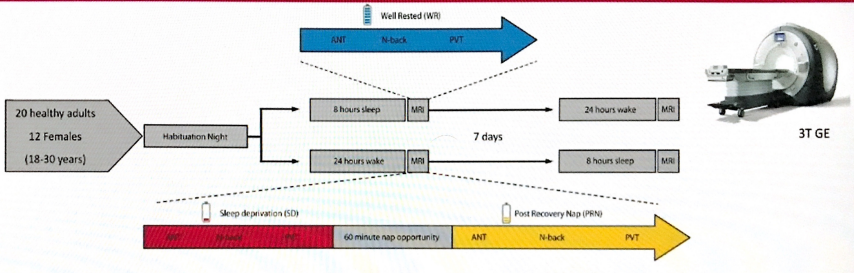
Aim 1: How does the brain state change following 24 hours of total sleep deprivation, and is this altered following a nap?

PREDICTION: Global integration will increase

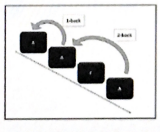
Aim 2: Does the intra-individual change in brain connectivity inform on the individual level of change in performance?

PREDICTION: More integration = worse performance

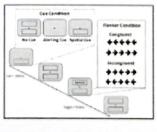
STUDY DESIGN



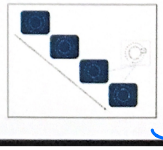
3T GE



N-Back Task



Attention Network Task



Psychomotor Vigilance Task

TODO : Read

SUMMARY

SD = sleep Deprivation

As expected,

- SD = ↓ cognitive performances
- Post nap = ↑ cognitive performances

Additionally,

- SD = widespread ↑ functional connectivity, ↑ total cortical integration

The increase in total integration was robustly associated with the decrease in performance on more complex cognitive tasks.

ness = ↑ functional integrat° in cortical networks

prolonged wakeful = ↓ cognitive performance