Graph-theoretic Analysis of Resting State EEG in Disorders of Consciousness

Srivas Chennu*[,1], Eléonore Pérès[1], Evelyn Kamau[1], Paola Finoia[2], Judith Allanson[1]

John D. Pickard[1], Tristan Bekinschtein[2], Adrian M. Owen[3]

[1]Department of Clinical Neurosciences, University of Cambridge [2]MRC Cognition and Brain Sciences Unit, Cambridge

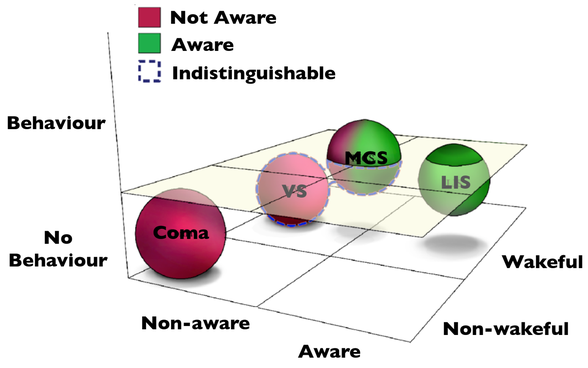
[3]The Brain and Mind Institute, University of Western Ontario

1 BACKGROUND

How can we best characterise the functional integrity of brain networks in disorders of consciousness (DoC)?

Disorders of Consciousness

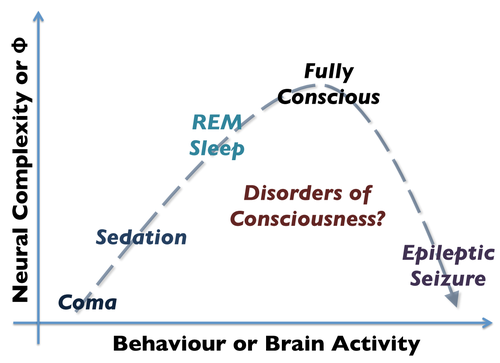
Vegetative and minimally conscious states



VS and MCS are clinically charactersed by "wakeful unawareness"

Neural Complexity[1]

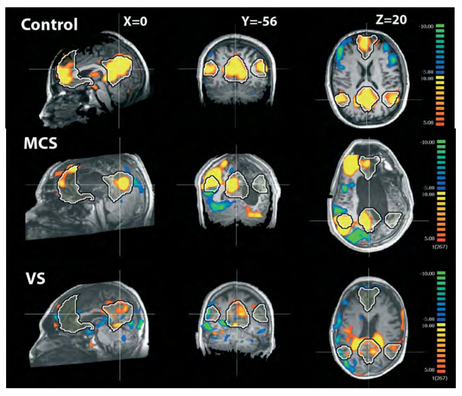
Functional integration vs. differentiation



Level of consciousness reflects balance between integration & segregation of brain activity

Resting State fMRI[2]

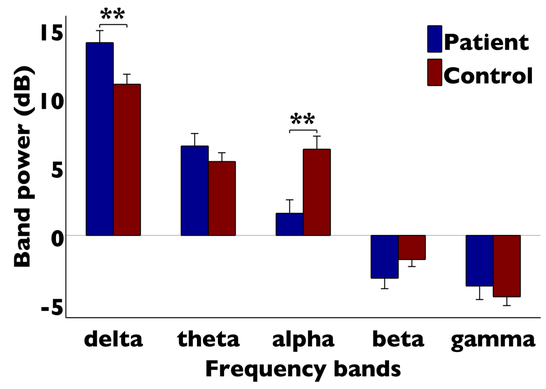
Disrupted functional connectivity in DoC



fMRI default mode brain networks are functionally disintegrated in DoC

Resting State EEG?

Evidence of slowing in natural brain rhythms

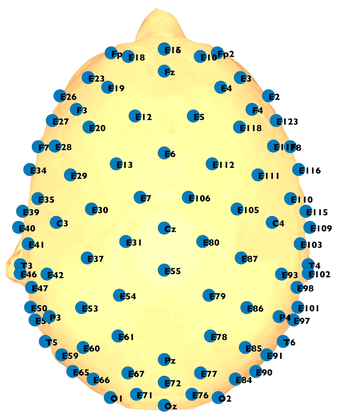


Higher delta (0.5-4 Hz) and lower alpha (8-12 Hz) power observed in patients

2 METHODOLOGY

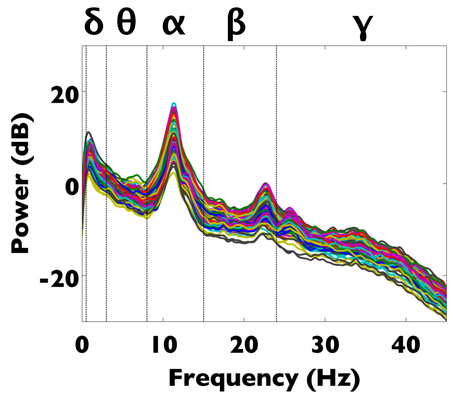
Using spectral coherence to construct graphs and estimate measures of functional interactions between brain regions

High Density EEG



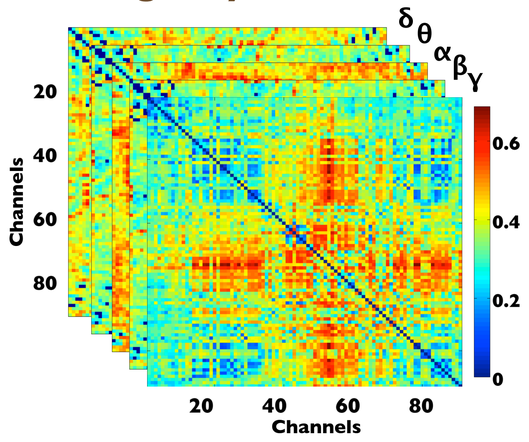
10 minutes of 91-channel EEG from 26 controls & 23 patients (17 MCS & 6 VS)

Cross-spectral Density



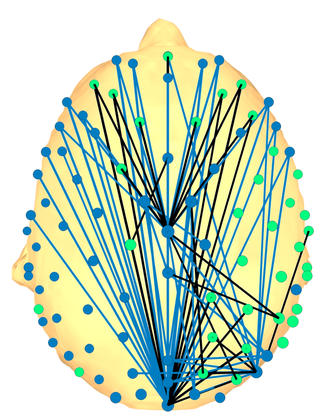
Coherence between channel pairs calculated within 5 canonical frequency bands

Imaginary Coherence[3]



Only imaginary component of coherence retained to eliminate volume conduction effects

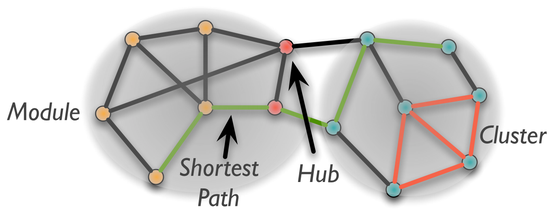
Brain Graphs[4]



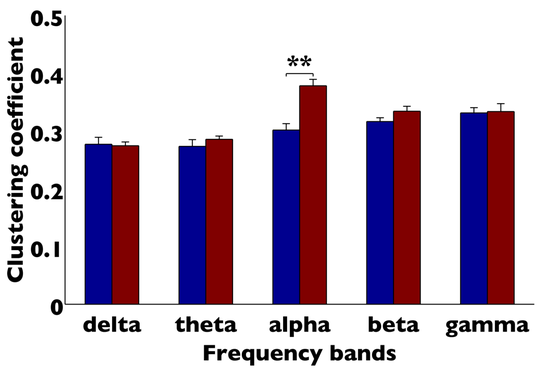
Measures estimated from graph theory and mapped back onto topographical space

3 RESULTS I

Patient brains are less clustered, less efficient, more modular and more decentralised than healthy brains

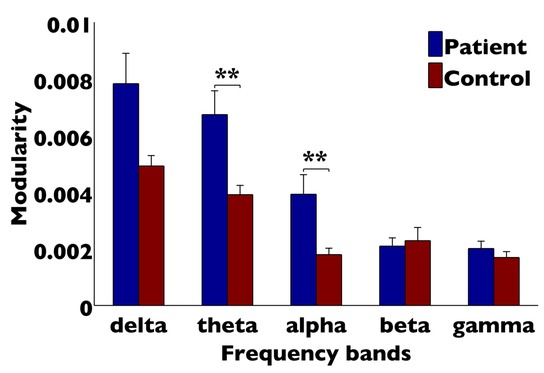


Clustering Coefficient *- fraction of node neighbours that are also neighbours of each other*



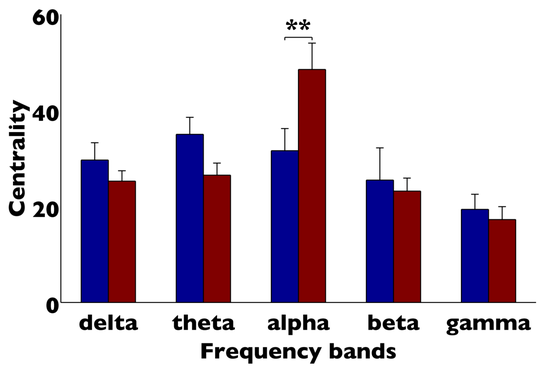
*Patient graphs are **less clustered** than controls*

Modularity *- extent to which graph can be optimally subdivided into loosely connected modules*



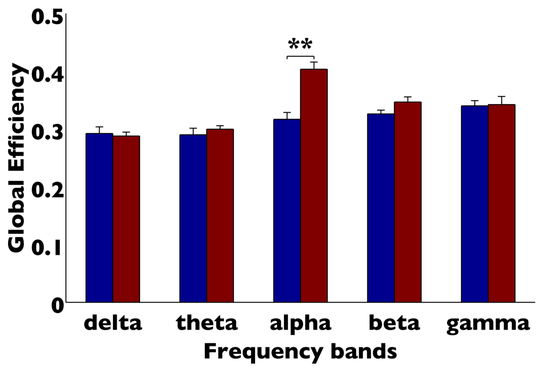
*Patient graphs are **more modular** than controls*

Centrality *- average number of central hub nodes that lie on shortest paths between node pairs*



*Patient graphs have **fewer hubs** than controls*

Global efficiency *- inverse of average length of shortest paths between nodes*

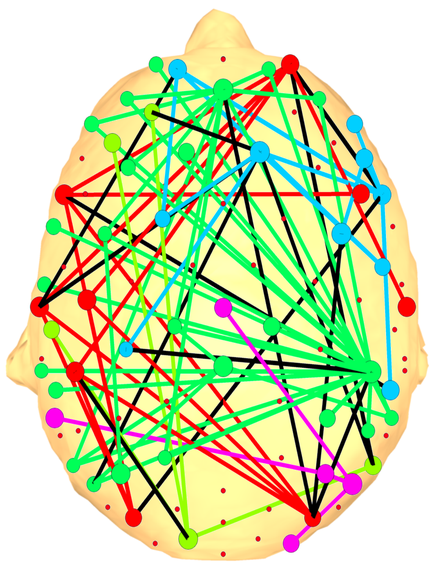


*Patient graphs are **less efficient** than controls*

4 RESULTS II

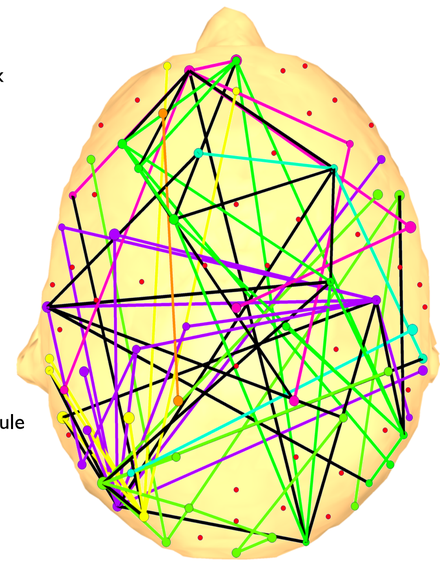
Modular structure highlights stronger temporo-frontoparietal connectivity in controls

Average Control Graph



Strongly connected vertex
Weakly connected vertex
Strongly coherent edge
Weakly coherent edge
Vertices coloured by module
Intra-modular edges
Inter-modular edges

Average Patient Graph



EEG channels (vertices) and alpha-band coherence (edges) are coloured by modular structure

*Graph theory identifies modules that connect **temporo-frontoparietal regions** more strongly in controls*

5 CONCLUSIONS AND DIRECTIONS

- EEG spectral power and coherence are modulated by level of awareness
- Graph theory can be used to characterise patterns in connectivity based on coherence
- Functional disintegration associated with DoC observed in resting state EEG and fMRI
- Alpha and theta bands are important markers of differences in arousal and awareness
  - *What can be inferred about individual patients using these methods ?*
  - *Can such theoretical techniques inform clinical diagnosis and interventions ?*

References

1. Tononi, G. **An information integration theory of consciousness**, *BMC Neuroscience*, 2004
2. Soddu, A. et al. **Resting state activity in patients with disorders of consciousness**, *Funct. Neuro.*, 2011
3. Nolte, G. et al. **Identifying true brain interaction from EEG data using the imaginary part of coherency**, *Clin. Neurophy.*, 2004
4. Rubinov, M. et al. **Complex network measures of brain connectivity: Uses and interpretations**, *Neuroimage*, 2010

***Contact** sc672@cam.ac.uk