UNIVERSITY OF CAMBRIDGE

[1]Department of Clinical Neurosciences • [2]Division of Anaesthesia •
[3]Department of Psychology • * Contact: imc31@cam.ac.uk

Brain network dynamics during recovery from acute coma

Iulia M. Comșa[1*], Stein Silva[2], David K. Menon[2], Tristan A. Bekinschtein[3], Srivas Chennu[1]

INTRODUCTION

COMA

In the landscape of consciousness disorders, coma is the absence of both awareness and wakefulness.

MOTIVATION

Current behavioural markers routinely used in clinical care are insufficiently informative for accurate prognosis of coma after traumatic brain injury[1].

A BETTER APPROACH?

Graph theory can quantify key properties of brain connectivity networks at various organization scales. Thus, it can potentially inform about the brain states of comatose patients and aid in clinical diagnostics.

SUMMARY

We investigated the evolution of brain network characteristics early after traumatic brain injury in 11 acute comatose patients, using overnight EEG recordings. Then we correlated the results with patient outcomes after two months.

METHODS

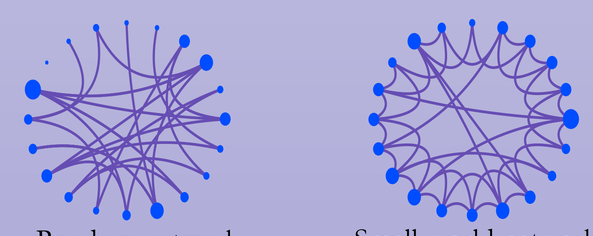
TIMELINE

Proportional changes in graph theoretical measures from session 1 to session 2 were correlated with CRS-R scores after 2 months.

Among other scales of behavioural assessment, the **CRS-R (Coma Recovery Scale Revised)**[2] is used clinically in patients with disorders of consciousness to measure the degree of visual, auditory and motor response, communication ability, and wakefulness.

COMPLEX NETWORKS

Small-world networks have clusters of inter-connected nodes arranged in a way that allows information to traverse the whole network in a small number of steps. The brain is often considered a small-world network at many levels of connectivity: anatomical and functional, cellular and macroscale[4].

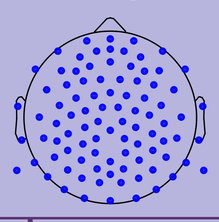


Networks with similar properties include protein interactions or the World Wide Web.

EEG ANALYSIS

High-density EEG

91 scalp channels
Continuous overnight recordings

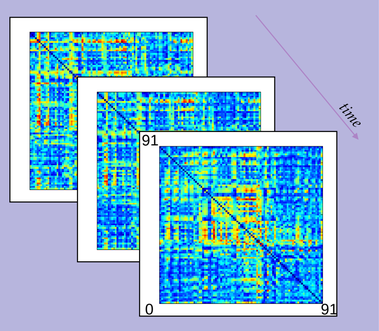


Cross-spectral analysis

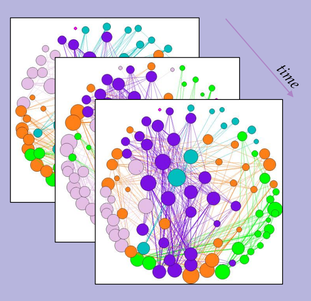
10 second epochs
1-20 Hz (step: 0.1 Hz)

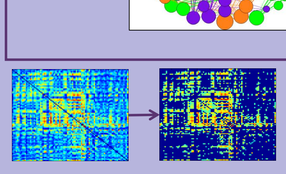
Connectivity networks

91 x 91 channel matrices
10 minute (60 epochs) WPLI windows
3 canonical frequency bands:
- *Delta: 1-4 Hz*
- *Theta: 4-8 Hz*
- *Alpha: 8-13 Hz*



Graph theory





Threshold

Keep 10-50% strongest connections

CONNECTIVITY NETWORKS

The **Weighted Phase Lag Index (WPLI)**[3] estimates functional connectivity between brain regions. It uses cross-spectral analysis to compute phase differences between signals and it corrects for volume conduction.

What network properties can graph theory discover?

Segregation

The presence of local, specialised groups of nodes at micro- and mesoscale level: *node clustering coefficient, modularity*.

Integration

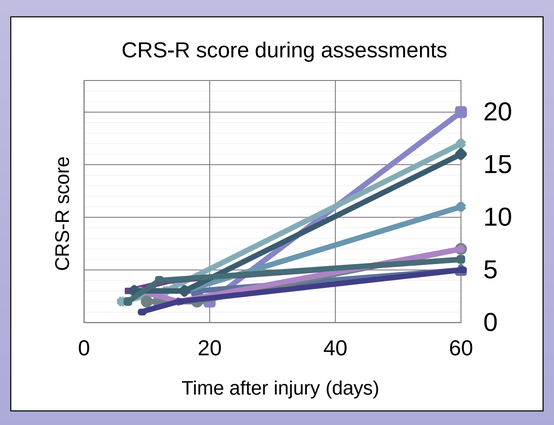
The facility of long-range information exchange across nodes in the network at macroscale level: *characteristic path length, global efficiency*.

Node centrality

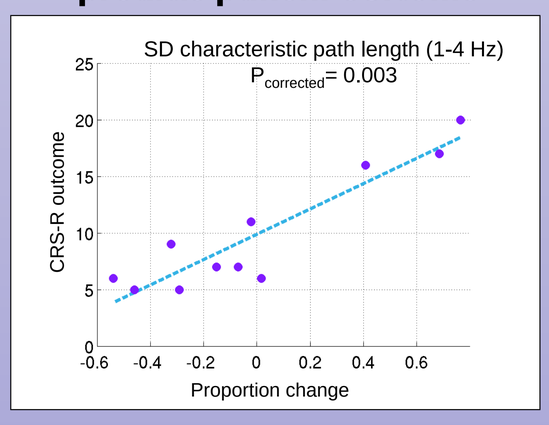
Nodes involved in information exchange between modules: *betweenness, participation coefficient*.

RESULTS

Early CRS-R score is uncorrelated with patient outcome



Increased integration variability in delta networks predicts patient outcome

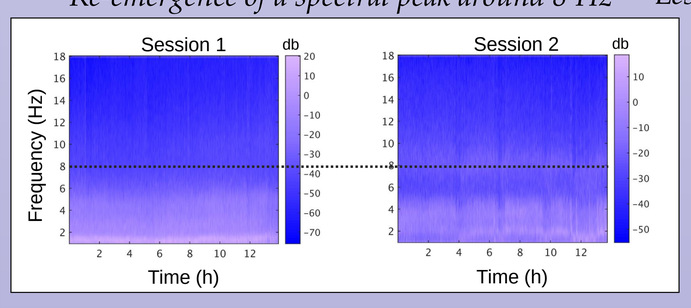


A recovery profile

Within this cohort, the patient with the best CRS-R outcome had a poor initial prognosis. His EEG reveals that his brain networks had started recovering two weeks after injury, before any behavioural signs.

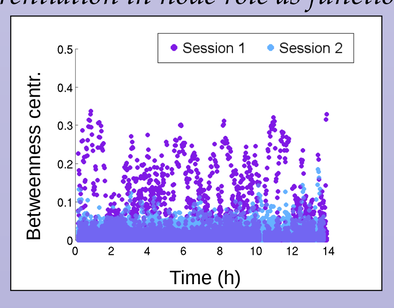
Power spectra

Re-emergence of a spectral peak around 8 Hz



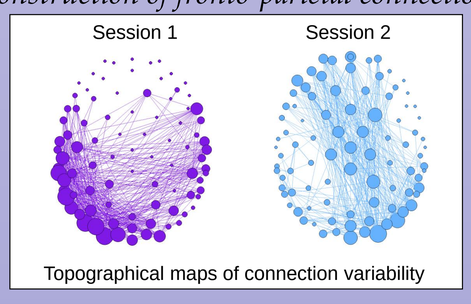
Betweenness centrality of all nodes in alpha networks

Less differentiation in node role as functional hubs



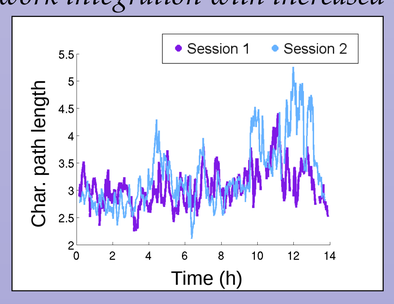
Variability in individual connections in theta networks

Reconstruction of fronto-parietal connections



Characteristic path length in delta networks

Higher network integration with increased variability



CONCLUSIONS

- Brain connectivity dynamics show signs of recovery **before** behavioural improvement.
- **Increased variability of integration in delta connectivity networks** predicts the outcome of patients with acute coma after traumatic brain injury.
- Recovery profiles show **early reconstruction of alpha and theta network topographical properties**, in particular fronto-parietal connections; these are known to support cognitive functions essential to awareness, such as attention and working memory[5].

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