

What can neural measures of conscious level tell us about the inner lives of patients with disorders of consciousness?

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Introduction

Disorders of consciousness are conditions caused by severe brain damage that involve significant impairments to communication and consciousness.

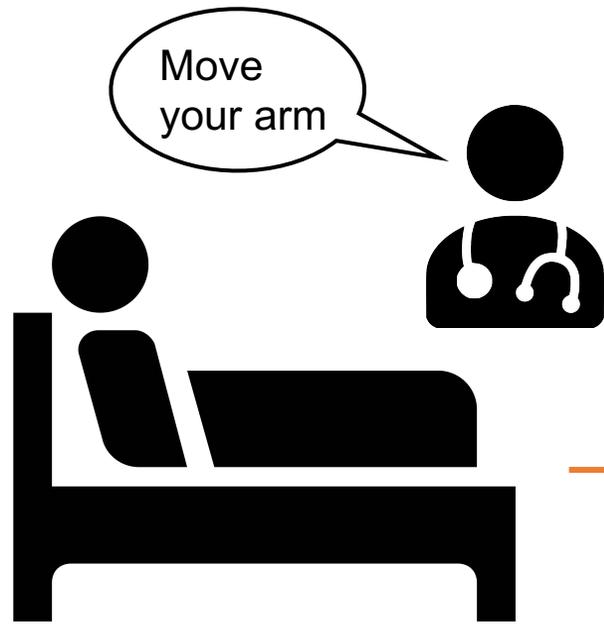
These disorders pose clinical and ethical challenges, because although many of these patients are unresponsive or minimally responsive, research suggests that they can still have sophisticated forms of conscious experience [1].

We have **very limited understanding of what consciousness is really like for these patients** where it is present, though further insight could positively inform decisions related to their treatment and welfare.

Here, I will briefly discuss how neural measures of conscious level, based on resting state brain activity, could provide insight into conscious experience in disorders of consciousness.

Conscious level: clinical concept intended to indicate how conscious an individual is

Assessing consciousness in DOC patients



Behavioural tests
Glasgow Coma Scale, Coma recovery scale revised

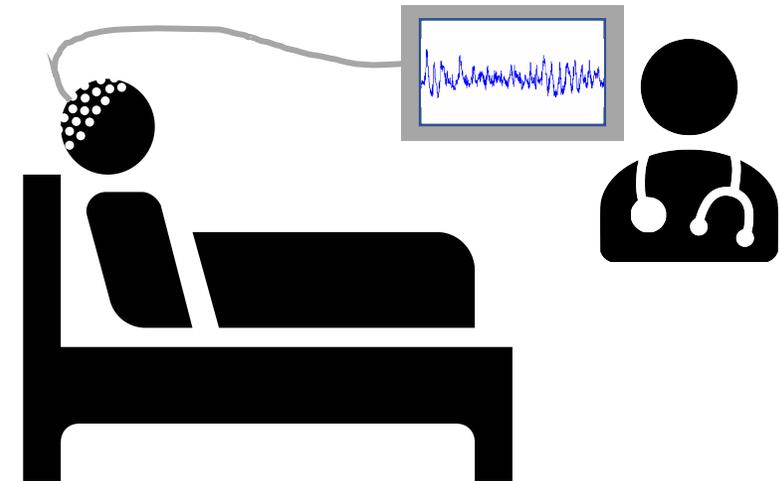
- Gold standard in clinical settings
- Assesses presence of non-reflexive physical behaviour
- **Misdiagnoses up to 40% of conscious DOC patients who cannot produce required behaviours**

Vegetative state

No signs of conscious behaviour

Minimally conscious state

Intermittent signs of conscious behaviour



Passive neural activity

Complexity, spectral properties, functional connectivity, etc.

- Measures of conscious level based on passive neural activity index unidimensional properties in neural data that are thought to be intrinsically related to consciousness.
- Passive neural measures should in principle be able to identify whether consciousness is present or not in all patients, regardless of which specific conscious behaviours they display.

Passive neural measures of consciousness

Specific example: measures approximating **brain complexity** (e.g. Lempel-Ziv complexity, permutation entropy, and fractal dimension).

Brain complexity has been thought to be intrinsically related to conscious “level” [2].

These measures have been applied in a range of conscious states and in DOC.

Case study: brain complexity

Given that consciousness is increasingly thought to be a multidimensional phenomenon, made up of many dimensions that can vary independently, what does it really mean for someone to have high or low brain complexity at a particular point in time?

What information can these measures provide about consciousness that’s useful in an ethical and clinical context?

Brain complexity in different conscious states

Lower spontaneous complexity ←		Normal waking consciousness ← →		→ Higher spontaneous complexity
Vegetative state	Minimally conscious state	Task focus; Meditation	Mind wandering	Psychedelics Ketamine Depression Schizophrenia
NREM sleep	REM sleep	Viewing visual noise	Viewing movie	
Anaesthesia Non-DOC TBI Alzheimers ADHD Anxiety Autism Anorexia Nervosa		Peak at age 60		

High vs low complexity?

- These results indicate that either high or low brain complexity can be associated with abnormal functioning or impairment.
- They also suggest that high brain complexity may indicate the presence of specific features of consciousness (increases in sensory richness, fewer automatic and deliberate constraints on thought) rather than conscious level *per se*.

Clinical relevance of brain complexity for DOCs

Overall, the relationship between brain complexity, consciousness and quality of life may be more complex than is often imagined. This may also be true of other kinds of passive neural measures of consciousness.

From levels to a richer assessment of conscious experience?

Maximising the clinical utility of these measures for patients may require reconceptualising and studying them as markers of specific groups of neurocognitive functions or dimensions of consciousness.

Relationship with quality of life

It is not clear that brain higher complexity is associated with increased wellbeing or quality of life. This will require further empirical investigation.

Proposed treatments that may increase brain complexity (like psychedelics [3]) will not necessarily improve quality of life for DOC patients.

References

- [1] Owen AM, Coleman MR, Boly M, Davis MH, Laureys S, Pickard JD. *Detecting Awareness in the Vegetative State*. *Science*. 2006;313 (5792):1402-1402.
- [2] Tononi G, Edelman GM, *Consciousness and Complexity*. *Science*. 1998; 282(5395):1846-1851.
- [3] Scott G, Carhart-Harris RL, *Psychedelics as a treatment for disorders of consciousness*, *Neuroscience of Consciousness*, Volume 2019, Issue 1, 2019, niz003.

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Static slides available on conference website or via email.