

Consciousness from an Empirical Stance

Colloquium at the Center for Mind Brain and Culture, Emory

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Introduction

Two basic questions for a science of consciousness:

- Theoretical: *What is consciousness?*
- Empirical: *What counts as a measurement of consciousness?*

Together, these interrelated questions generate the ...

- **Problem of Coordination:** Align the theory with the target phenomena by linking the terms in the theoretical model to measurement procedures.
- Through the attempt to diagnose and treat traumatic brain injury, there is sustained effort to address this problem in clinical neuroscience.

➤ *Issue for today's colloquium:* Is there substantive progress on the coordination problem?

The Empirical Stance

- Treat the problem of coordination as an issue strictly *internal* to scientific representation
- Treat consciousness as an unobservable or hidden variable
 - Suitable data representations are needed

I. Φ and PCI

An answer to the theoretical question: Φ *Integrated Information Theory*

- Consciousness is a system property consisting in dynamic complexity (mutually dependent variables) or *integrated information*.
 - Φ is the variable representing this system property
- Freely adapted from statistical mechanics and information theory – Φ is like inverse entropy
 - When entropy has run its course, a system ceases to exist as such because the microstates (constituents) become completely disordered.
 - “Gain in entropy means loss of information” - G.N. Lewis
 - According to Tononi, *loss of Φ means loss of consciousness*
 - Φ quantifies integrated information in terms of the difference between current system dynamics and those of the closest possible pair of unintegrated systems.

An answer to the empirical question: PCI

Perturbational Complexity Index

- Clinical objective: Reliably distinguish Minimal Conscious State from Permanent Vegetative State
- PCI: A “scalar measure of the compressibility of the EEG response to TMS”(Tononi & Koch, 2014, pp.6)
 - If the EEG is sufficiently disordered, the inference is that the patient is vegetative.
 - If the EEG is sufficiently complex, the inference is that the cortex is still at least somewhat integrated and the patient is minimally conscious

Constructing the data model:

- Generate an idealized binary matrix, representing spatiotemporal response
- **Compress** the matrix: apply the Lempel-Ziv measure of algorithmic complexity, finding the integration of the response above & beyond its strength and extent
 - LZ eliminates redundancy by estimating the minimal number of different patterns necessary to describe the matrix
- Asymptotically, PCI = 1 for maximally complex TMS evoked potentials.
- PCI is directly inspired by Φ : “... its apparent usefulness supports the notion that consciousness is linked to complexity, measured as the information content of distributed causal interactions in the brain” (Casali, Gosseries et al, 2014, p.8).
- See the figures, attached

II. The Problem of Coordination

The problem is one of reference:

“... how, or in what sense, can an abstract entity ‘save’ or fail to ‘save’ this concrete phenomenon? What is the pertinent relation that holds or does not hold between the mathematical structure described by our equations and that natural or artificially produced process?” (van Fraassen, 2008, p.245)

Answer: The pertinent relation is that of **mapping**

- Define a function from the elements of the model onto some other structure, or *embed* some other structure back into the abstract model.
- But what other structure?

Two ways to understand coordination

- *Galilean approach:* The relevant mapping relation obtains between the theory and the world itself – the function ranges over some target system in reality.
 - In this case, Φ maps directly onto consciousness.
 - “The universe is written in the language of mathematics”
 - Traditional bugbear for a science of consciousness: Experience is not a set!

- *Empiricist approach*: Coordination is mapping between theoretical model and data model
 - The target must first be *represented* through the construction of data models and smoothed surface (statistical) models
 - Φ is a general theory insofar as it ranges over a domain of possible data models

A three-place relation: $theory \leftrightarrow data\ model \leftrightarrow target\ system$ $\Phi \leftrightarrow PCI \leftrightarrow consciousness$

- New data models presuppose
 - Pre-existing practices of observation
 - Background theoretical criteria.
- Theoretical innovation and refinement is spurred by feedback from new measurements.
- Metaphysical intuitions about the target system are not an independent criterion – they are informed by the evolution of the two kinds of representations

III. Improving Coordination

The coordination of Φ with PCI requires more than just a general idea that consciousness emerges through complexity:

- *Ordinal scale*: Are scalar distances proportional and significant in the target?
 - How can researchers establish a precise calibration for MCS?
- *Marginal distortion*: Does the chosen proxy variable behave consistently across the scale?
 - Are there perspectival effects?
- *Absolute zero*: Is the asymptotic $PCI = 0$ analogous to freezing?

Historical analogy: Similar problems were encountered – and overcome - during the development of the liquid thermometer and the emergence of the kinetic theory of temperature (van Fraassen, 2008)

- If Φ is to earn empirical bona fides and distinguish itself from competing theories of consciousness, there must be progress in these and related issues

Conclusion: Empiricism, Φ , and PCI

Together, Φ and PCI have made a substantive start on the problem of coordination

- Φ gains empirical content and PCI gains theoretical significance
- Empirical Stance: Measurement is *the act of locating an item in a logical space*
 - Φ defines the logical space, and PCI populates the space
- Legitimizing the MCS movement? Intuitions are already changing.
 - Ghost Hunters?
 - Through a Glass, Darkly?

Figures

Assessing consciousness in coma and related states using TMS combined with EEG

O. Gosseries et al / *Annales Françaises d'Anesthésie et de Réanimation xxx (2014) xxx-xxx*

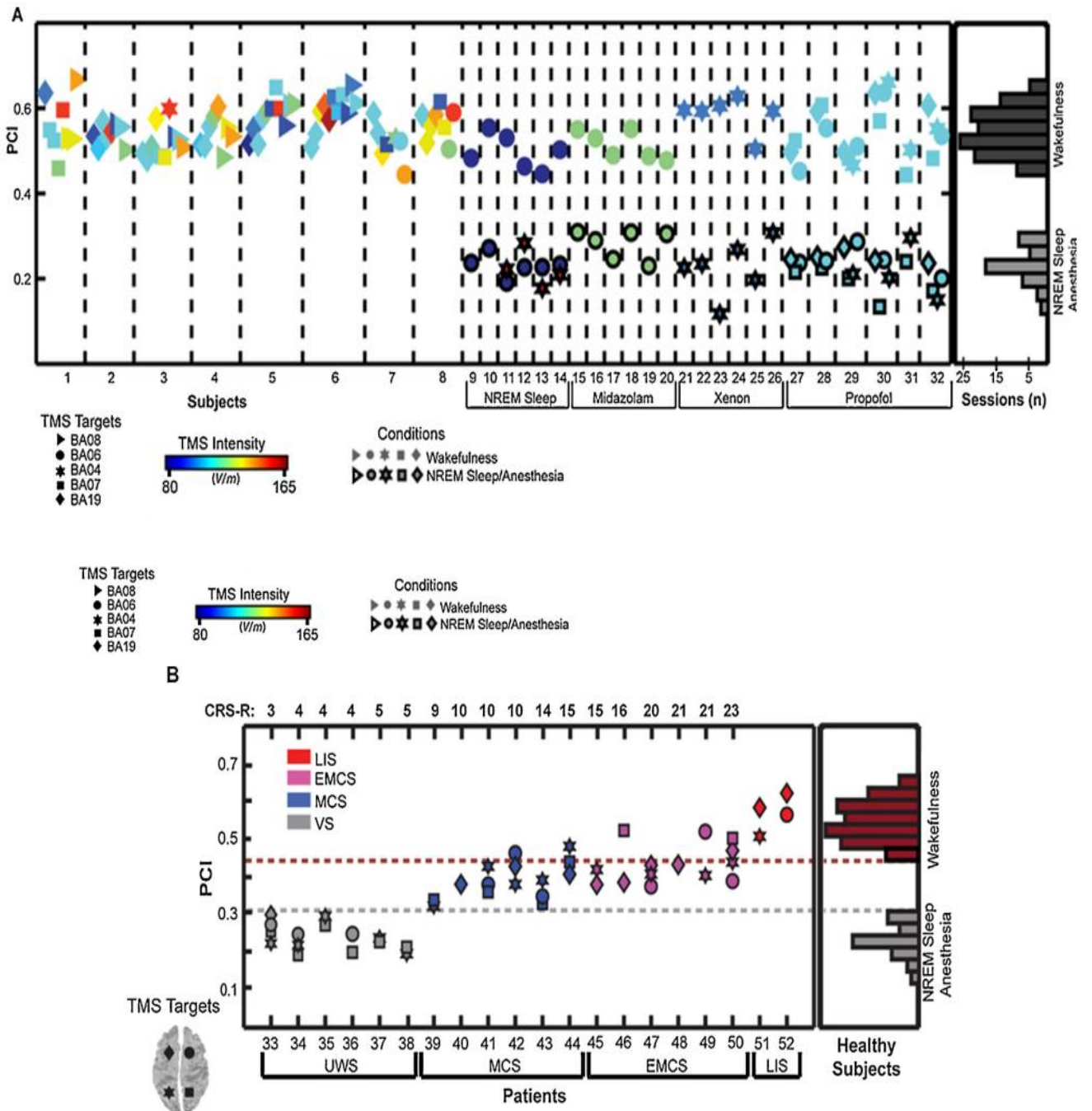


Fig. 5. The Perturbational Complexity Index. A. PCI values in healthy subjects. PCI measured during consciousness ranged between 0.44 and 0.67, whereas the PCI measured during unconsciousness ranged between 0.12 and 0.31. B. PCI values in severely brain-injured patients. PCI progressively increases from unresponsive wakefulness (UWS) to minimally conscious (MCS) and to recovery of functional communication (EMCS). PCI attains levels of healthy awake subjects in LIS patients. CRS-R: Coma Recovery Scale-Revised.