

Consciousness and Complexity: an exploration across brain states, scales and models

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Theoretical neuroscience suggest that consciousness depends on the ability of neural elements to engage in complex activity patterns that are, at once, distributed within a system of interacting cortical areas (integrated) and differentiated in space and time (information-rich) (i.e. brain complexity). Based on this principle, we have been developing and testing a theory-driven empirical method to assess brain complexity based on a combination of transcranial magnetic stimulation (TMS) and electroencephalography (EEG). Overall, the assessment of brain complexity provides a reliable measuring scale along the unconsciousness/consciousness spectrum and allows a robust assessment of unresponsive individuals (such as locked-in, minimally conscious and vegetative state patients) whose level of consciousness cannot be assessed behaviorally.

Starting from the experimental evidence of a link between consciousness and complexity, we moved on to explore the mechanisms by which brain complexity collapses and recovers in the human brain. Specifically, we wanted to test the hypothesis that neuronal bistability – the intrinsic tendency of cortical neurons to fall into a silent OFF-period after an initial activation - may play an important role in impairing the brain's capacity to integrate information not only during NREM sleep but also in anesthesia and in brain-injured patients. We try to address this question at multiple scales (macro, meso and micro) of investigation, by recording brain responses to direct cortical stimulations using (1) TMS/EEG, (2) intracranial electrical stimulation/recordings in neurosurgical patients as well as in the animal model and (3). These measurements provide convergence evidence that bistability and neuronal OFF-periods may play an important role in preventing the build-up of brain complexity. Since bistability is, in principle, a reversible dynamics, this finding may point to novel strategies to promote recovery of consciousness after brain injury.