Consciousness & Effective Connectivity

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A compilation of papers and snippets I, with my very limited knowledge in the field of neuroscience, found interesting and illuminating.

Tononi & Massimini seem to be two ‘big shots’ that produce a lot of interesting research. They proposed to measure consciousness in terms of the balance between integration and differentiation, or the effective connectivity between different regions of the brain (causal influence between regions) and the possibility of these regions to behave differently, increasing the number of possible states (entropy).

### Breakdown of Cortical Effective Connectivity During Sleep (Massimini et al. 2005)

This is the main idea:

*"Recently we have proposed that consciousness depends critically not so much on firing rates, synchronization at specific frequency*

*bands, or sensory input per se, but rather on the brain\_s ability to integrate information, which is contingent on the effective connectivity among*

*functionally specialized regions of the thalamocortical system. Effective connectivity refers to the ability of a set of neuronal groups to causally affect the firing of other neuronal groups within a system. The fading of consciousness during NREM sleep episodes early in the night, evidenced by short or blank reports of cognitive activity upon awakening , would then be associated with an impairment of cortical effective connectivity."*

very short paper with nice, insightful graphics

### see also Cortical reactivity and effective connectivity during REM sleep in humans (Massimini et al. 2010)

### A Theoretically Based Index of Consciousness Independent of Sensory Processing and Behavior (Casali et al. 2013)

*Theoretical indices based on this principle have been designedto assess the joint presence of differentiation and integration in neural systems. Simple systems of simulated elements or under highly restrictive assumptions and have not been tested on human brains. Currently used empirical indices of consciousness, instead, are based either on integration alone [as judged by the extent or synchronization of cortical activation or on differentiation alone as judged by entropy or spectral content and do not reliably assess consciousness in individual patients or across many different conditions. In a recent series of experiments, we assessed the electroencephalographic (EEG) response to transcranial magnetic stimulation (TMS) during physiological, pharmacological, and pathological loss of consciousness. We found that, compared to responses of conscious, wakeful individuals, brain responses of people who had lost consciousness became either local (suggesting a loss of integration) or global but stereotypical (suggesting a loss of differentiation). Nevertheless, these studies did not allow us to quantify brain complexity across subjects and conditions, a requirement for a reliable, unified measurement scale. Here, we introduce an empirical measure of brain complexity, the perturbational complexity index (PCI), which gauges the amount of information contained in the integrated response of the thalamocortical system to a direct perturbation.*

Results & Discussion are very interesting.

### Neural correlates of consciousness: progress and problems (Koch et al. 2016)

Section ‘Neurophysiology -activated EEG’, for a crash course in classifying EEG  into wake/sleep and why this is a good but not perfect indication of consciousness.

Section ‘Neural differentiation and integration’, for a crash course in the role of differentation and integration in consciousness, and the PCI metric.

### Improved Measures of Integrated Information (Tegmark 2016)

This is from Max! A comparison of measures of integrated information.

### Nonlinear Multivariate Analysis of Neurophysical Signals (Pereda, Quiroga, and Bhattacharya 2005)

*In this work, we first describe the multivariate linear methods most commonly used in neurophysiology and show that they can be extended to assess the existence of nonlinear interdependences between signals. We then review the concepts of entropy and mutual information followed by a detailed description of nonlinear methods based on the concepts of phase synchronization, generalized synchronization and event synchronization. In all cases, we show how to apply these methods to study different kinds of neurophysiological data.*

# References

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