Title: Attractors in the Conscious Brain: Dynamical Informational Structures

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Abstract:

The dynamical activity of the human brain depicts an extremely complex energy landscape that changes over time. We propose here a novel mathematical formalism for characterizing how the attractors landscape evolves in time. Furthermore, we demonstrate that this formalism serves to distinguish quantitatively and rigorously between different brain states. In particular, by using a whole-brain dynamical model integrating the underlying anatomical structure with the local node dynamics based on a Lotka-Volterra description, we compute analytically the instantaneous global attractors of this cooperative system and their associated directed graphs, called the informational structures. The informational structure describes precisely the past and future behavior in terms of a directed graph composed of invariant sets (nodes) and their corresponding connections (links). We characterize a brain state by the time variability of these informational structures. This variability is analyzed applying the Lotka-Volterra Transform, a mathematical operator defined to exactly reproduce the empirical BOLD fMRI signals by finding the growth rate function that tracks their time-evolution. The innovative view relies on the fact that we are computing an asymptotic attractor at every time instant, i.e., the state that the system would achieve in the limit assuming that particular value of the growth rate parameter. All this applied to our results shows that the dynamics of the awake brains reflect a greater functional complexity than deeply asleep brains and a greater unpredictability of the conscious brain dynamics since there is maximum entropy and minimal information. This theoretical framework is potentially highly relevant for the development of biomarkers assessing the level of consciousness of healthy subjects undergoing different stages of sleep, the effect of anesthesia or psychedelic drugs like LSD, subjects prevented from communication due to language disorders, and in coma patients.