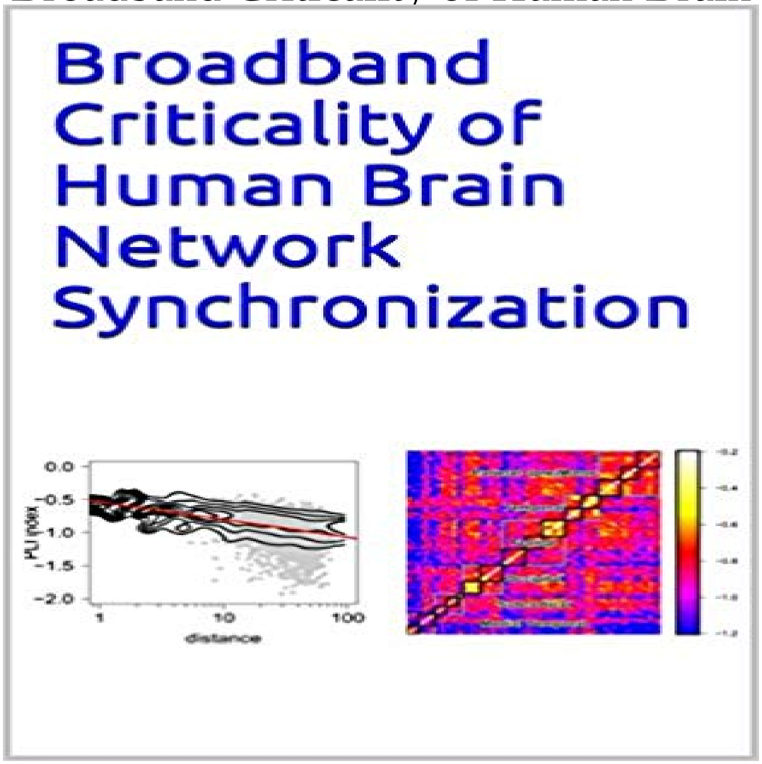
Broadband Criticality of Human Brain Network Synchronization



Self-organized criticality is an attractive model for human brain dynamics, but there has been little direct evidence for its existence in large-scale systems measured by neuroimaging. In general, critical systems are associated with fractal or power law scaling, long-range correlations in space and time, and rapid reconfiguration in response to external inputs. Here, we consider two measures of phase synchronization: the phase-lock interval, or duration of coupling between a pair of (neurophysiological) processes, and the lability of global synchronization of a (brain functional) network. Using computational simulations of two mechanistically distinct systems displaying complex dynamics, the Ising model and the Kuramoto model, we show that both synchronization metrics have power law probability distributions specifically when these systems are in a critical state. We then demonstrate power law scaling of both pairwise and global synchronization metrics in functional MRI and magnetoencephalographic data recorded from normal volunteers under resting conditions. These results strongly suggest that human brain functional systems exist in an endogenous state of dynamical criticality, characterized by a greater than random probability of both prolonged periods of phase-locking and occurrence of large rapid changes in the state of global synchronization, analogous to the neuronal avalanches previously described in cellular systems. Moreover, evidence for critical dynamics was identified consistently in neurophysiological systems operating at frequency intervals ranging from 0.050.11 to 62.5125 Hz, confirming that criticality is a property of human brain functional network organization at all frequency intervals in the brains physiological bandwidth.

This pattern of results indicates that scaling of synchronization metrics can arise in critical systems regardless of the underlying mechanisms and that broadband criticality is clearly evident in large scale human brain networks derived from substantively different modalities of neuroimaging data.Self-organized criticality is an attractive model for human brain dynamics, but there has been little direct evidence for its existence in large-scale systemsBroadband criticality of human brain network synchronization. Kitzbichler MG, Smith ML, Christensen SR, Bullmore E. Broadband criticality of human brain Citation: Farmer S (2015) Comment on Broadband Criticality of Human Brain Network Synchronization by Kitzbichler MG, Smith ML,Broadband criticality of human brain network synchronization. Self-organized criticality is an attractive model for human brain dynamics, but there has been little direct evidence for its existence in large-scale systems measured by neuroimaging. Self-organized criticality is an attractive model for human brain dynamics, but there has been little direct evidence for its existence in large-scale Citation: Kitzbichler MG, Smith ML, Christensen SR, Bullmore E (2009) Broadband Criticality of Human Brain Network Synchronization. Full-Text Paper (PDF): Comment on Broadband Criticality of Human Brain Network Synchronization by Kitzbichler MG, Smith ML, ChristensenBroadband Criticality of Human Brain Network Synchronization. Authors: Kitzbichler, Manfred G. Smith, Marie L. Christensen, Soren R. Bullmore, Ed. Self-organized criticality (where systems spontaneously organize E (2009) Broadband Criticality of Human Brain Network Synchronization. Citation: Kitzbichler MG, Smith ML, Christensen SR, Bullmore E (2009) Broadband Criticality of Human Brain Network Synchronization.Broadband criticality of human brain network synchronization. PLoS Computational Biology, 5(3), e1000314. Kotter, R. (2004). Online retrieval, processing, andKitzbichler MG, Smith ML, Christensen SR, Bullmore E (2009), Broadband criticality of human brain network synchronization. PLoS Comput Biol 5(3):e1000314