Functional Connectivity Differences in fMRI Data across the Sleep/Wake Cycle are Explained by Changing Bifurcation Properties of a Whole Brain Computational Model.

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Background:
Functional connectivity (FC) between brain areas is not fixed but fluctuates across time giving rise to various FC states. It was recently demonstrated that waking and anesthesia in monkeys can be distinguished solely based on the repertoire of such FC states with more diverse patterns found in the awake state. The neuronal mechanisms behind these findings are unclear. Here we test the hypothesis that the brain increases its dynamical repertoire during waking by tuning itself to a precise global working point, using whole brain modeling of fMRI data.

Methods:
BOLD signals were obtained from healthy human subjects during resting wakefulness (AW) and three different levels nonREM sleep (N1-N3). Brain areas were delineated based on the Hagmann parcellation scheme and different FC states were extracted using Fano factor (FF) analysis of the discretized time series in small time windows (~5 TR). Node dynamics of the model were approximated by a Hopf bifurcation and nodes were connected using the Hagmann structural connectivity matrix.

Results:
During AW, the discretized data showed transient bursts of activity synchronized across the entire brain which were interleaved with periods of highly desynchronized activity. During the deepest phases of sleep (N3) these bursts were entirely absent and desynchronization was prevalent. Synchronization was characterized by high FFs and high average FC values, while desynchronization was accompanied by low FFs and little global correlation. Accordingly, FF distributions during AW were heavy tailed, while sleep was characterized by progressively narrowing distributions towards small values. Analysis of the model revealed stochastic transitions between globally synchronized activity and desynchronization, similar to the awake state, when its working point was set at the bifurcation value. In contrast, desynchronized sleep activity was mimicked with model parameters being set further away from the bifurcation.

Conclusions:
We demonstrate that humans during waking can show transitions between synchronized and desynchronized dynamics, while loss of consciousness is characterized by a reduction to uncorrelated dynamics. Our whole brain model revealed that the larger synchronization repertoire in the awake state can be explained by a dynamical system set to a single working point, which is shifted during sleep.