Figure Legends

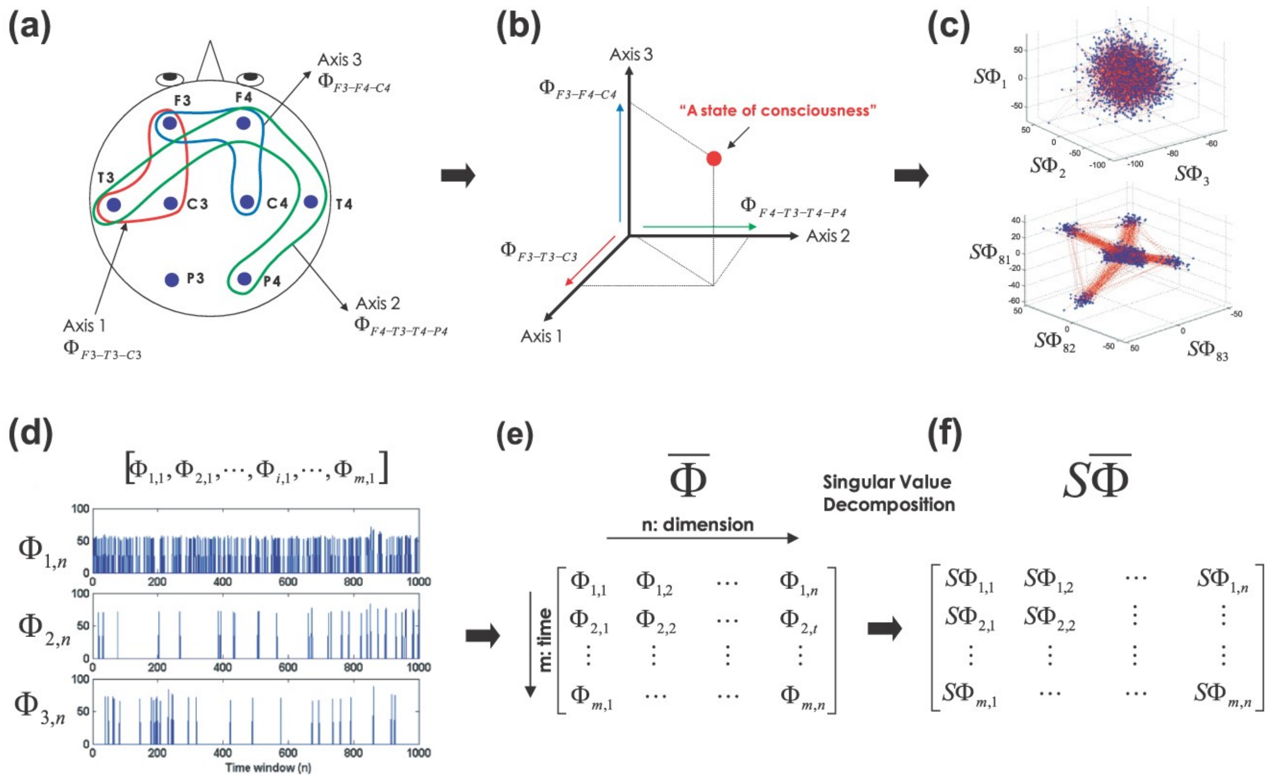

Figure 1: **Schematic of state space reconstruction from multi-channel EEG**. (a) Three primary EEG complexes determined by the minimum information bipartition method. (b) The three EEG complexes were used to construct the state space. In practice, all types of EEG complexes observed during the EEG recording were used to construct the state space of consciousness. (c) Two trajectories, composed of two different EEG complex sets, show distinctive transition processes. (Upper figure) Trajectory of three higher ranked EEG complexes. (Lower figure) Trajectory of the three lower ranked EEG complexes. (d) Time evolution of three primary EEG complexes. (e) Sequences of the

EEG complexes occurring during the recording period were used to construct the trajectory in the state space. (f) Orthogonal axes of the state space, as determined by singular value decomposition.

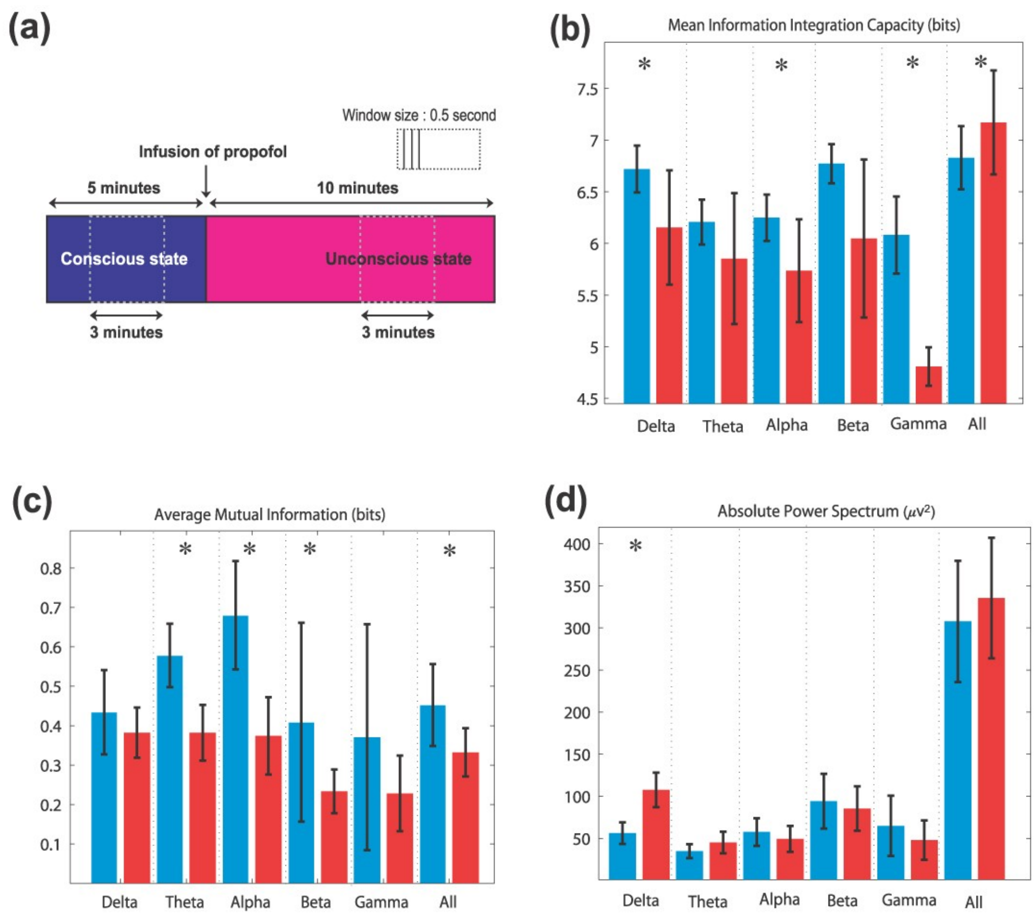

Figure 2: **General anesthesia reduces information integration**. (a) Schematic of the anesthesia experiment. The three minute long EEG periods were selected for analysis before and after the injection of propofol. (b) The mean information integration (MII) capacity, (c) average mutual information (AMI) and (d) absolute power spectrum for

various spectral bands in the conscious and the unconscious states. "*" marker indicates significant change after loss of consciousness (Willcoxon signed rank test, p<0.01).

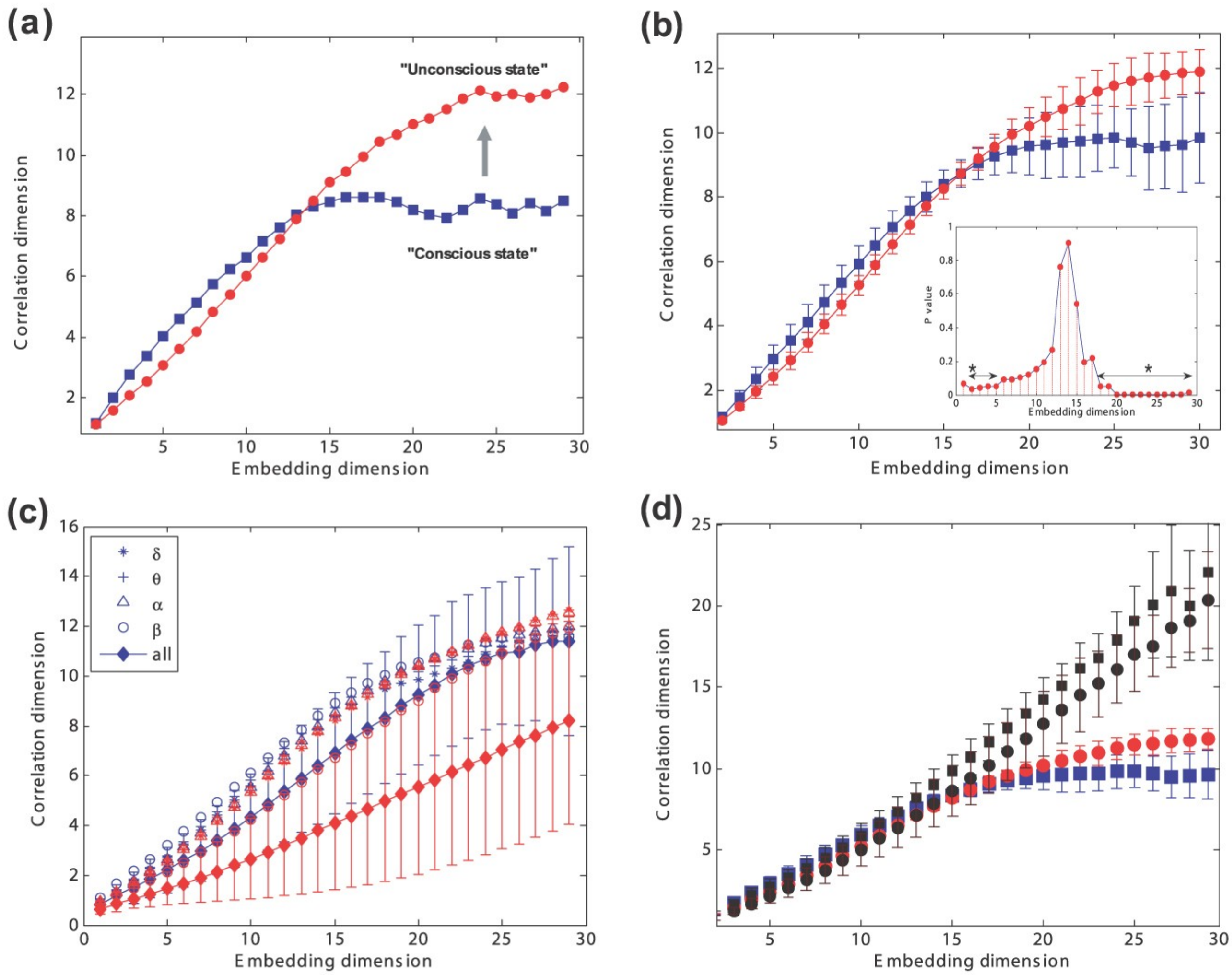

Figure 3: **Differential dimensionalities reflect the dynamic properties of conscious and anesthetized states**. (a) The dimensionality of the trajectory constructed by the gamma band in the conscious state was increased after loss of consciousness (blue square: conscious state, red circle: unconscious state). (b) The mean correlation dimensions of the conscious and unconscious states for 14 subjects (blue square: conscious state, red circle: unconscious state). The conscious state showed a lower dimensional structure, saturating at about 9.7 of the mean correlation dimension. The inset shows the p-values of the Wilcoxon signed rank test at each embedding dimension (* indicates that $p < 0.05$). (c) The mean correlation dimensions of various spectral bands such as delta, theta, alpha, beta and raw EEG. (blue color: conscious state, red color: unconscious state). Error bars denote the standard deviation of the correlation dimension of raw EEG. (d) Application of the surrogate test to the gamma band EEG. The randomized data (black circle and black square) are clearly distinguished from the original data (red circles and blue squares, respectively) in the estimation of the correlating dimension. The mark and error bars at each embedding dimension indicate the mean and standard deviation of the correlation dimension values for the 14 subjects.

Appendix: Methods

Determination of EEG complexes

A subset S taken from all EEG channels, X, was partitioned into A and its complement B(B=S-A). The causally effective connection between A and B was defined by effective information

$$EI(A \leftrightarrow B) = EI(A \to B) + EI(B \to A)$$

, where $EI(A \to B)$ and $EI(B \to A)$ measures the casually effective connection linking A to B and B to A, respectively, by mutual information. Under Gaussian assumptions for the multi-channels EEGs, all derivations from independence among the two complementary parts A and B of a subset S of X are expressed by the covariance among the EEG channels. Therefore, $EI(A \to B)$ was calculated with the following relations,

$$EI(A \to B) = MI(A^{\max}; B),$$

$$MI(A^{\max}; B) = H(A^{\max}) + H(B) - H(A^{\max} B),$$

$$H(A) = (1/2)\ln\left[(2\pi e)^n \left|COV(A)\right|\right]$$

, where $A^{\max}$ is the independent Gaussian noises and COV(A) is the covariance matrix of the EEG channels partitioned into A.

Within the subset S, we considered all possible bipartitions and found the minimum information bipartition, MIB(S), for which the normalized effective information became a minimum, as well as the corresponding value of $\Phi(S)$, which quantified the capacity of the information integration of the subset S.

$$MIB(S) = \frac{EI(A \leftrightarrow B)}{\min(H^{\max}(A), H^{\max}(B))},$$

$$\Phi(S) = EI(MIB(S)).$$

Originally, a subset S with is called "complex", if it is not included within a subset having higher Φ, but, here, in the application to EEG, the MIB subset is called "EEG complex". The EEG complexes were searched out by using the Matlab toolbox, which provided by G. Tononi and O. Sporns. The main output is a list of all the EEG complexes found and their values. The top 30 EEG complexes in the list reflect the most relevant information for the global brain function, occupying about 60% of the total cumulative frequencies of EEG complexes.

The long term EEG was segmented into 500 ms EEG windows, overlapping by 400 ms. The top 30 EEG complexes ranked by its values were selected at each window and were put together into a pool of EEG complexes. Approximately 90 different types of EEG complexes were found for each subject. Thus, we determined the dimension of the state space as 90. Each type of EEG complex and its value was set as an axis and the coordinate value of the axis, respectively, in the state space. The rest of the coordinates not involved in the top 30 EEG complexes were all padded with zero.

Reconstruction of the trajectory and the state space

For the dimensional analysis, we used the five minute EEG periods in the conscious and unconscious states. From the same windowing procedure as above, 2995 windows were produced, and the trajectory and the state space were reconstructed by the EEG complexes found from these windows. To make the axes orthogonal and to take the principle components from the trajectory, the singular value decomposition was applied to the trajectory. The trajectory, M, is decomposed into $M = USV^T$, where U and V is the unitary matrices, V^T is the conjugate transpose of V, and S is a diagonal matrix whose elements are the singular values of the M, the trajectory projected to the principle axes is defined as $M_{svd} = MV$. Here, the primary principle axes (from the second to the thirtieth principle axes) of the projected trajectory, M_{svd}, were used for the dimension analysis.