

# Supplementary Materials for

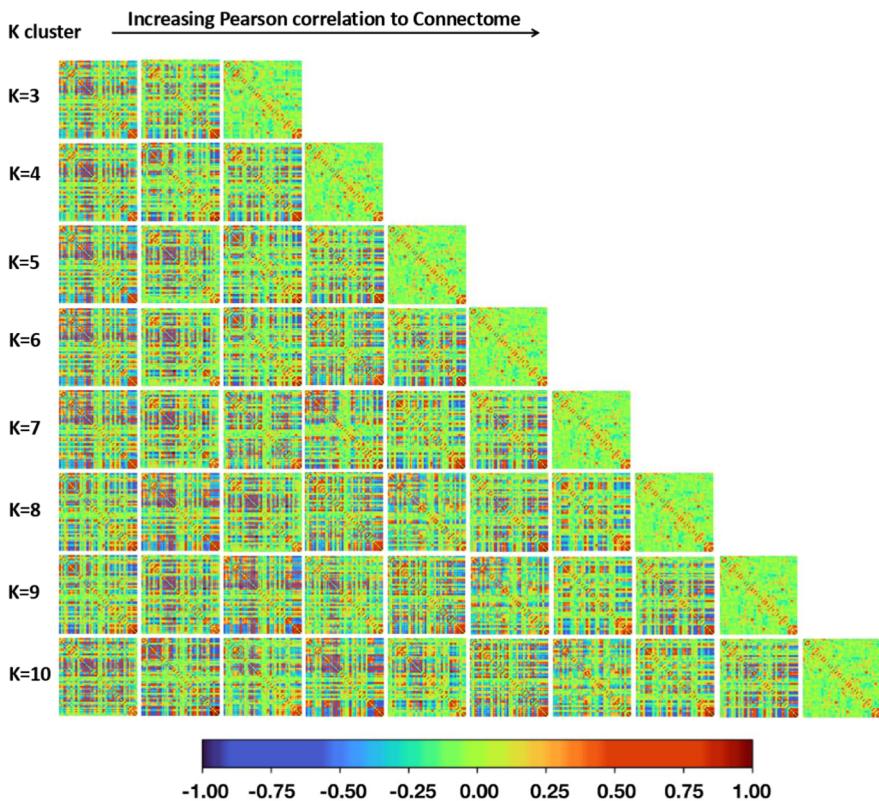
## Dynamical structure-function correlations provide robust and generalizable signatures of consciousness in humans

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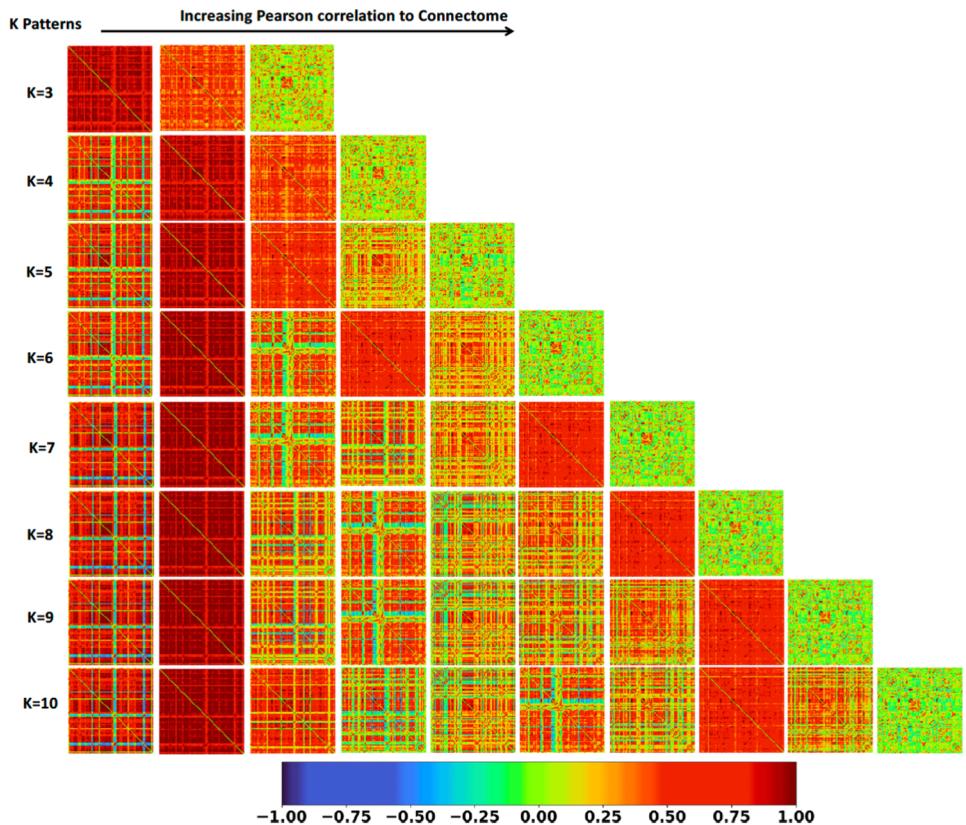
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- Fig. S2. Dynamical functional coordination patterns from deep sleep dataset
- Fig. S3. Increase in SFC and reduction of Shannon Entropy in unconscious states using sliding-window correlation in both datasets.
- Fig. S4. Reproduction of Figures 2 and 4 using narrower bandwidth filter between 0.04 and 0.07 Hz.
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- Table S4. Network-level ROIs of the Desikan-Killiany parcellation used for the general anaesthesia dataset.
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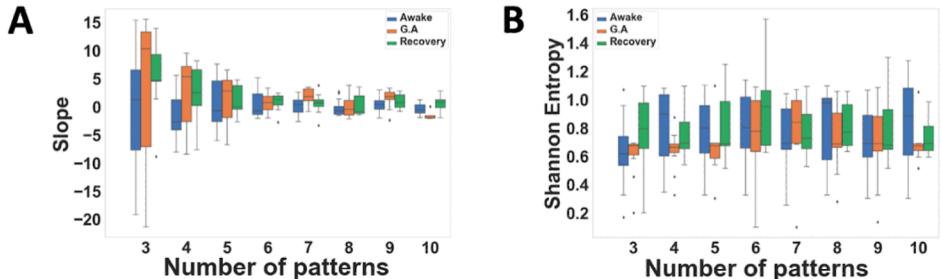


**Figure S1. Dynamic functional coordination patterns from propofol general anaesthesia dataset using  $K = 3 \dots 10$  number of clusters in the k-means algorithm.** For each value of  $K$  patterns are ordered based on their similarity to underlying anatomical connectivity, from the least (left) to the most similar (right) in terms of the SFC. The SFC values can be found in Table S3A.

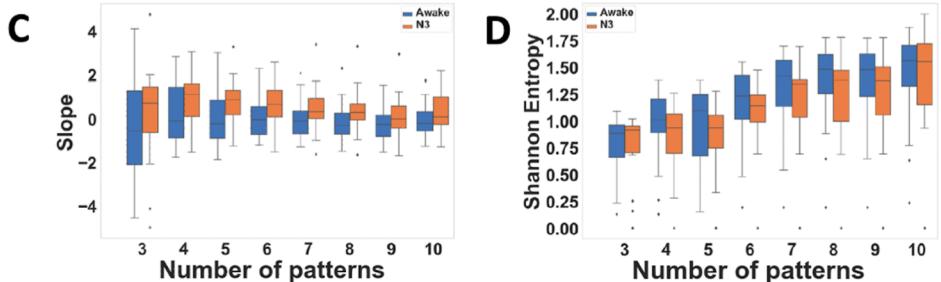


**Figure S2. Dynamic functional coordination patterns from the dataset of sleep using  $K = 3 \dots 10$  number of clusters in the K-means algorithm.** For each value of  $K$  patterns are ordered based on their similarity to underlying anatomical connectivity, from the least (left) to the most similar (right). The SFC values can be found in Table S3B.

## General Anesthesia

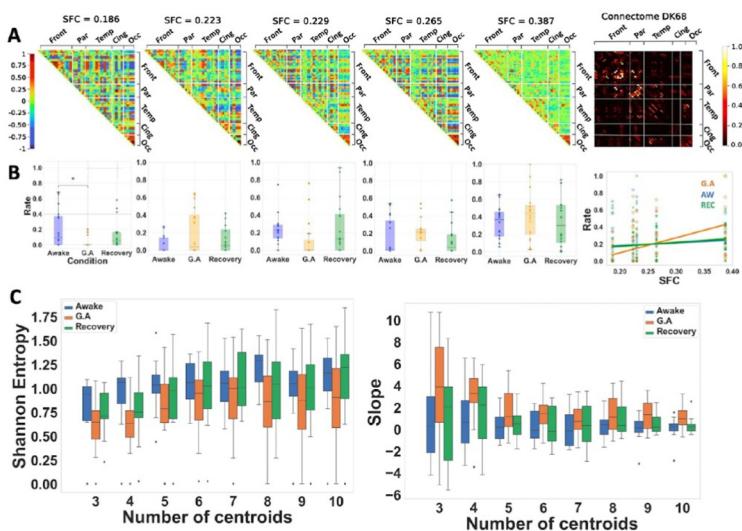


## Deep Sleep

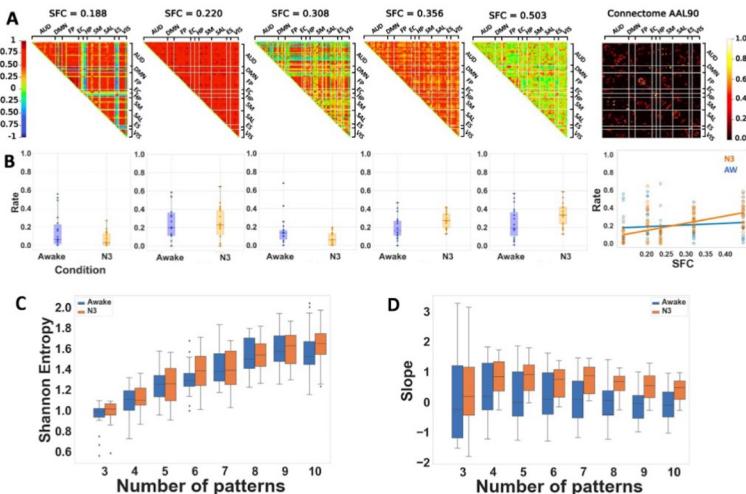


**Figure S3. Increase in SFC and reduction of Shannon Entropy in unconscious states using sliding-window correlation in both datasets.** Reproduction of the main measures of interest (A and C: coefficient of slope ; B and D: Shannon Entropy) using the sliding window methodology. Similar results as using the phase coherence methodology are obtained using this approach in both general anaesthesia (A and B) and deep sleep (C and D) datasets, demonstrating the robustness of our findings across different analytical approaches.

# General Anesthesia

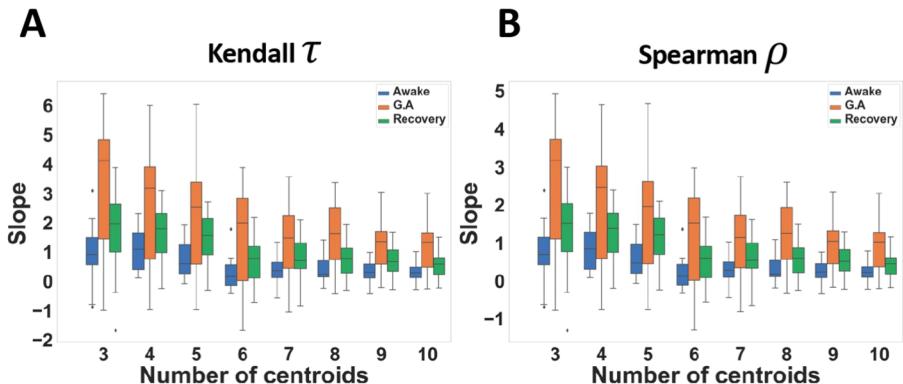


# Deep Sleep

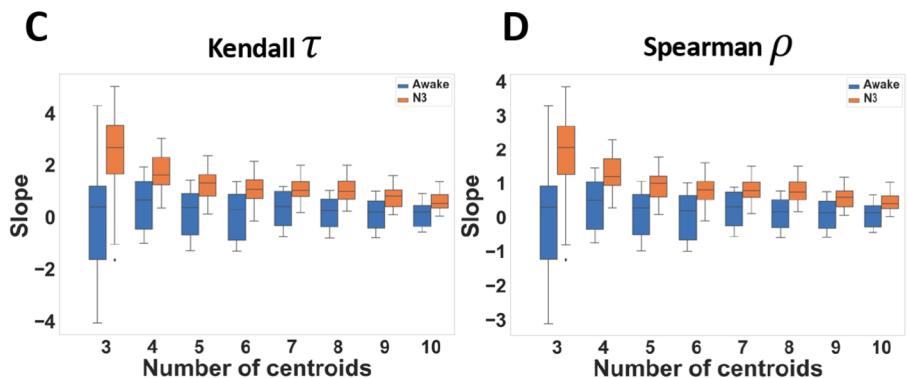


**Figure S4. Reproduction of Figures 2 and 4 using narrower bandwidth filter between 0.04 and 0.07 Hz.** Similar results are found in both datasets in terms of Slope and Shannon Entropy using the filter between 0.04 and 0.07 Hz than a broader filter (0.01–0.1 Hz) used in the main text, showing robustness of the results to the choice of bandwidth filtering.

## General Anesthesia

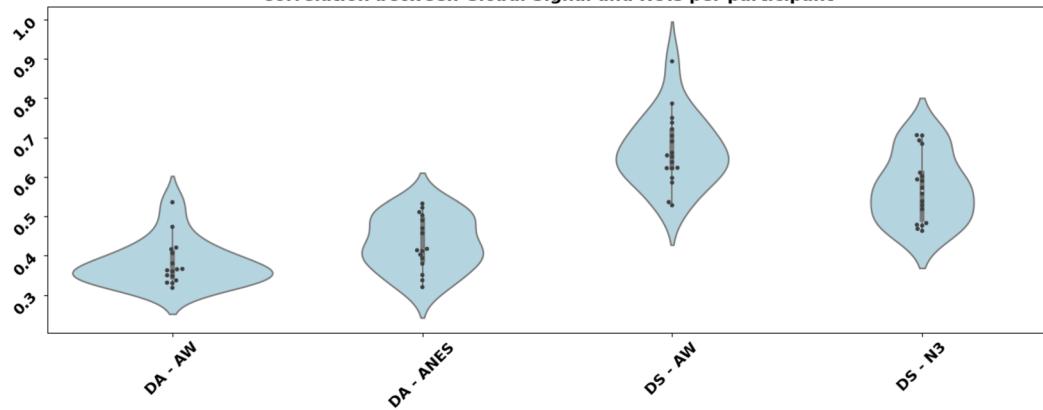


## Deep Sleep



**Figure S5. Coefficients of linear regressions slope between FC presence rates and associated SFC computed with different measures of correlation.** Kendall's tau (A and C) and Spearman rho (B and D), for different number of centroids ( $K = 3\dots10$ ). In figures 2 and 4 in the main text, we show these coefficients computed using Pearson correlation as measure of similarity between SC and FC to be able to compare our results with previous results. The result of the increase of this slope during unconsciousness is robust to different choices in ways to compute similarity. A) and B) General anaesthesia dataset. C) and D) Sleep dataset. All boxplots extend from the first quartile to the third quartile of the distributions, with a line at the median. The whiskers extend from the box to the farthest data point lying within  $1.5 \times$  the interquartile range from the box.

**Correlation between Global Signal and ROIs per participant**



**Figure S6. Correlation between the average BOLD global signal and single region BOLD ROIs per participant.** The violin plots illustrate the the correlation between the BOLD signal of each region of interest and the average BOLD signal per participant in each database and each condition. There is a lower correlation in the database of general anaesthesia (DA) in both the awake state (AW) and general anaesthesia state (ANES) than in the database of sleep (DS) in both the awake state (AW) and deep sleep (N3).

# Tables S1. Statistical tables for the general anaesthesia dataset.

Repeated measure ANOVA comparing presence rates for k=5

<i>Pattern #</i>	<i>Condition</i>	<i>Mean (SD)</i>	<i>Sum of Squares</i>	<i>Num df</i>	<i>Den df</i>	<i>f-value</i>	<i>p-value</i>
1	Awake	0.21 (0.080)	0.50			6.2	<b>0.0056</b>
	G.A	0.10 (0.10)					
	Recovery	0.23 (0.14)					
2	Awake	0.20 (0.085)	0.33	2	30	20.0	<b>&lt;0.001</b>
	G.A	0.060 (0.063)					
	Recovery	0.19 (0.087)					
5	Awake	0.32 (0.064)	0.66			4.7	<b>0.016</b>
	G.A	0.47 (0.22)					
	Recovery	0.39 (0.072)					

T-test paired samples, Bonferroni correction, comparing occurrence of brain states for k=5

<i>Pattern #</i>	<i>Compared conditions</i>	<i>Mean (SD)</i>	<i>df</i>	<i>t-value</i>	<i>Adjusted p-value</i>
1	Awake	0.21 (0.08)		4.3	<b>0.0019</b>
	G.A	0.10 (0.10)			
	G.A	0.10 (0.10)			
	Recovery	0.23 (0.14)			
2	Awake	0.20 (0.085)	30	5.9	<b>&lt;0.001</b>
	G.A	0.060 (0.063)			
	G.A	0.060 (0.063)			
	Recovery	0.19 (0.087)			
5	Awake	0.21 (0.08)		5.2	<b>&lt;0.001</b>
	G.A	0.10 (0.10)			
	G.A	0.10 (0.10)			
	Recovery	0.09 (0.10)			

Repeated measure ANOVA comparing slopes' coefficient for all tested values of number of patterns

K-number of patterns	Condition	Mean (SD)	Sum of Squares	Num df	Den df	f-value	p-value
k=3	Awake	1.1 (1.0)	72.4			14.4	<0.001
	G.A	3.2 (1.8)					
	Recovery	1.7 (0.9)					
k=4	Awake	0.8 (0.53)	42.1			5.2	0.011
	G.A	2.0 (1.6)					
	Recovery	1.3 (0.66)					
k=5	Awake	0.66 (0.51)	34.4			8.9	<0.001
	G.A	1.9 (1.4)					
	Recovery	1.1 (0.6)					
k=6	Awake	0.57 (0.45)	31.0			9.2	<0.001
	G.A	1.8 (1.3)					
	Recovery	1.1 (0.54)					
k=7	Awake	0.65 (0.37)	25.3			8.3	0.0014
	G.A	1.7 (1.2)					
	Recovery	1.0 (0.51)					
k=8	Awake	0.44 (0.35)	21.2			7.9	0.0017
	G.A	1.4 (1.1)					
	Recovery	0.88 (0.51)					
k=9	Awake	0.42 (0.29)	20.6			8.5	0.0012
	G.A	1.4 (1.1)					
	Recovery	0.8 (0.45)					
k=10	Awake	0.5 (0.3)	15.8			8.0	0.0016
	G.A	1.3 (1.0)					
	Recovery	0.8 (0.46)					

T-test paired sample, Bonferroni correction, comparing slopes' coefficient for k=5

Compared conditions	Mean (SD)	df	t-value	Adjusted p-value
Awake	0.66 (0.51)	30	3.3	0.012
G.A	1.9 (1.45)			
G.A	1.9 (1.45)		2.5	0.048
Recovery	1.1 (0.59)			

Repeated measure ANOVA comparing Shannon Entropy for all tested values of number of patterns

K-number of patterns	Condition	Mean (SD)	Sum of Squares	Num df	Den df	f-value	p-value
K=3	Awake	1.0 (0.068)	1.3			11.7	<0.001
	G.A	0.77 (0.26)					
	Recovery	1.0 (0.062)					
K=4	Awake	1.3 (0.071)	1.6			8.4	0.0012
	G.A	1.0 (0.31)					
	Recovery	1.2 (0.078)					
K=5	Awake	1.5 (0.063)	2.2			13.0	<0.001
	G.A	1.1 (0.35)					
	Recovery	1.4 (0.082)					
K=6	Awake	1.6 (0.055)	2.6			11.8	<0.001
	G.A	1.3 (0.37)					
	Recovery	1.5 (0.099)					
K=7	Awake	1.7 (0.069)	2.6			8.7	0.0010
	G.A	1.4 (0.39)					
	Recovery	1.7 (0.10)					
K=8	Awake	1.9 (0.087)	2.9			7.9	0.0017
	G.A	1.5 (0.43)					
	Recovery	1.8 (0.11)					
K=9	Awake	2.0 (0.080)	3.4			9.1	<0.001
	G.A	1.6 (0.45)					
	Recovery	1.9 (0.10)					
K=10	Awake	2.1 (0.099)	3.5			6.8	0.0035
	G.A	1.7 (0.48)					
	Recovery	1.9 (0.12)					

T-test paired sample, Bonferroni correction, comparing Shannon Entropy for k=5

Compared conditions	Mean (SD)	df	t-value	Adjusted p-value
Awake	1.49 (0.063)	30	3.9	0.0031
G.A	1.15 (0.35)			
G.A	1.15 (0.35)		3.3	0.010
Recovery	1.29 (0.083)			

Repeated measure ANOVA comparing Markov Entropy for all tested values of *number of patterns*

K-number of patterns	Condition	Mean (SD)	Sum of Squares	Num df	Den df	f-value	p-value
K=3	Awake	0.55 (0.075)	0.62			9.8	<0.001
	G.A	0.38 (0.16)					
	Recovery	0.51 (0.06)					
K=4	Awake	0.68 (0.058)	0.63			9.8	<0.001
	G.A	0.51 (0.16)					
	Recovery	0.62 (0.079)					
K=5	Awake	0.81 (0.016)	0.087			61.0	<0.001
	G.A	0.71 (0.027)					
	Recovery	0.78 (0.018)					
K=6	Awake	0.70 (0.048)	0.43			17.7	<0.001
	G.A	0.53 (0.13)					
	Recovery	0.66 (0.056)					
K=7	Awake	0.68 (0.048)	0.39			9.8	<0.001
	G.A	0.54 (0.15)					
	Recovery	0.65 (0.049)					
K=8	Awake	0.67 (0.049)	0.32			8.7	0.0010
	G.A	0.56 (0.14)					
	Recovery	0.65 (0.04)					
K=9	Awake	0.66 (0.041)	0.29			9.1	<0.001
	G.A	0.55 (0.13)					
	Recovery	0.63 (0.036)					
K=10	Awake	0.62 (0.043)	0.19			8.6	0.0011
	G.A	0.54 (0.10)					
	Recovery	0.61 (0.044)					

T-test paired sample comparing Markov Entropy for k=5, Bonferroni correction

Compared conditions	Mean (SD)	df	t-value	Adjusted p-value
Awake	0.81 (0.016)	30	1.1	<0.001
G.A	0.71 (0.027)			
G.A	0.71 (0.027)		6.6	
Recovery	0.78 (0.018)			

## Tables S2. Statistical tables for the deep sleep dataset

T-test paired samples, comparing occurrence of brain states for k=5

<i>Brain state #</i>	<i>Compared conditions</i>	<i>Mean (SD)</i>	<i>df</i>	<i>t-value</i>	<i>p-value</i>
1	Awake	0.13 (0.083)	35	5.0	<b>0.039</b>
	N3	0.098 (0.069)			
5	Awake	0.21 (0.13)	35	8.6	<b>0.0092</b>
	N3	0.34 (0.12)			

T-test paired comparing slopes' coefficient for all tested values of k

<i>K-number of patterns</i>	<i>Condition</i>	<i>Mean (SD)</i>	<i>Num df</i>	<i>Den df</i>	<i>t-value</i>	<i>p-value</i>
K=3	Awake	-0.53 (1.2)	2	35	1.6	<b>0.014</b>
	N3	0.7 (1.7)				
K=4	Awake	0.74 (1.0)	2	35	2.2	<b>0.033</b>
	N3	1.5 (0.79)				
K=5	Awake	0.60 (0.86)	2	35	2.4	<b>0.023</b>
	N3	1.3 (0.71)				
K=6	Awake	0.52 (0.72)	2	35	2.5	<b>0.020</b>
	N3	1.1 (0.56)				
K=7	Awake	0.39 (0.56)	2	35	2.9	<b>0.0072</b>
	N3	0.93 (0.43)				
K=8	Awake	0.42 (0.53)	2	35	3.0	<b>0.0061</b>
	N3	0.95 (0.41)				
K=9	Awake	0.29 (0.44)	2	35	2.1	<b>0.040</b>
	N3	0.60 (0.30)				
K=10	Awake	0.24 (0.39)	2	35	1.7	0.098
	N3	0.45 (0.26)				

### T-test paired comparing Shannon Entropy for all tested values of K

<i>K-number of patterns</i>	<i>Condition</i>	<i>Mean (SD)</i>	<i>Num df</i>	<i>Den df</i>	<i>t-value</i>	<i>p-value</i>
K=3	Awake	1.0 (0.10)	2	35	3.0	<b>0.0096</b>
	N3	0.87 (0.15)				
K=4	Awake	1.6 (0.13)			1.8	0.084
	N3	1.5 (0.12)				
K=5	Awake	1.8 (0.15)			2.0	<b>0.049</b>
	N3	1.6 (0.11)				
K=6	Awake	1.8 (0.15)			2.0	0.057
	N3	1.7 (0.11)				
K=7	Awake	2.0 (0.16)			0.76	0.45
	N3	1.9 (0.08)				
K=8	Awake	1.8 (0.14)			1.9	0.057
	N3	1.6 (0.11)				
K=9	Awake	1.9 (0.16)			0.76	0.45
	N3	1.8 (0.08)				
K=10	Awake	2.1 (0.17)			0.58	0.56
	N3	2.0 (0.096)				

### T-test paired comparing Markov Entropy for all tested values of K

<i>K-number of patterns</i>	<i>Condition</i>	<i>Mean (SD)</i>	<i>Num df</i>	<i>Den df</i>	<i>t-value</i>	<i>p-value</i>
K=3	Awake	0.51 (0.096)	2	35	2.1	<b>0.043</b>
	N3	0.40 (0.14)				
K=4	Awake	0.70 (0.082)			3.3	<b>0.0093</b>
	N3	0.61 (0.089)				
K=5	Awake	0.72 (0.043)			1.9	<b>0.046</b>
	N3	0.69 (0.081)				
K=6	Awake	0.72 (0.071)			2.1	<b>0.018</b>
	N3	0.68 (0.10)				
K=7	Awake	0.74 (0.066)			2.6	<b>0.037</b>
	N3	0.70 (0.070)				
K=8	Awake	0.74 (0.082)			1.7	0.071
	N3	0.71 (0.073)				
K=9	Awake	0.73 (0.050)			0.67	0.46
	N3	0.71 (0.061)				
K=10	Awake	0.72 (0.074)			0.58	0.31
	N3	0.51 (0.059)				

## Tables S3. Tables of SFC, computed using Pearson correlation

**Table S3A) General anaesthesia dataset**

<i>K-number of patterns</i>	<i>SFC</i>
K=3	0.217 ; 0.280 ; 0.373
K=4	0.208 ; 0.232 ; 0.277 ; 0.401
K=5	0.206 ; 0.216 ; 0.234 ; 0.286 ; 0.404
K=6	0.200 ; 0.216 ; 0.231 ; 0.232 ; 0.289 ; 0.405
K=7	0.195 ; 0.206 ; 0.222 ; 0.227 ; 0.256 ; 0.286 ; 0.398
K=8	0.191 ; 0.200 ; 0.200 ; 0.231 ; 0.239 ; 0.277 ; 0.278 ; 0.404
K=9	0.190 ; 0.194 ; 0.195 ; 0.221 ; 0.228 ; 0.243 ; 0.272 ; 0.275 ; 0.408
K=10	0.176 ; 0.183 ; 0.197 ; 0.203 ; 0.228 ; 0.229 ; 0.251 ; 0.261 ; 0.275 ; 0.411

**Table S3A) Deep sleep dataset**

<i>K-number of patterns</i>	<i>SFC</i>
K=3	0.212 ; 0.301 ; 0.489
K=4	0.186 ; 0.214 ; 0.327 ; 0.499
K=5	0.188 ; 0.220 ; 0.308 ; 0.356 ; 0.503
K=6	0.188 ; 0.220 ; 0.285 ; 0.315 ; 0.350 ; 0.503
K=7	0.188 ; 0.220 ; 0.285 ; 0.326 ; 0.333 ; 0.502
K=8	0.180 ; 0.222 ; 0.253 ; 0.281 ; 0.301 ; 0.330 ; 0.503
K=9	0.179 ; 0.222 ; 0.253 ; 0.279 ; 0.301 ; 0.319 ; 0.330 ; 0.503
K=10	0.173 ; 0.222 ; 0.227 ; 0.274 ; 0.301 ; 0.302 ; 0.321 ; 0.346 ; 0.503

**Table S4. Network-level ROIs of the Desikan-Killiany parcellation used for the general anaesthesia dataset.**

Anatomical Connectivity network	
<i>Frontal</i>	
Caudal middle frontal [Left; Right]	
Lateral orbital frontal [Left; Right]	
Media orbital frontal [Left; Right]	
Para-central [Left; Right]	
Pars opercularis [Left; Right]	
Pars orbitalis [Left; Right]	
Pars triangularis [Left; Right]	
Precentral gyrus [Left; Right]	
Rostral middle frontal [Left; Right]	
Superior frontal [Left; Right]	
Frontal pole [Left; Right]	
Insula [Left; Right]	
<i>Parietal</i>	
Inferior parietal [Left; Right]	
Post central [Left; Right]	
Precuneus [Left; Right]	
Superior parietal [Left; Right]	
Supramarginal [Left; Right]	
<i>Temporal</i>	
Bank STS [Left; Right]	
Entorhinal [Left; Right]	
Fusiform [Left; Right]	
Inferior temporal [Left; Right]	
Middle temporal [Left; Right]	
Superior temporal [Left; Right]	
Parahippocampal [Left; Right]	
Temporal pole [Left; Right]	
Transverse temporal [Left; Right]	
<i>Cingulate</i>	
Caudal anterior cingulate [Left; Right]	
Isthmus cingulate [Left; Right]	
Posterior cingulate [Left; Right]	
Rostral anterior cingulate [Left; Right]	
<i>Occipital</i>	
Cuneus [Left; Right]	
Lateral occipital [Left; Right]	
Lingual [Left; Right]	
Peri-calcarine [Left; Right]	

**Table S5. Network-level ROIs of the AAL parcellation used for the sleep dataset.**

Functional Connectivity network	
<i>Auditory</i>	
Frontal Inferior Opercular [Left]	
Frontal Inferior Triangular [Left]	
Cingulum Anterior [Left; Right]	
Cingulum Middle [Left; Right]	
Amygdala [Left; Right]	
Putamen [Left; Right]	
Supramarginal [Left; Right]	
Pallidum [Left; Right]	
Thalamus [Left; Right]	
Heschel [Left; Right]	
Temporal Superior [Left; Right]	
Temporal Middle [Left; Right]	
<i>Default Mode Network</i>	
Precuneus [Left; Right]	
Cingulum Posterior [Left; Right]	
Temporal Inferior [Left; Right]	
<i>Frontoparietal</i>	
Frontal Superior [Left; Right]	
Frontal Inferior Opercular [Right]	
Frontal Inferior Triangular [Right]	
Olfactory [Left; Right]	
Frontal Superior Medial [Left; Right]	
Frontal Medial Orbital [Left; Right]	
Rectus [Left; Right]	
Parietal Inferior [Left; Right]	
Angular [Left; Right]	
<i>Executive Control</i>	
Insula [Left; Right]	
Caudate [Left; Right]	
<i>Hippocampus</i>	
Hippocampus [Left; Right]	
ParaHippocampus [Left; Right]	
<i>Somatomotor</i>	
Precentral [Left; Right]	
Rolandic Opercular [Left; Right]	
Supplementary Motor Area [Left; Right]	
Postcentral [Left; Right]	
Parietal Superior [Left; Right]	
Paracentral Lobule [Left; Right]	
<i>Extrastriate</i>	
Frontal Superior Orbital [Left; Right]	
Frontal Middle [Left; Right]	
<i>Visual</i>	
Calcarine [Left; Right]	
Lingual [Left; Right]	
Occipital Superior [Left; Right]	
Fusiform [Left; Right]	