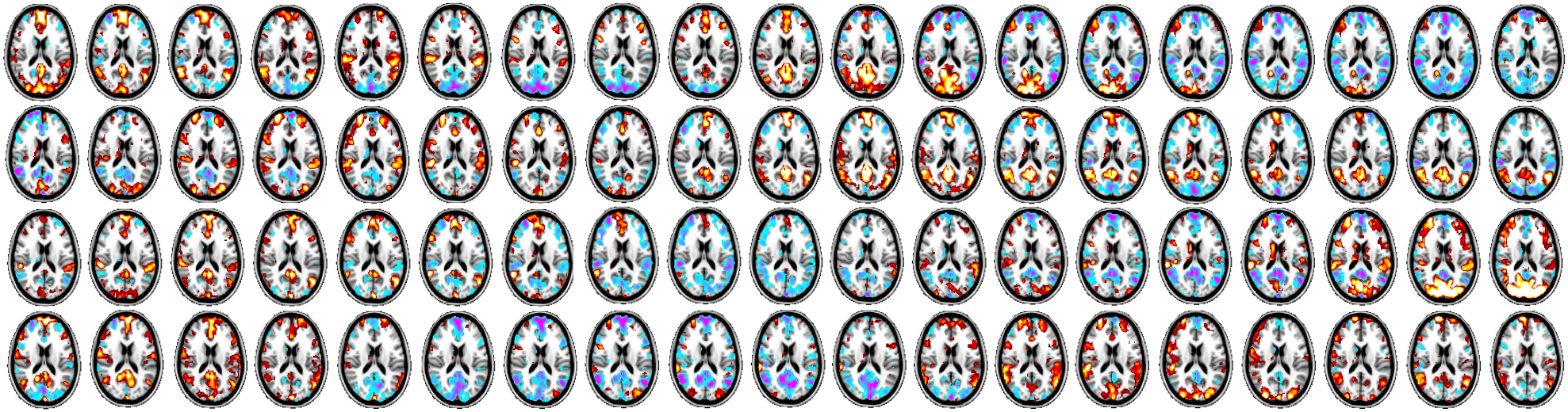
Clasificación de estados cerebrales usando neuroimágenes funcionales

Clase 2:

Conectividad funcional



Enzo Tagliazucchi (tagliazucchi.enzo@googlemail.com)

universidad de buenos aires - exactas
departamento de física

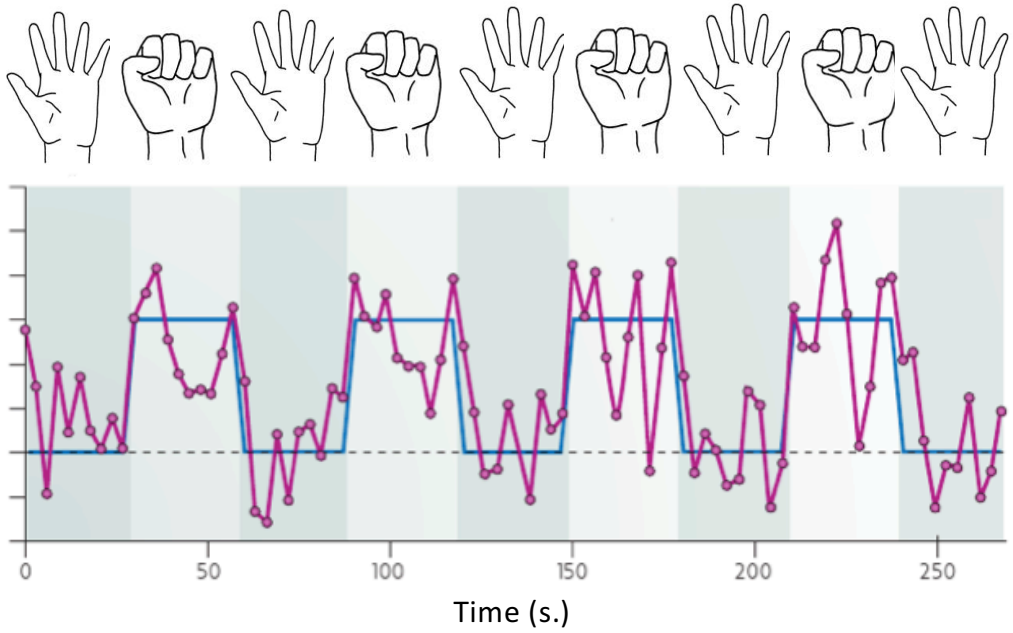
- Primera clase: introducción a las neuroimágenes funcionales + demostración práctica de preprocesado de datos funcionales.

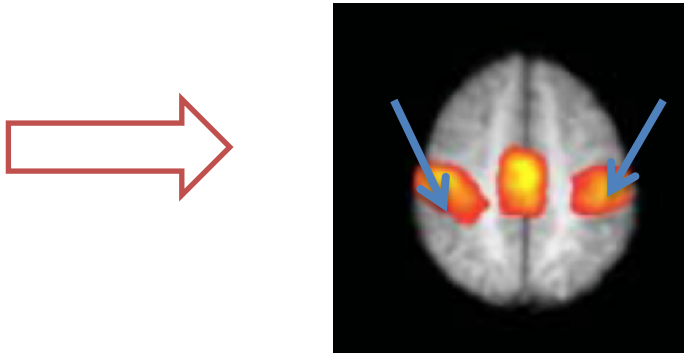
- Segunda clase: introducción a la idea de conectividad cerebral (funcional y anatómica) + demostración de obtención de conectividad funcional (Python)

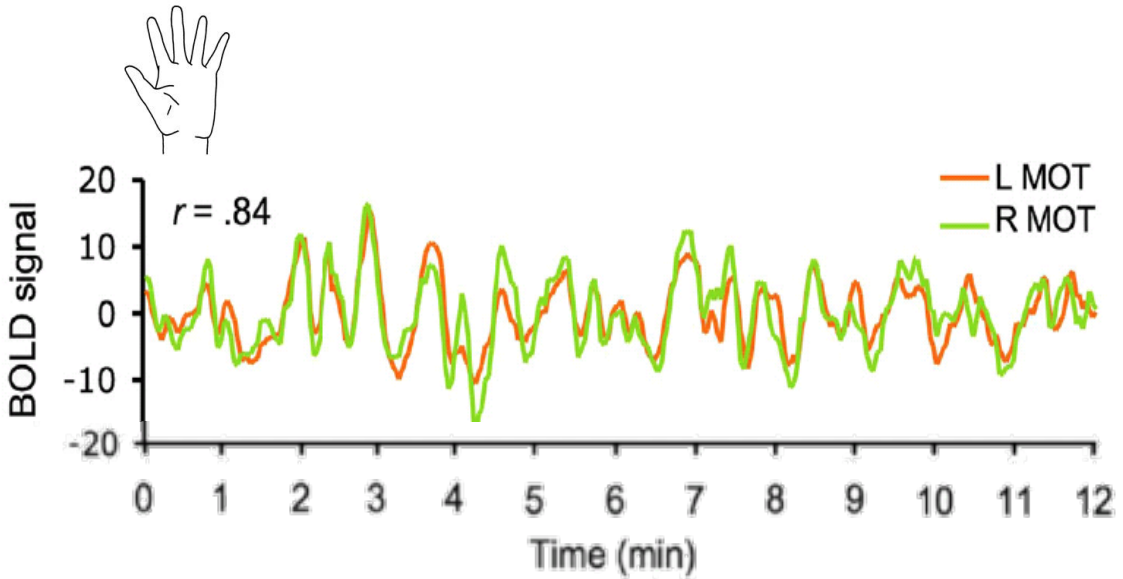
- Tercera clase: introducción básica a conceptos de machine learning + desarrollo de un clasificador para distinguir vigilia de sueño profundo (Python + scikit-learn)

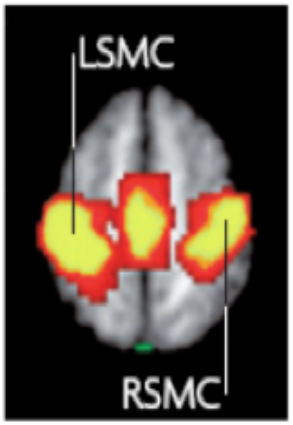
- Cuarta clase: más métodos de machine learning (feature selection, mapeo de relevancia de features, clasificadores multi clase) cómo medir significancia estadística de clasificadores, etc)

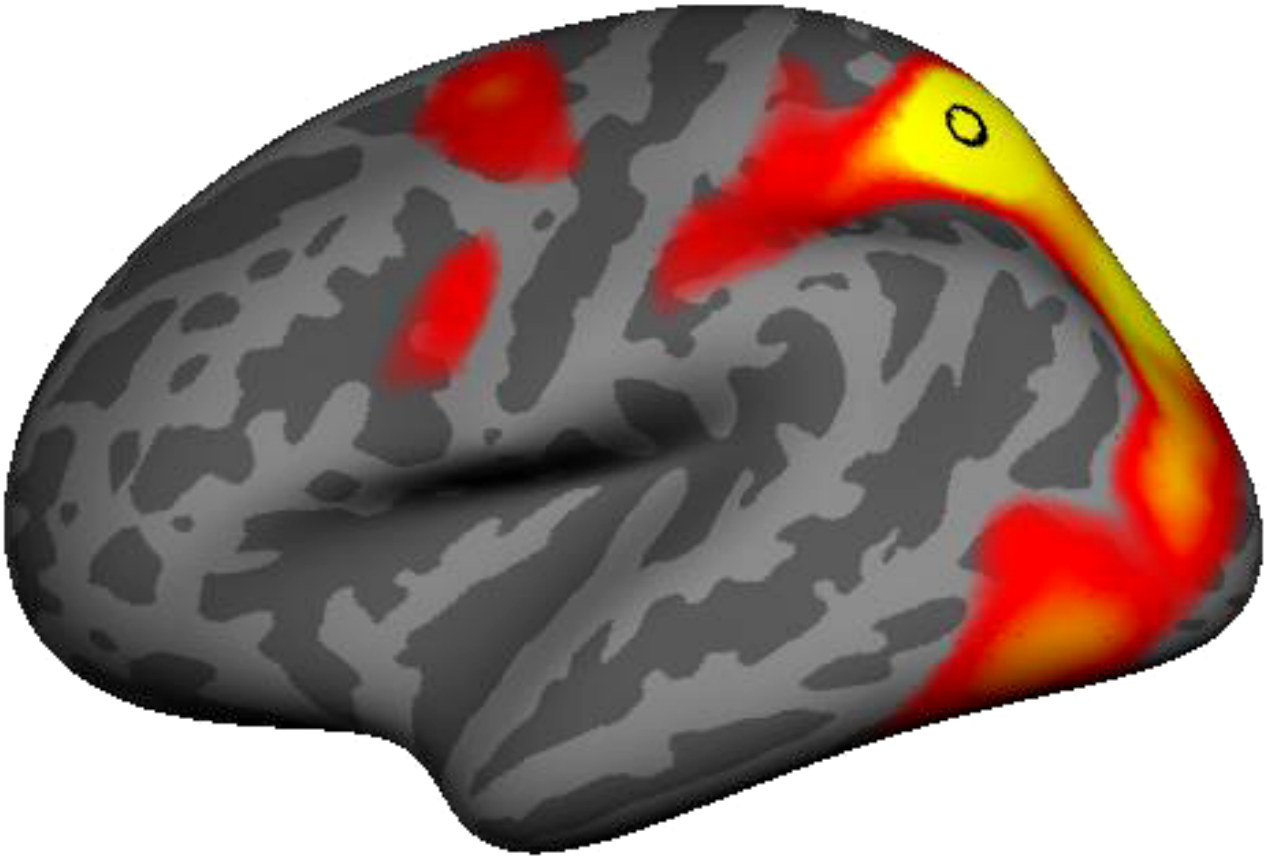
- Quinta clase: temas pendientes + charla general sobre investigación actual en conciencia + preguntas + evaluación

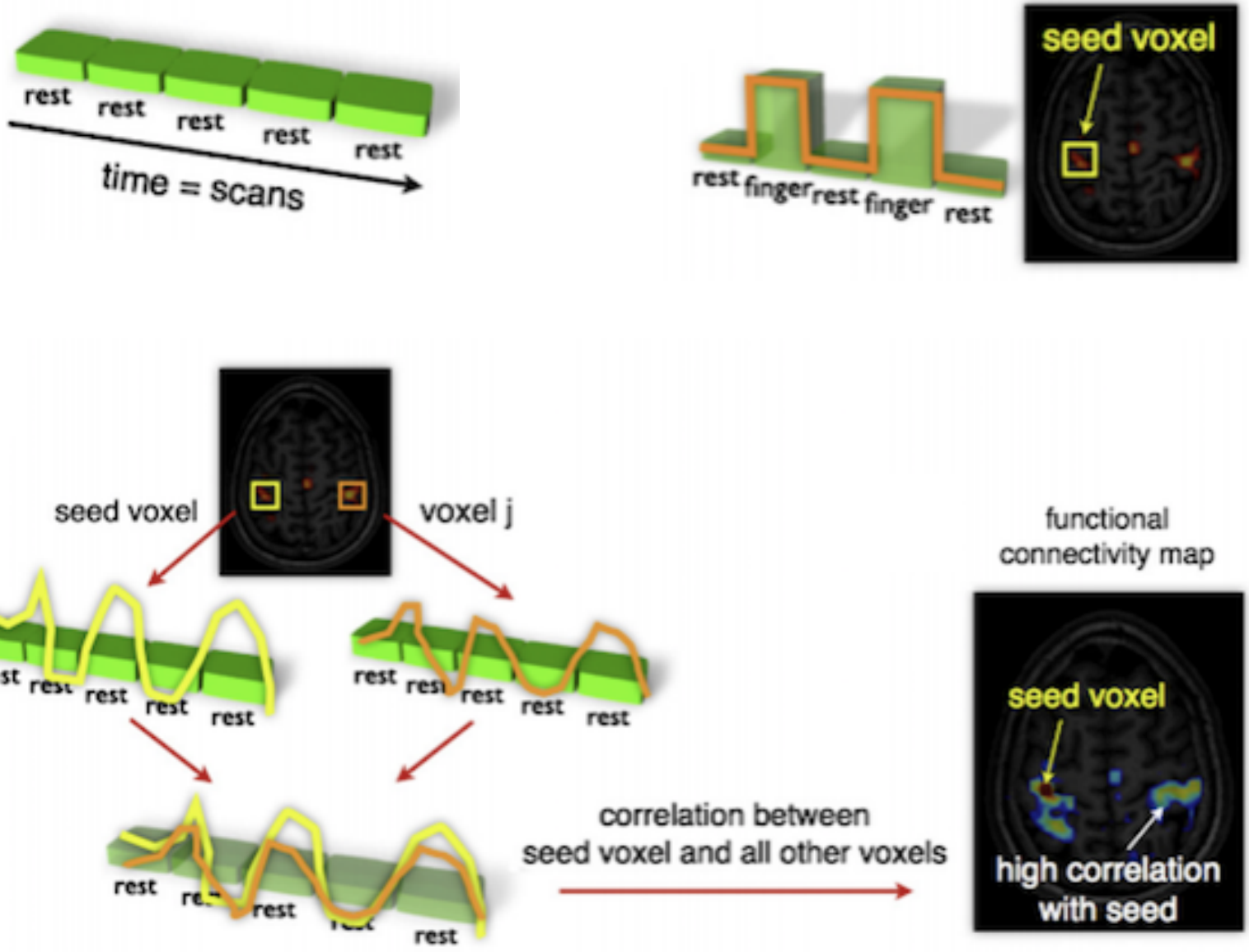

% BOLD signal change
3.0
2.5
2.0
1.5
1
0.5
0
−0.5
−1
0
50
100
150
200
250
Time (s.)



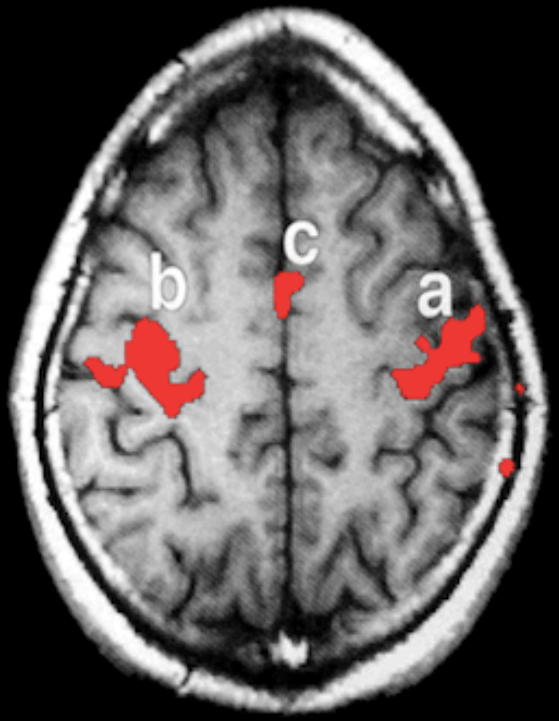

BOLD signal
r = .84
L MOT
R MOT
20
10
0
-10
-20
0
1
2
3
4
5
6
7
8
9
10
11
12
Time (min)


LSMC
RSMC

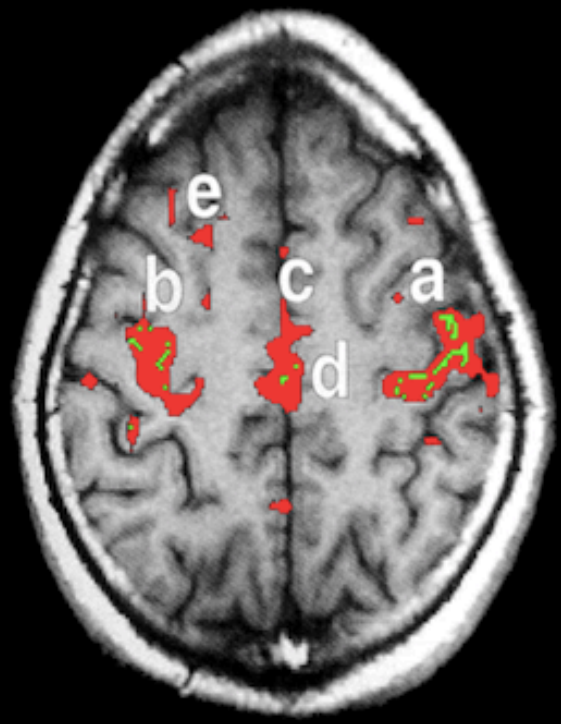



rest
rest
rest
rest
rest
time = scans
rest
finger
rest
finger
rest
seed voxel
seed voxel
voxel j
rest
rest
rest
rest
rest
rest
rest
rest
rest
rest
rest
rest
correlation between
seed voxel and all other voxels
functional
connectivity map
seed voxel
high correlation
with seed

Resting Motor Cortex Connectivity



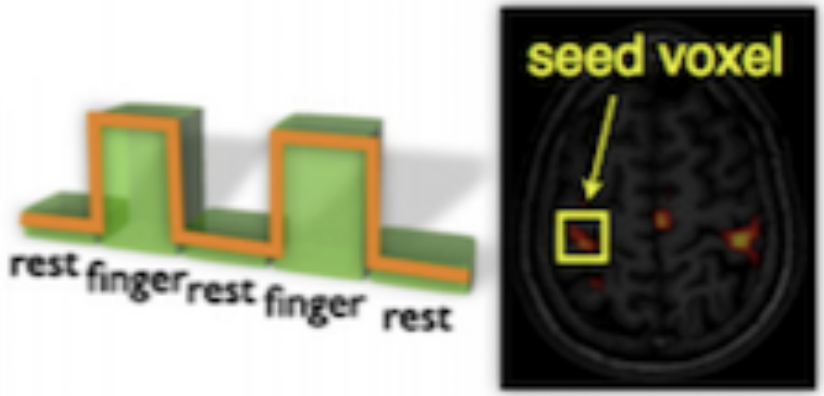
Motor cortex defined by task-activation *f*MRI



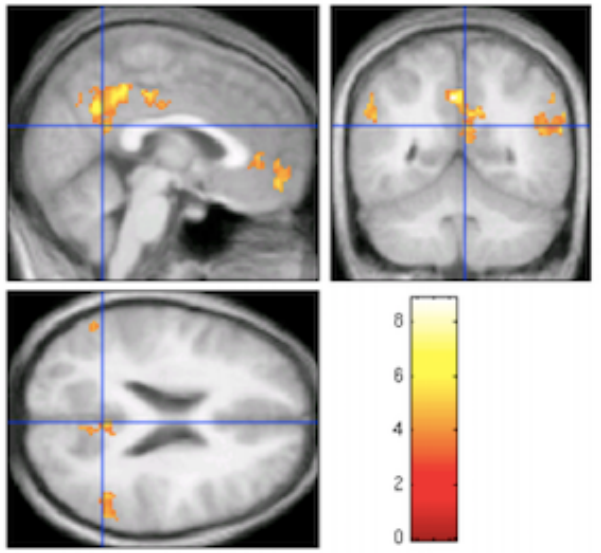
Spontaneous correlations with motor cortex

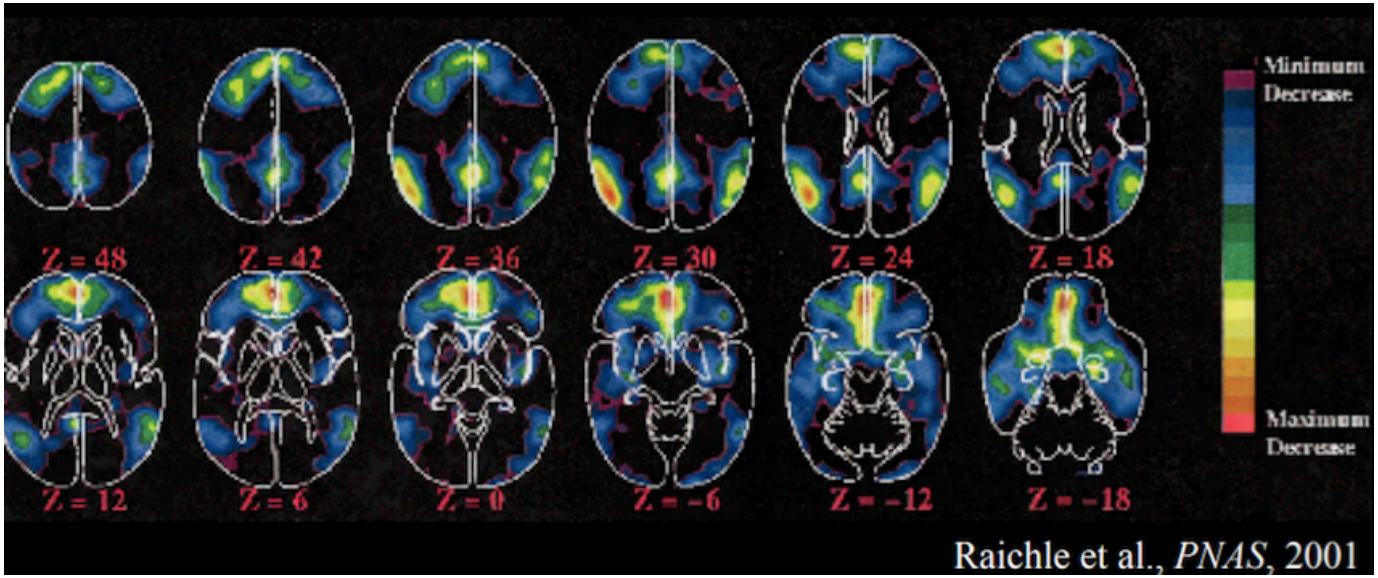
Biswal et al., *Magn Reson Med,* 1995

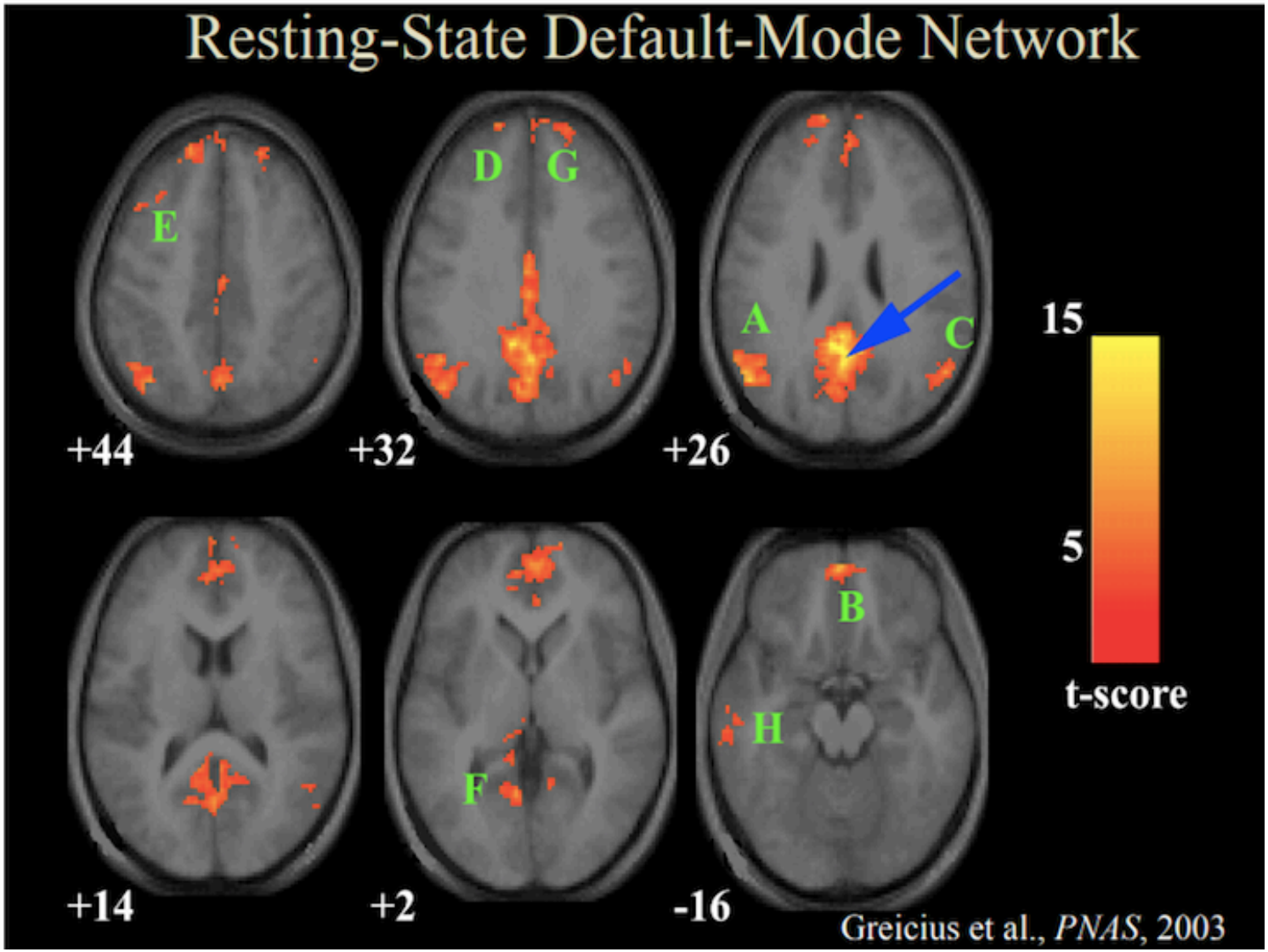
Activacion



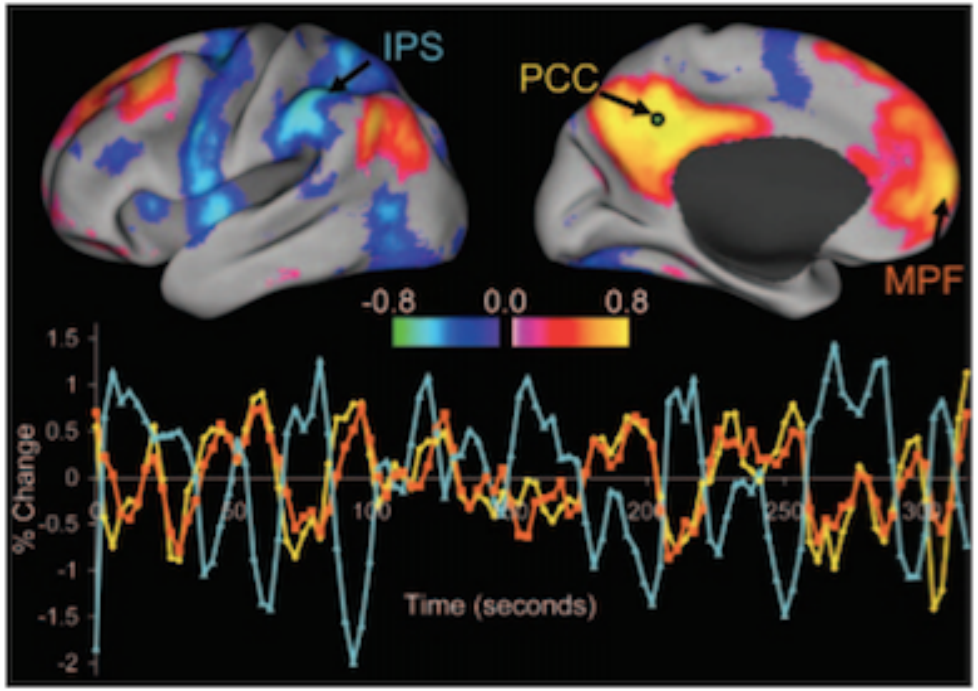
Desactivacion



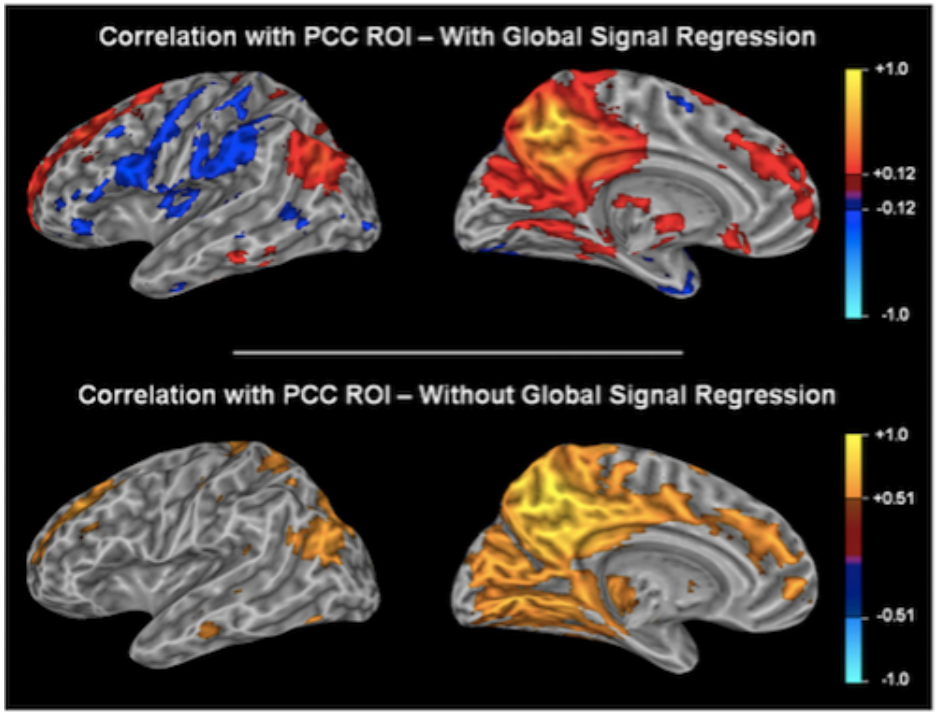



Resting-State Default-Mode Network
E
D
G
A
C
+44
+32
+26
15
5
t-score
B
H
F
+14
+2
-16
Greicius et al., PNAS, 2003

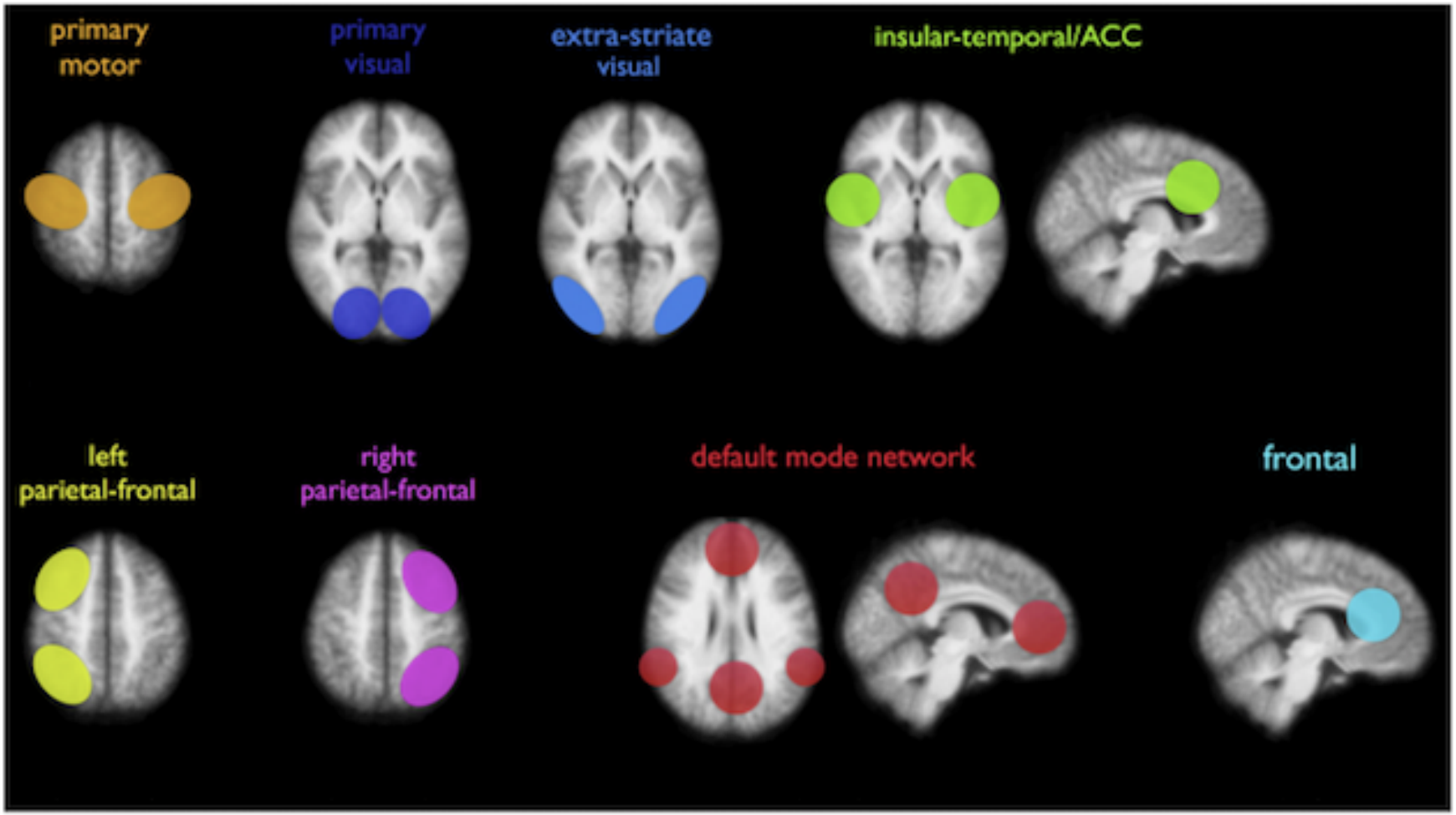
Redes anticorrelacionadas…



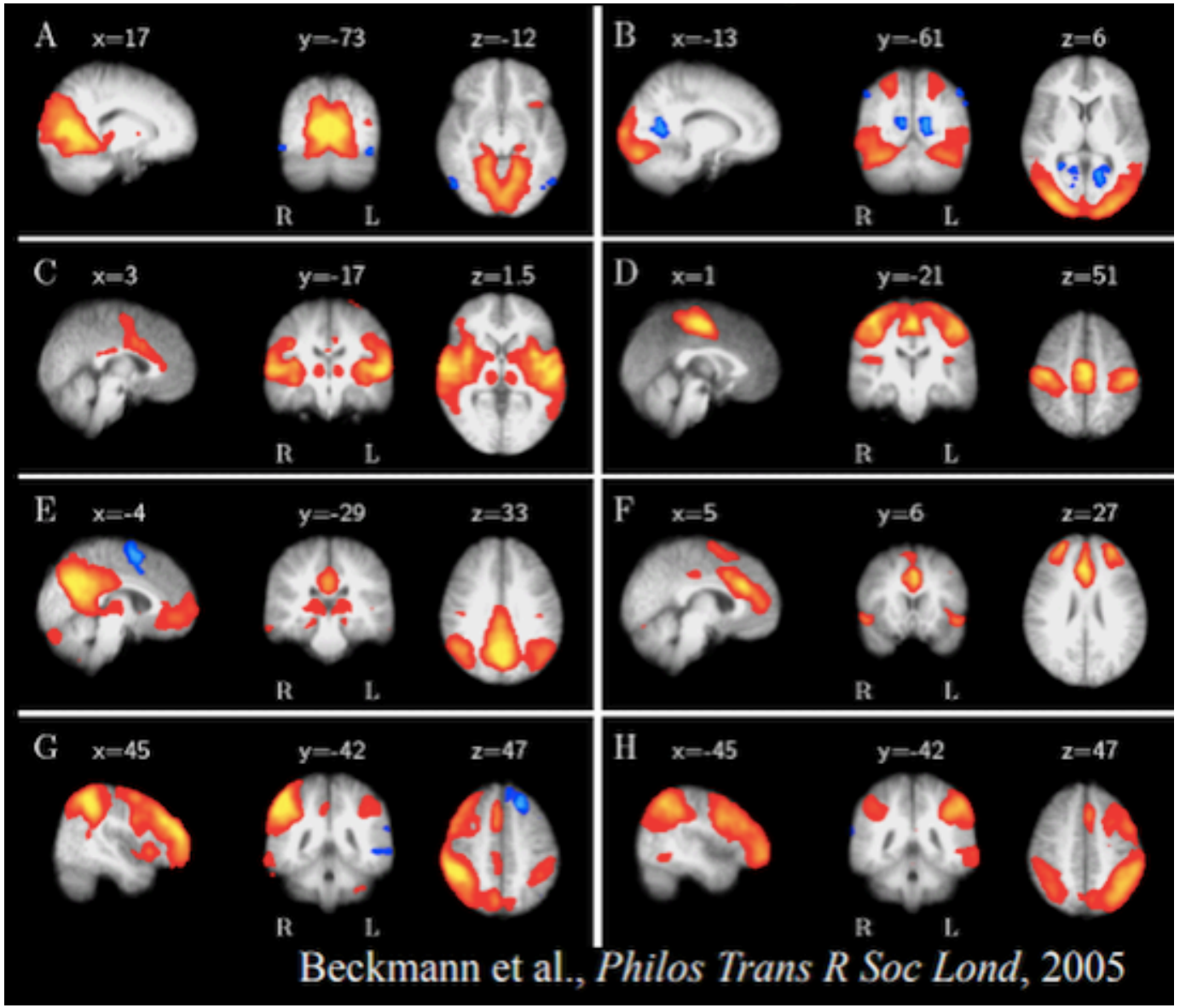
… resultado de la regresion global



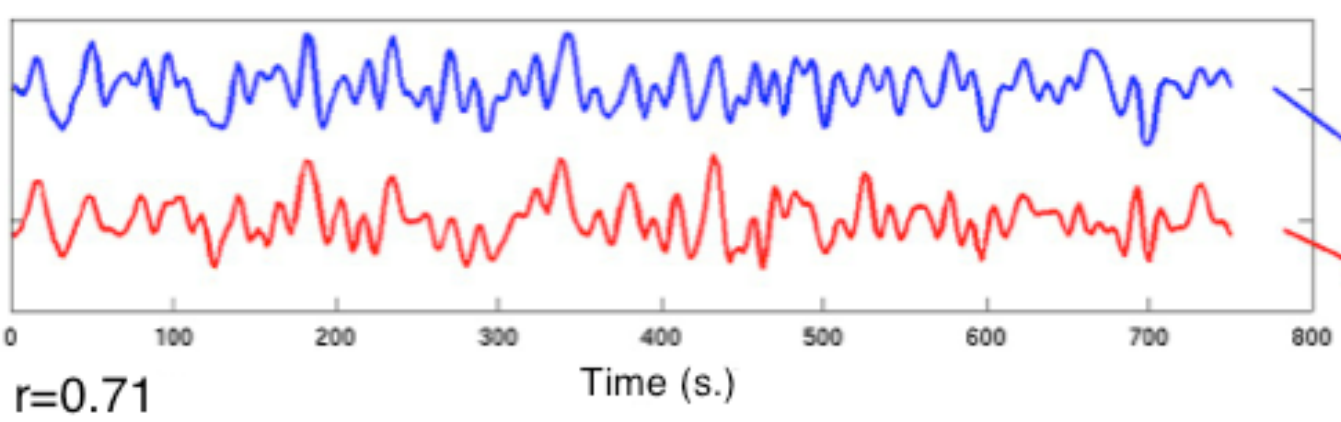
Otras redes en el cerebro?

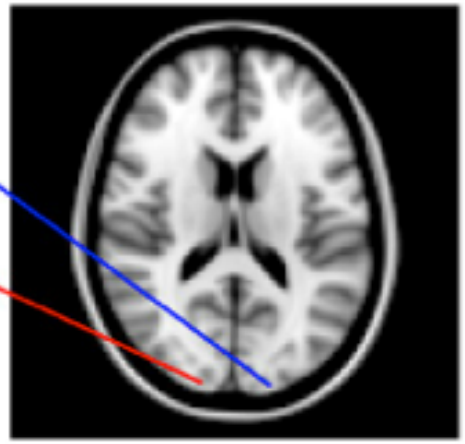


Resting state networks (RSN)



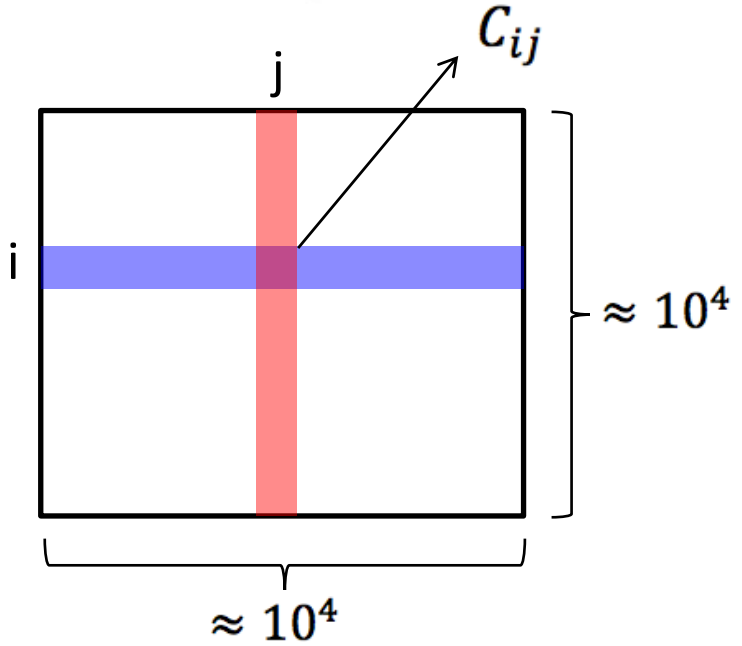
Matriz de correlacion entre regiones de interes





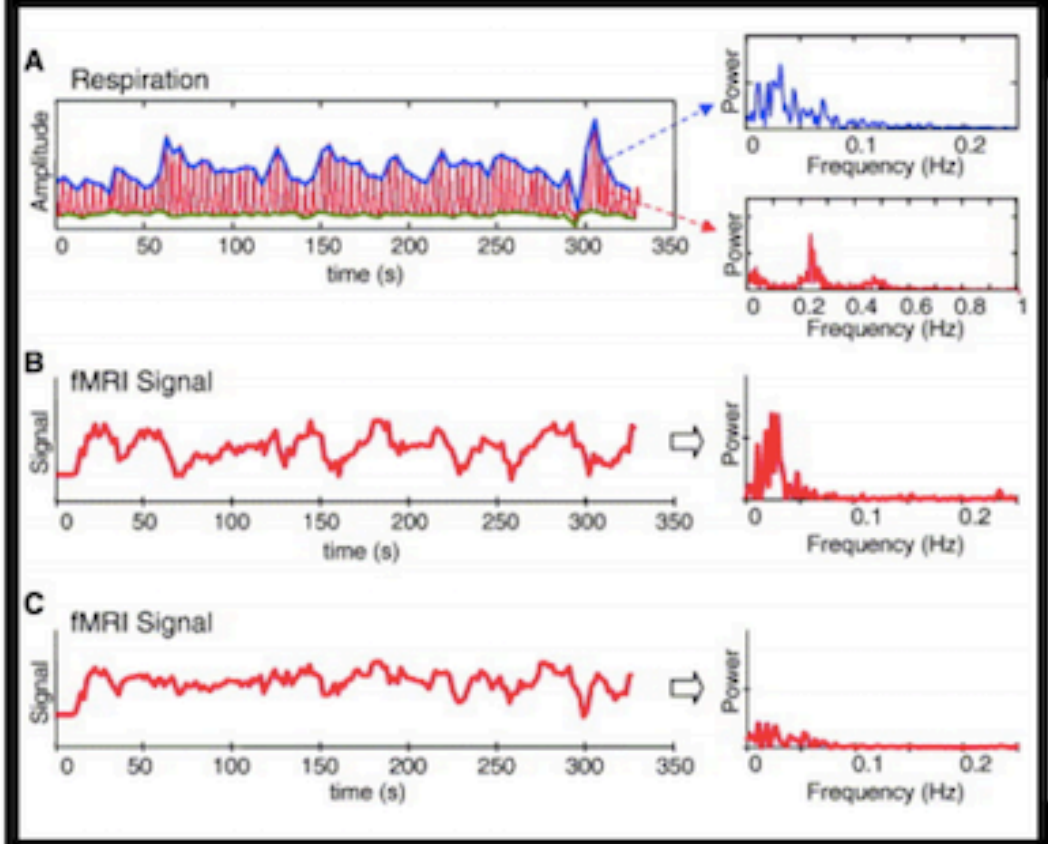
$$r = \frac{< (x - \mu_x)(y - \mu_y) >}{\sigma_x \sigma y}$$

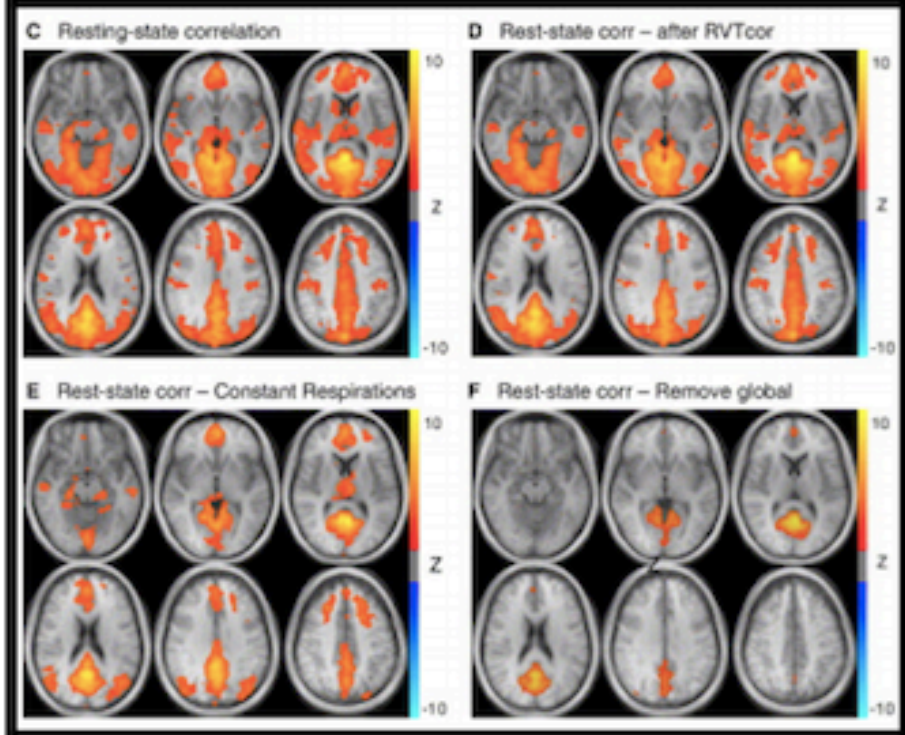
← Correlación temporal entre la actividad



Matriz de correlación:
Contiene la correlación entre todos los pares de series de tiempo medidos en un experimento de fMRI

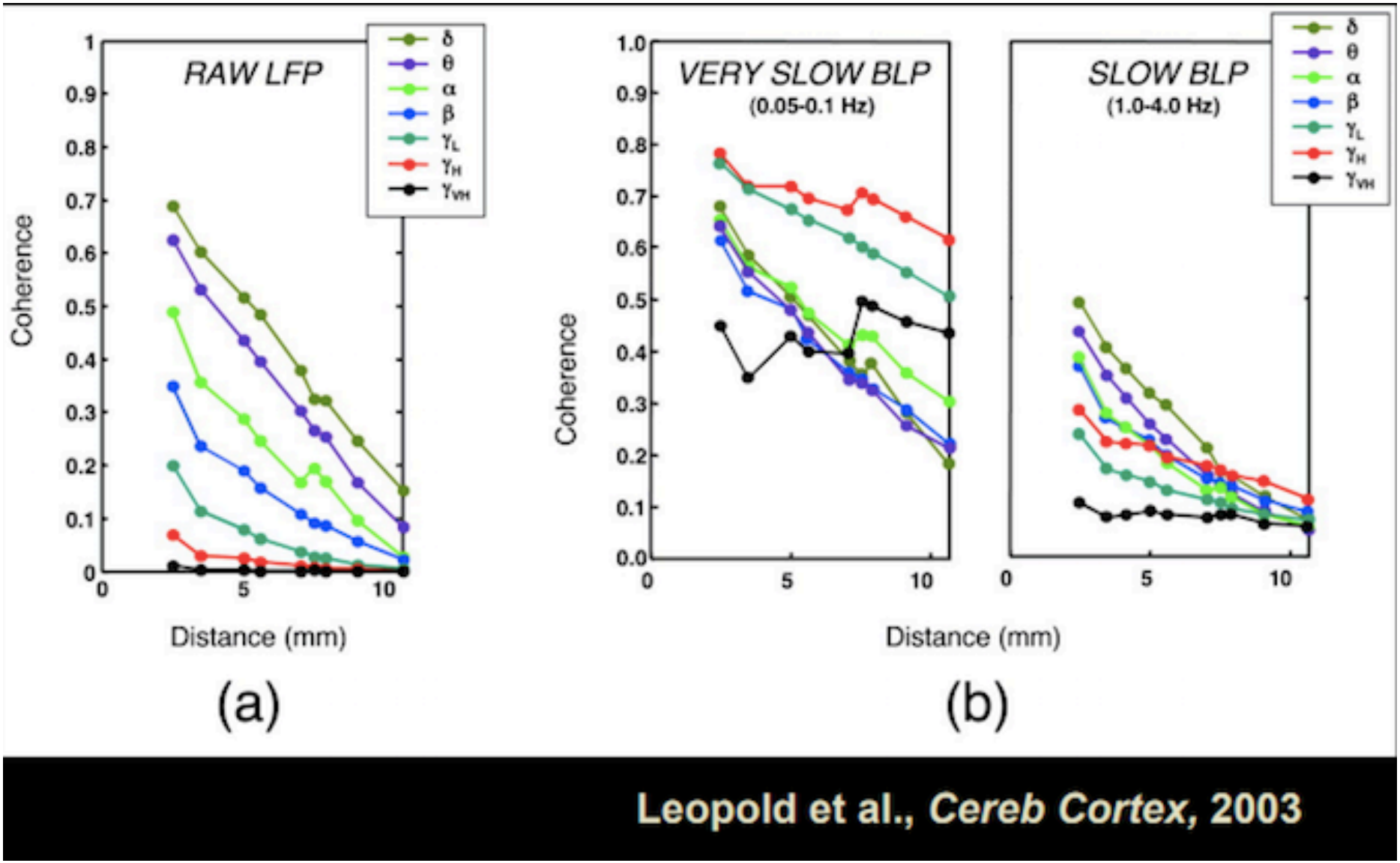
Low-Frequency Respiratory Cycle Noise

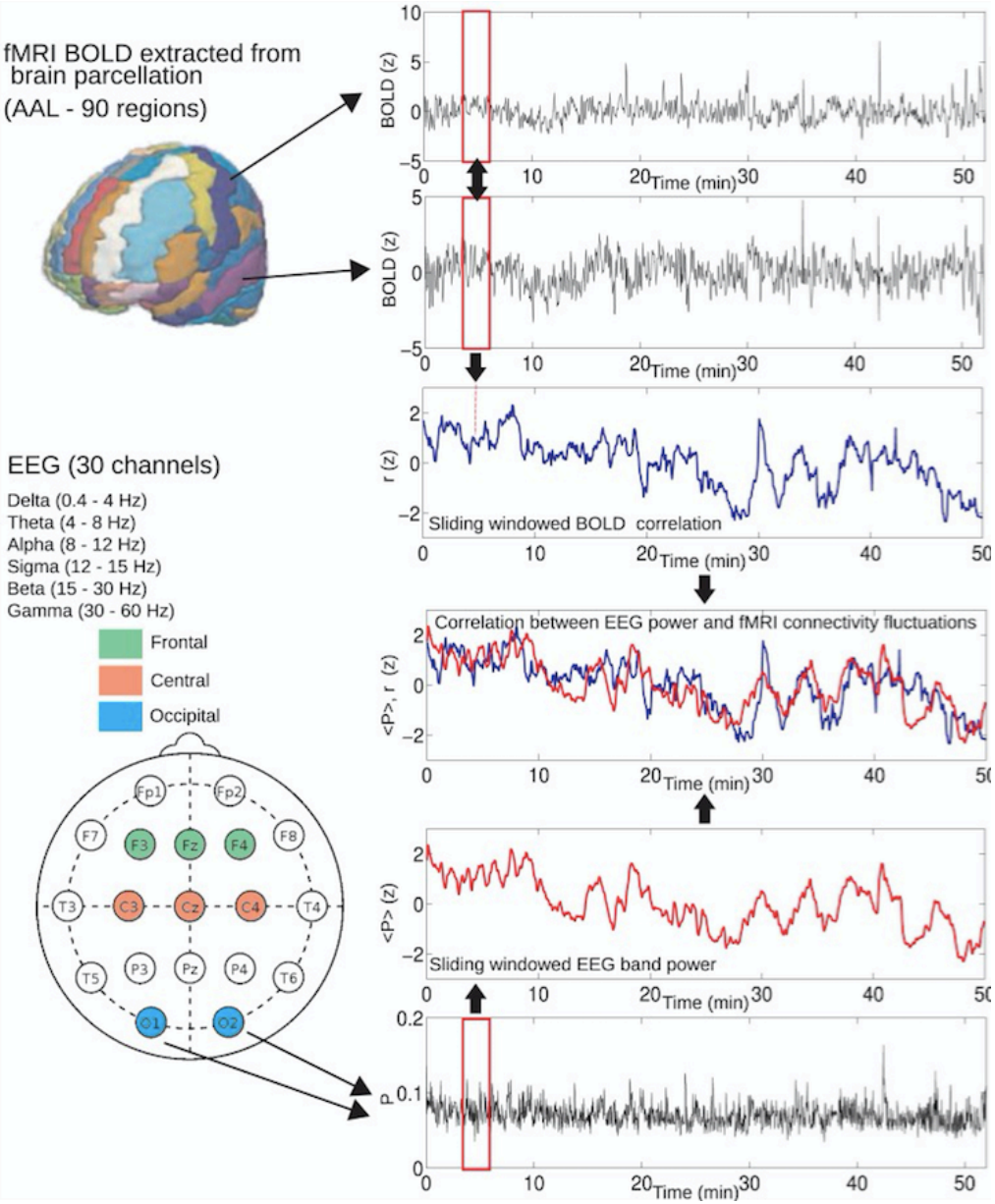


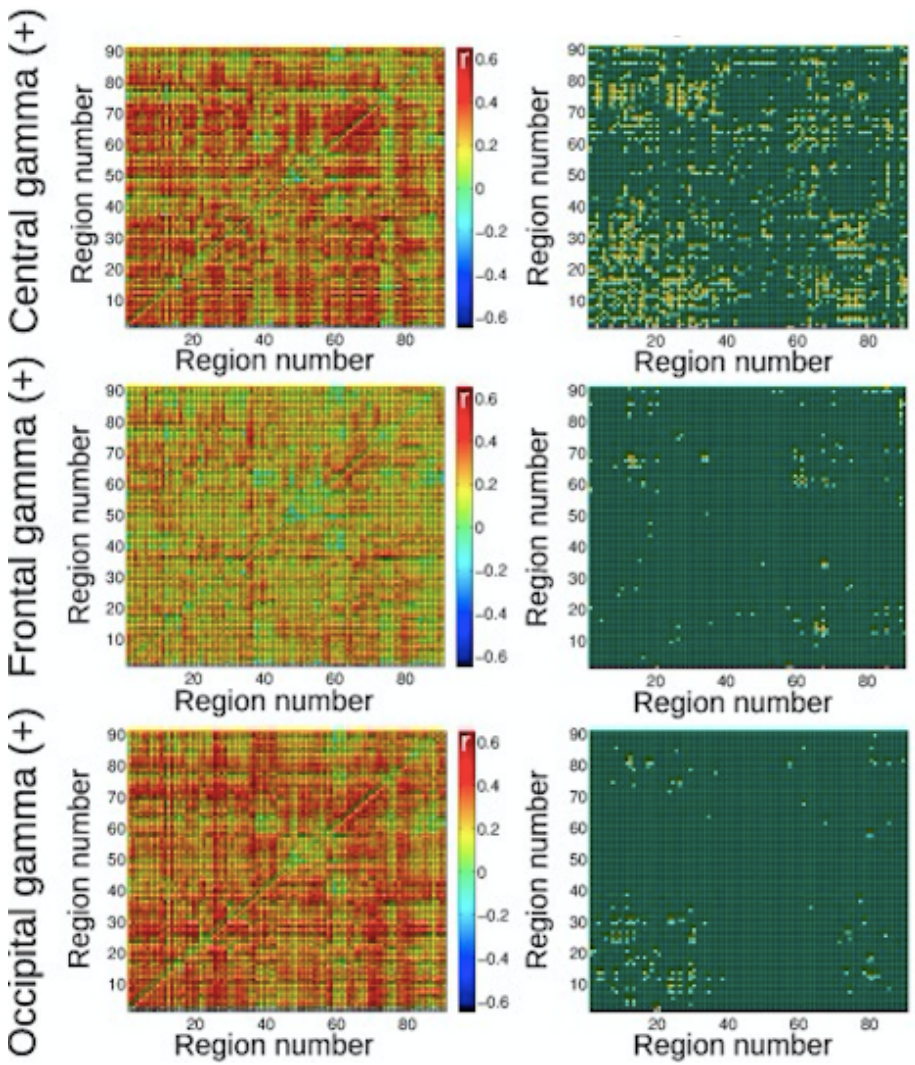


Birn et al., *Neuroimage*, 2006

Correlaciones de larga distancia en la envolvente de gamma (> 40 Hz)

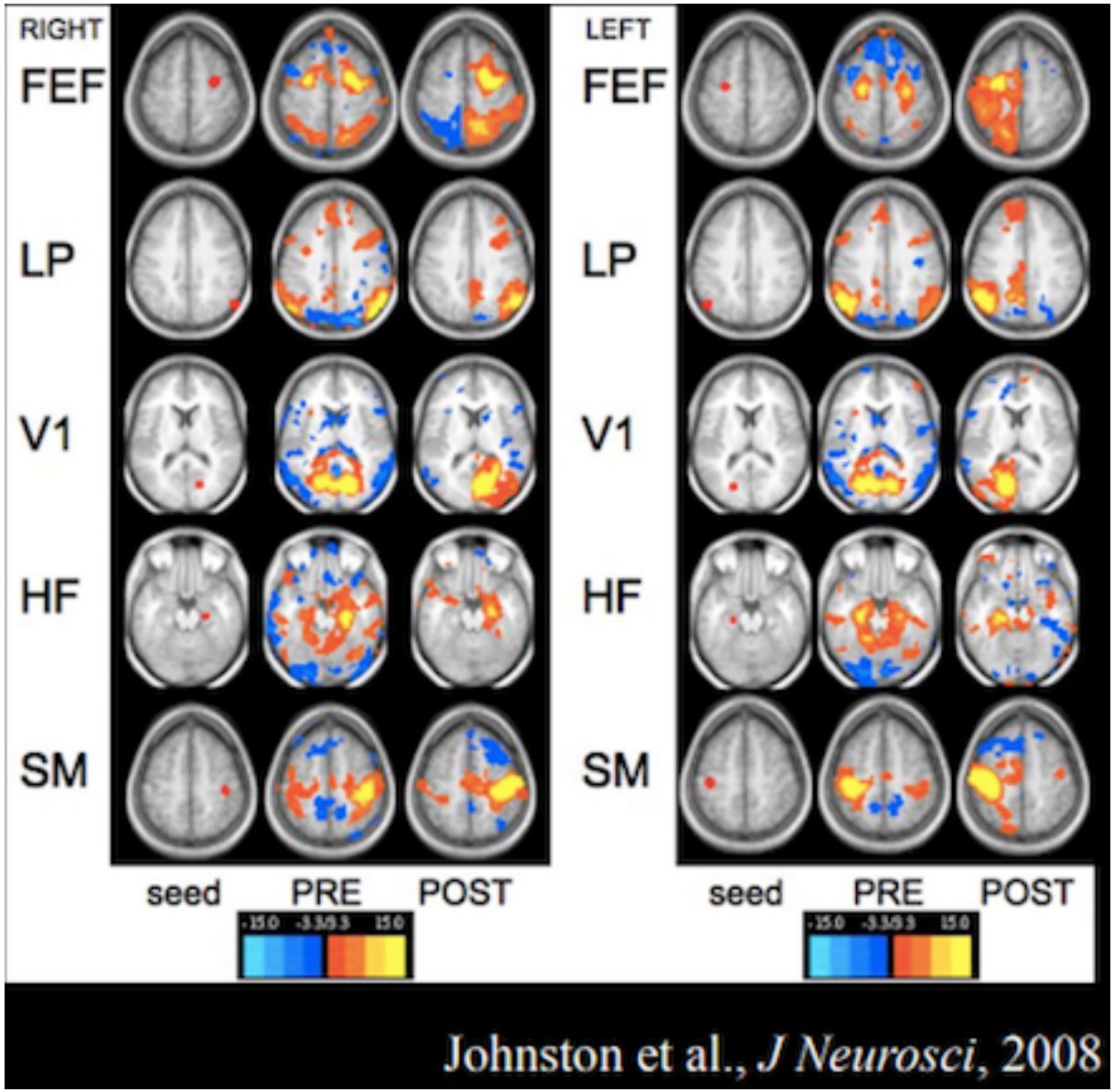




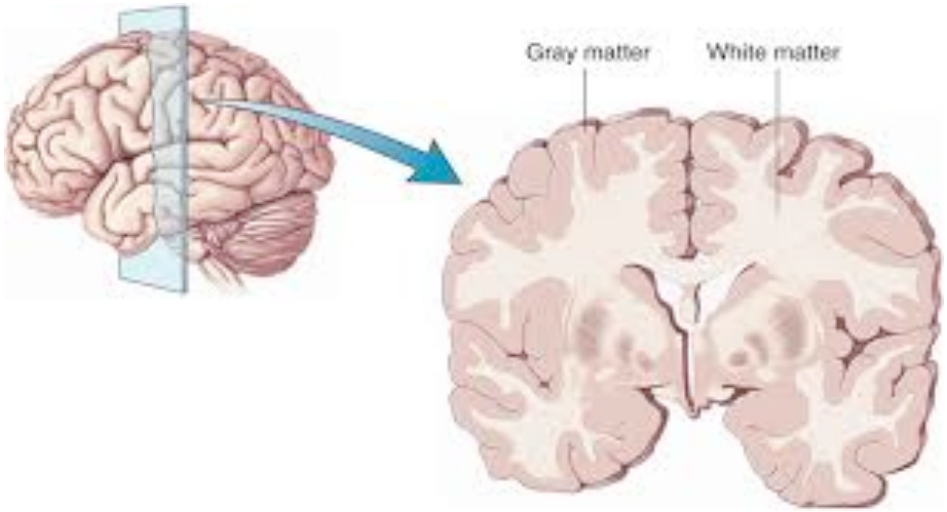


Tagliazucchi et al., 2012

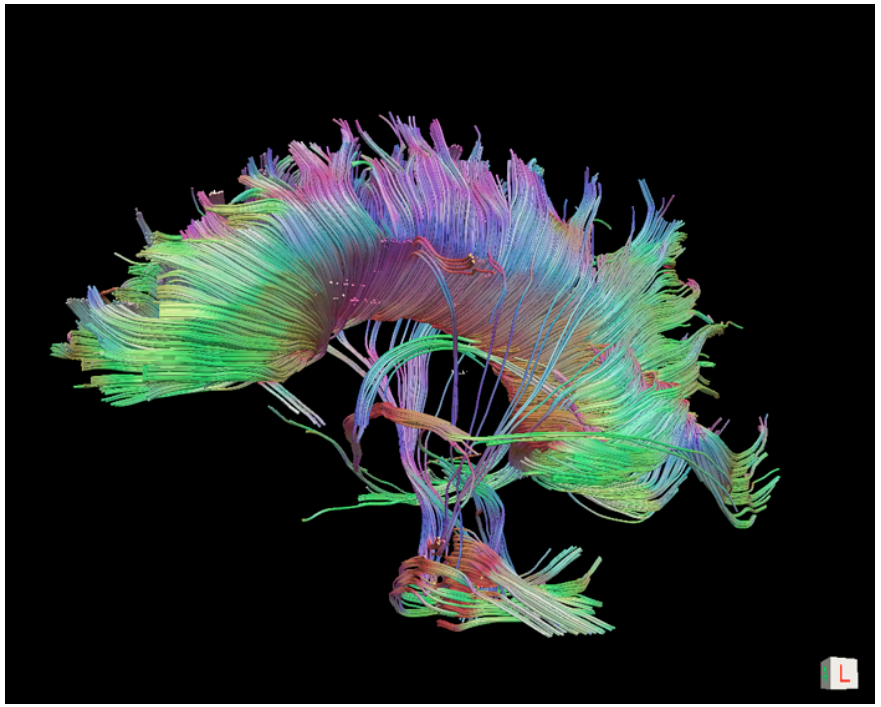
Reseccion del cuerpo calloso



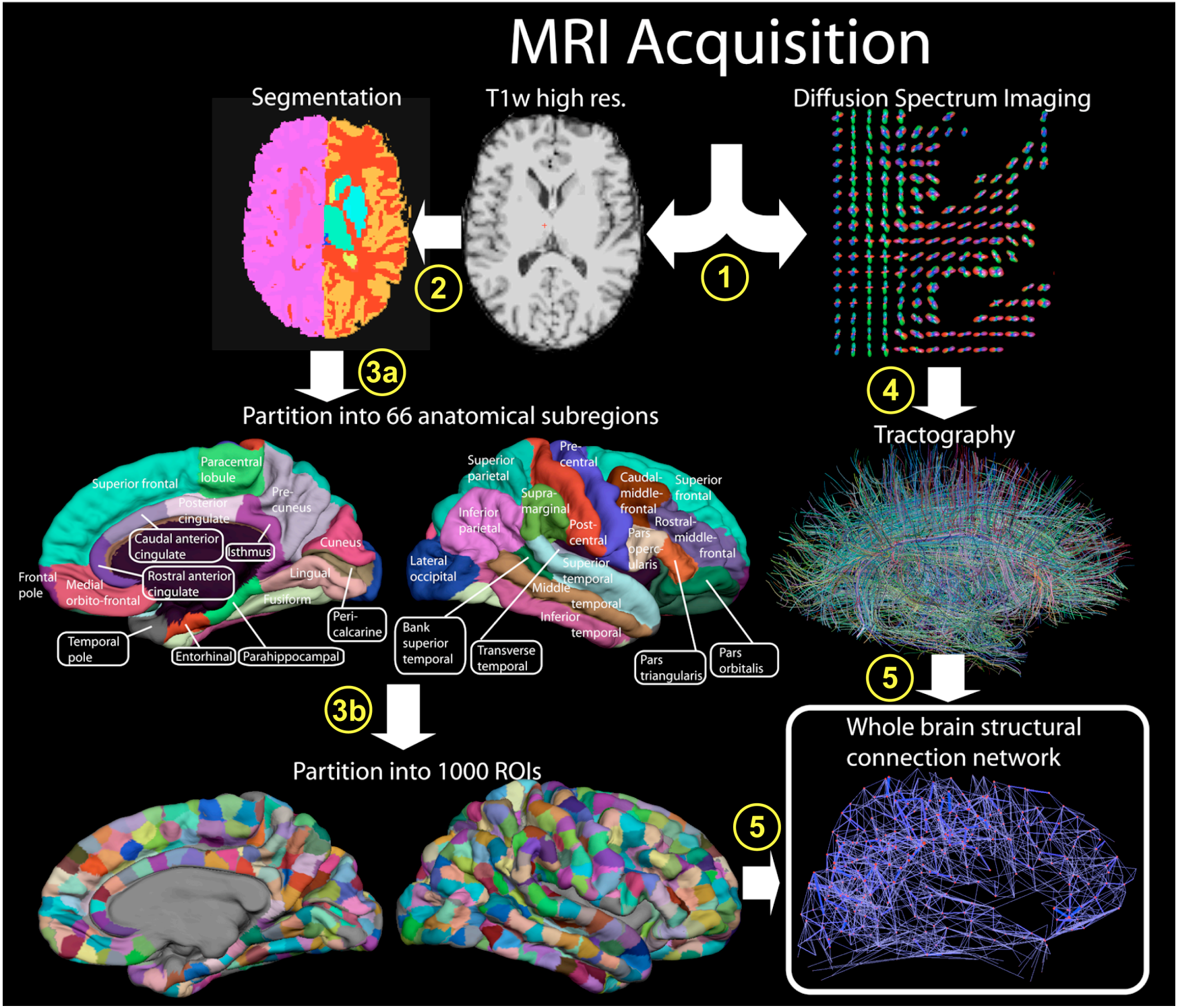
Conectividad *estructural* del cerebro



Tensor de difusión
Diffusion Tensor Imaging (DTI)



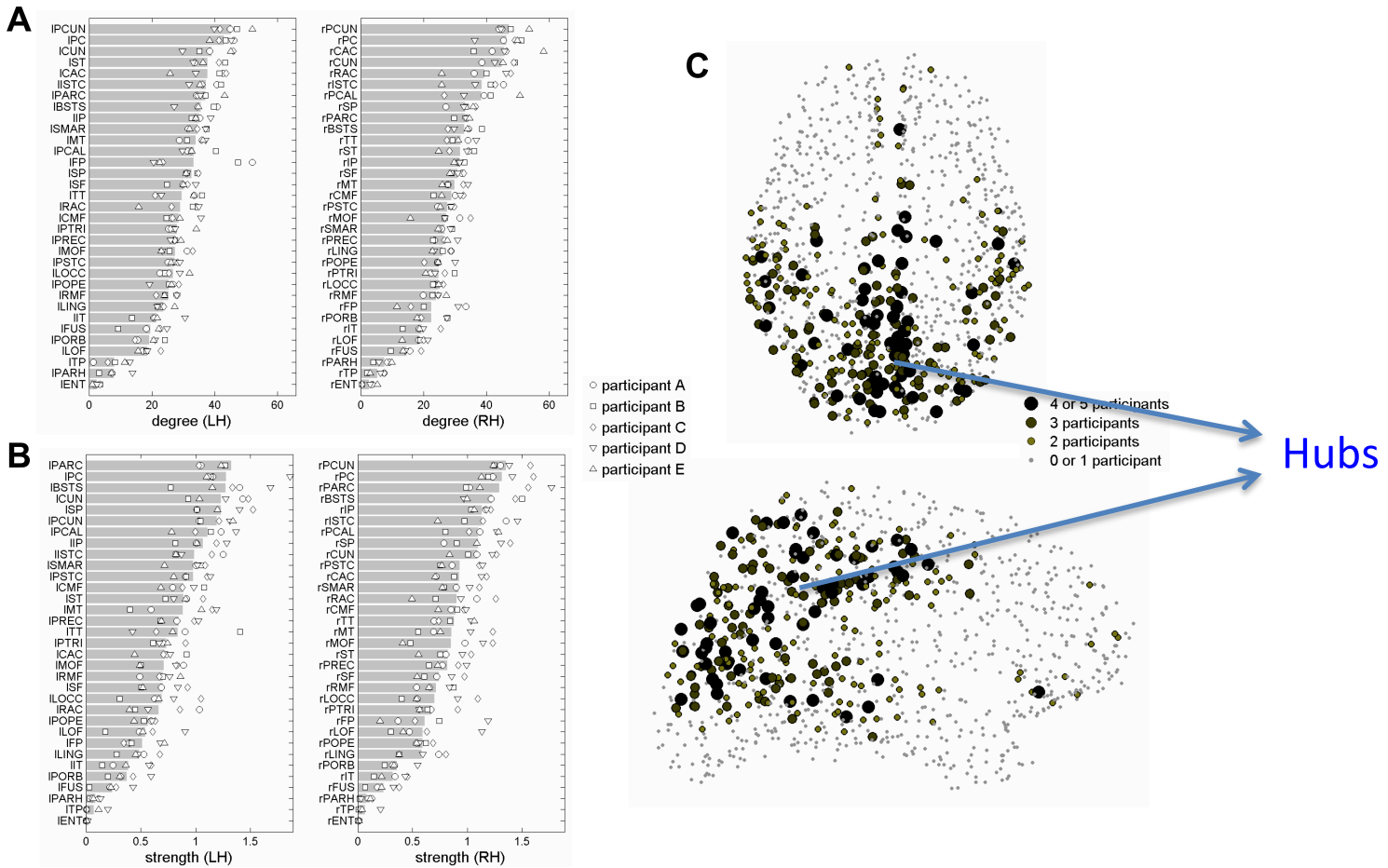
Materia blanca está compuesta principalmente de manojos de axones (“cables”) que conectan distintas zonas de la corteza


MRI Acquisition
Segmentation
T1w high res.
Diffusion Spectrum Imaging
1
2
3a
4
Partition into 66 anatomical subregions
Tractography
Superior frontal
Paracentral lobule
Pre-cuneus
Posterior cingulate
Caudal anterior cingulate
Isthmus
Cuneus
Frontal pole
Medial orbito-frontal
Rostral anterior cingulate
Lingual
Fusiform
Peri-calcarine
Temporal pole
Entorhinal
Parahippocampal
Superior parietal
Pre-central
Caudal-middle-frontal
Superior frontal
Supra-marginal
Inferior parietal
Post-central
Rostral-middle-frontal
Pars opercularis
Lateral occipital
Superior temporal
Middle temporal
Inferior temporal
Bank superior temporal
Transverse temporal
Pars triangularis
Pars orbitalis
5
3b
Partition into 1000 ROIs
Whole brain structural connection network

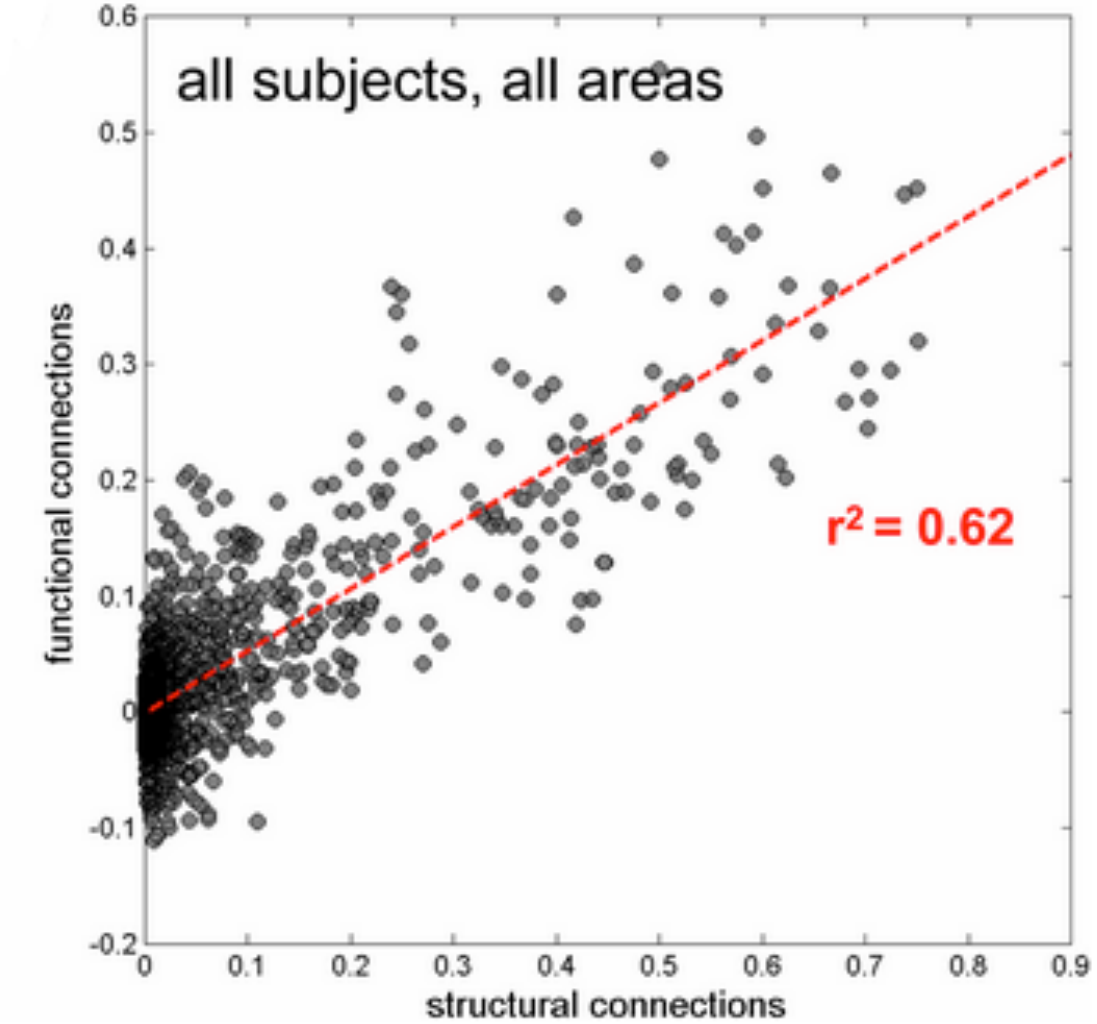
Mapping the Structural Core of Human Cerebral Cortex

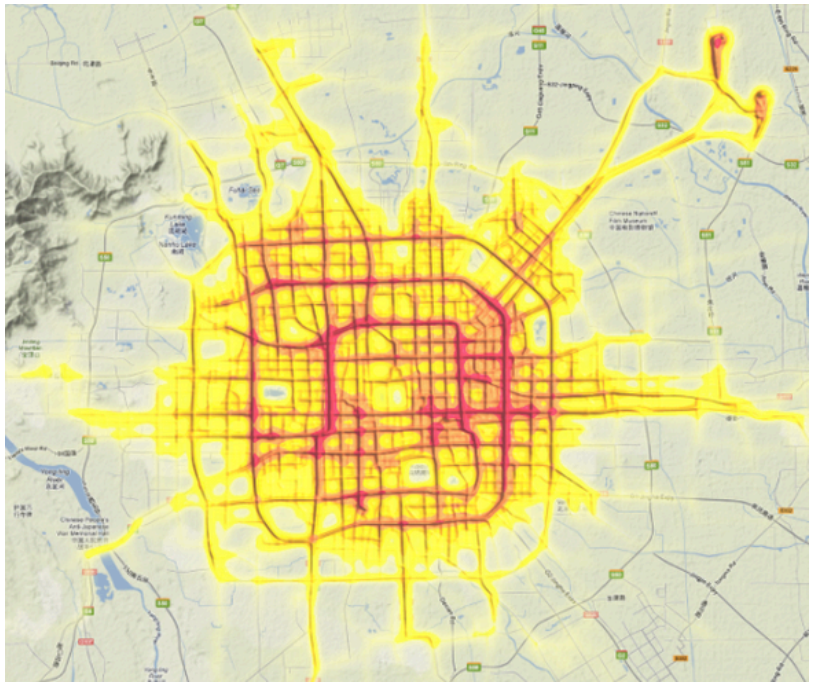
Patric Hagmann, Leila Cammoun, Xavier Gigandet, Reto Meuli, Christopher J Honey, Van J Wedeen, Olaf Sporns

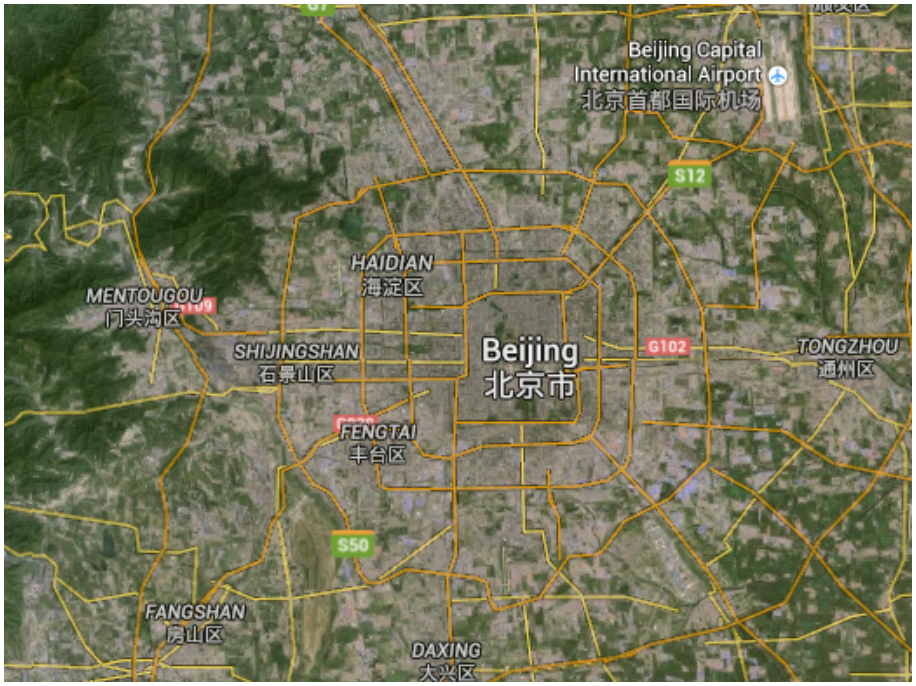
Published: July 1, 2008 • http://dx.doi.org/10.1371/journal.pbio.0060159



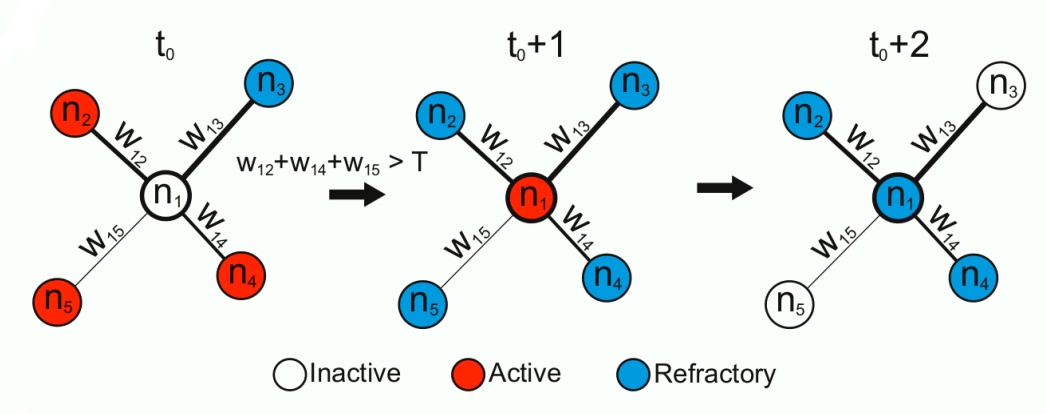
La conectividad funcional refleja la conectividad estructural






Beijing Capital
International Airport
北京首都国际机场
S12
HAIDIAN
海淀区
MENTOUGOU
门头沟区
SHIJINGSHAN
石景山区
Beijing
北京市
G102
TONGZHOU
通州区
FENGTAI
丰台区
S50
FANGSHAN
房山区
DAXING
大兴区

Surgen "las redes de estado de reposo" de la anatomía cerebral (redes de conectividad anatómica) bajo principios suficientemente generales?



Nodo *j* inactivo ⇨ activo:

Espontáneamente ($p=10^{-3}$) o si

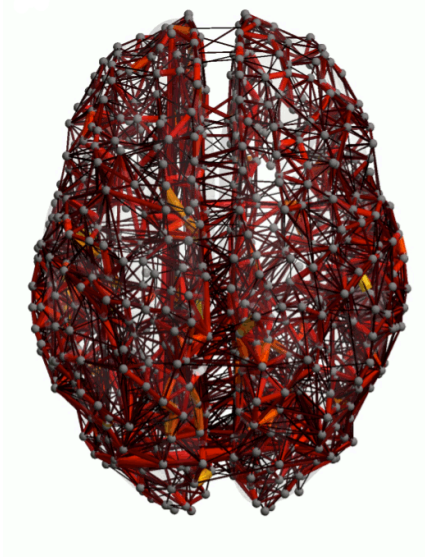
$$\sum_{i\ active} W_{ij} > T$$

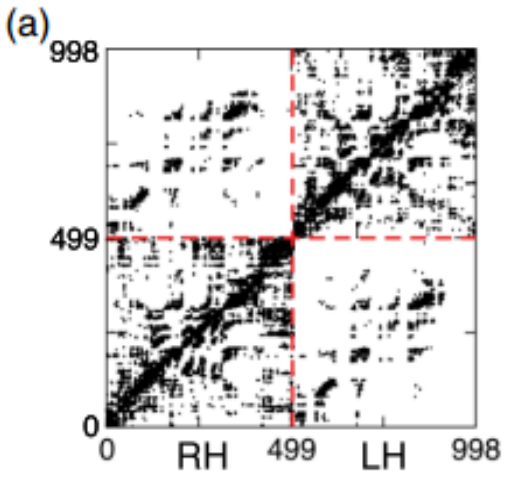
Nodo *j* activo ⇨ refractorio:

Siempre (p=1)

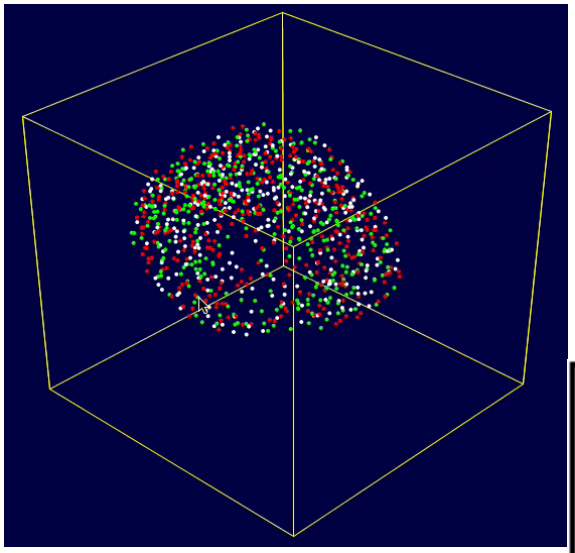
Nodo *j* refractorio ⇨ inactivo:

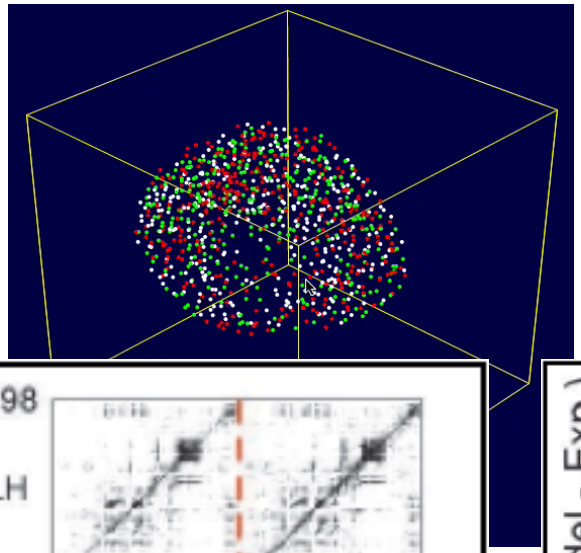
Espontáneamente ($p=10^{-1}$)

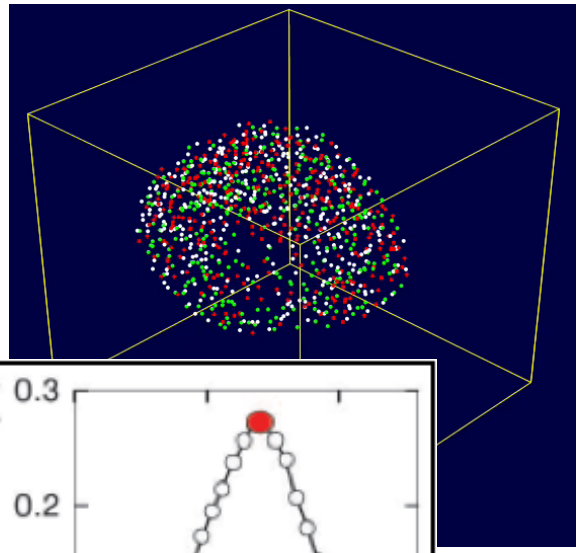


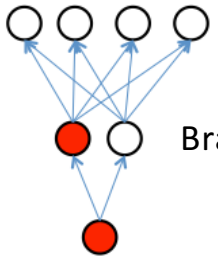


Inactivo Activo Refractario

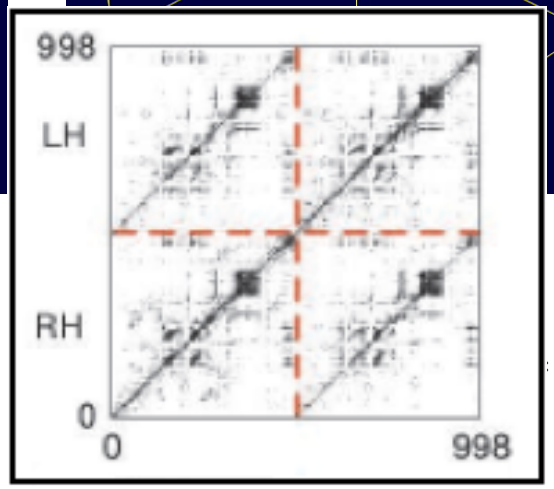




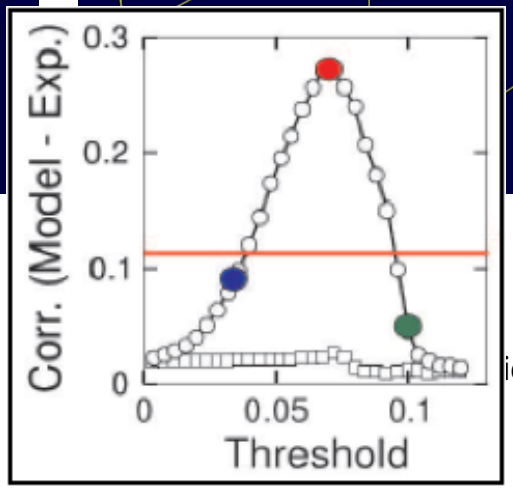




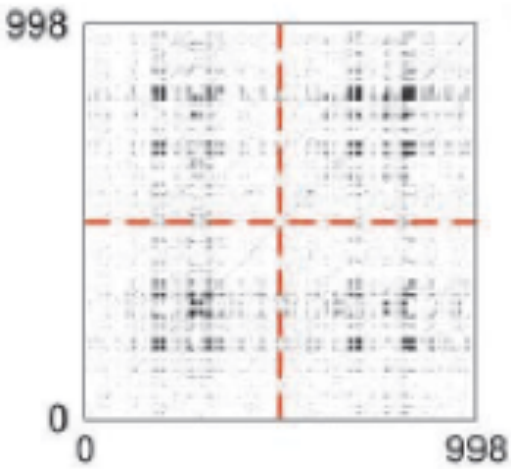
Branching ratio < 1

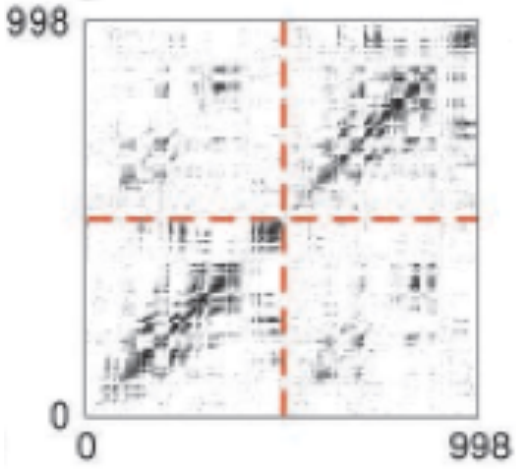


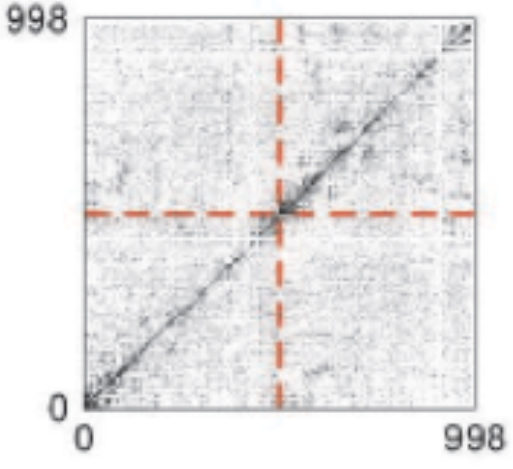
1

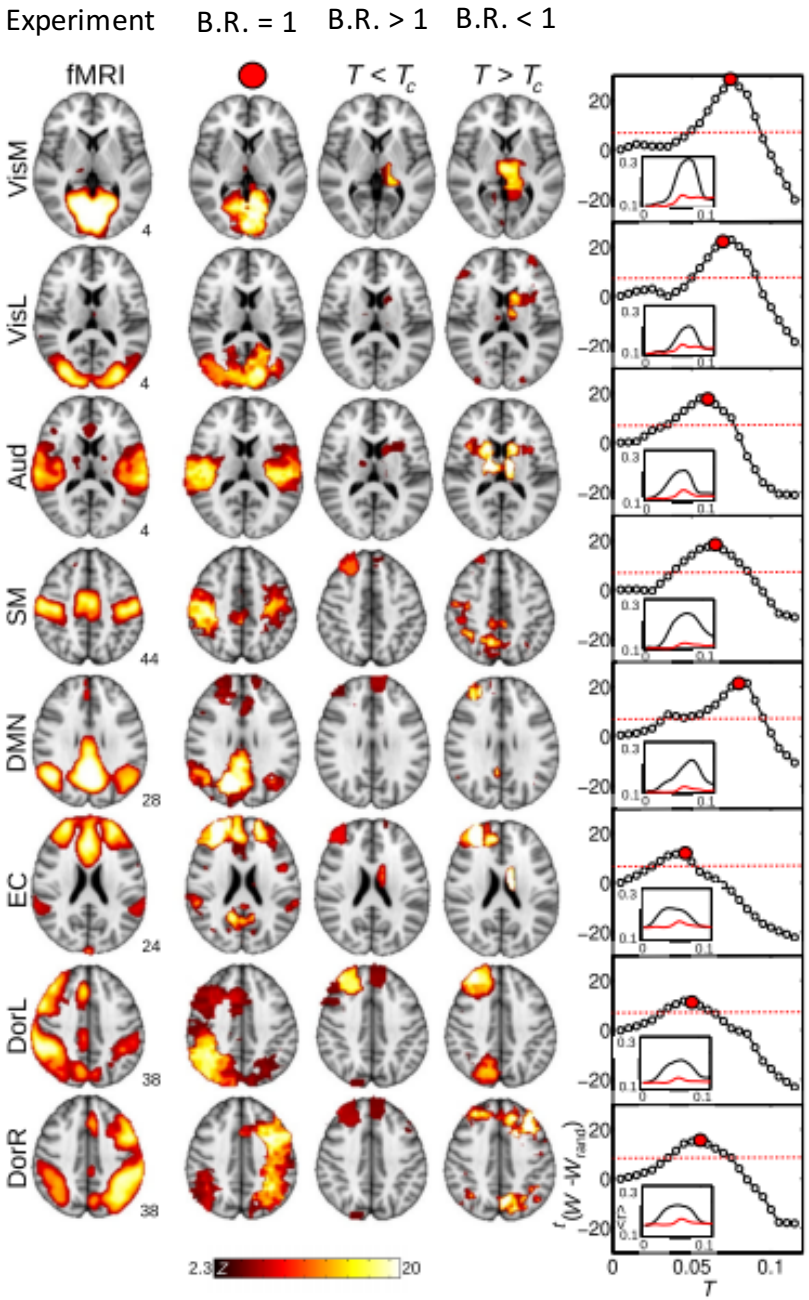


io > 1



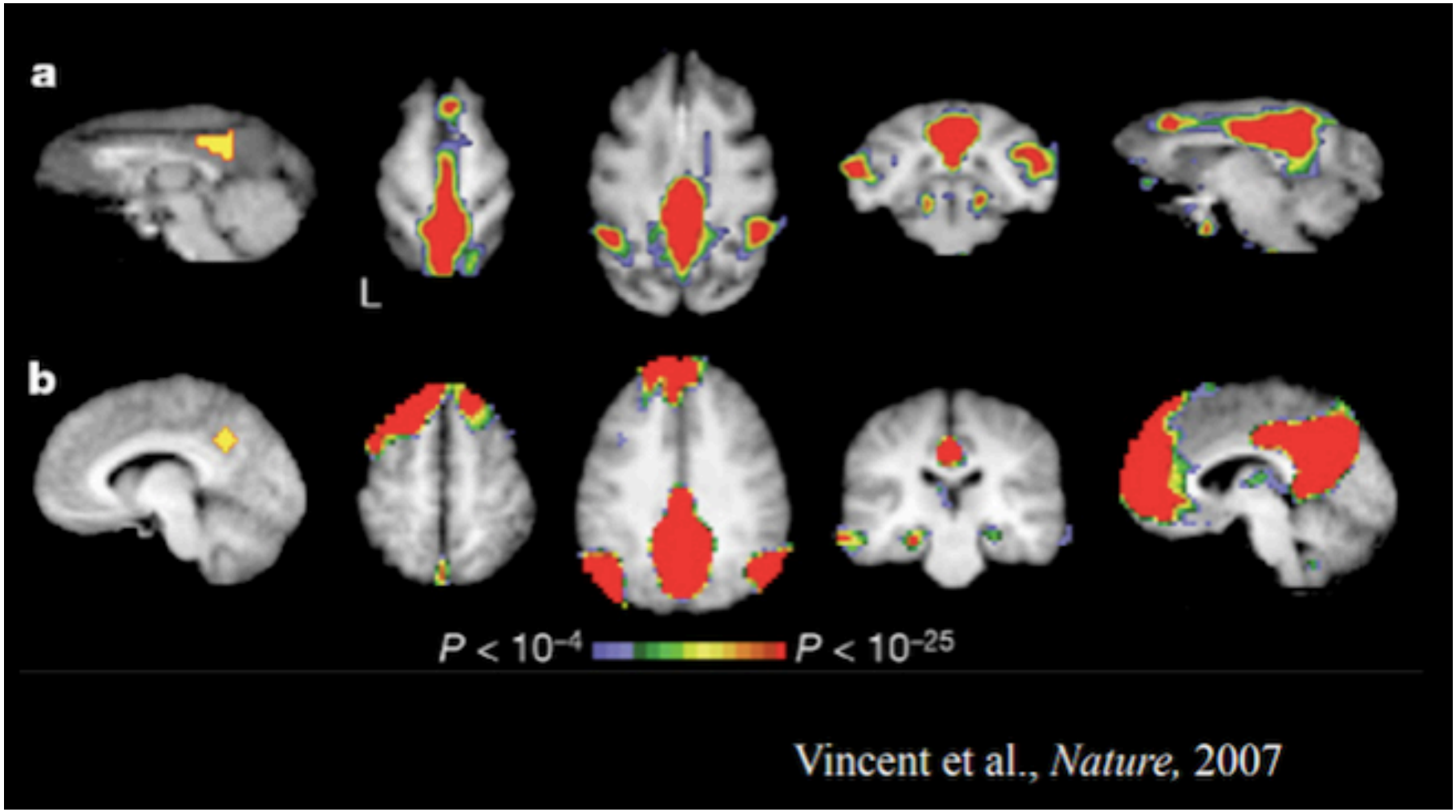




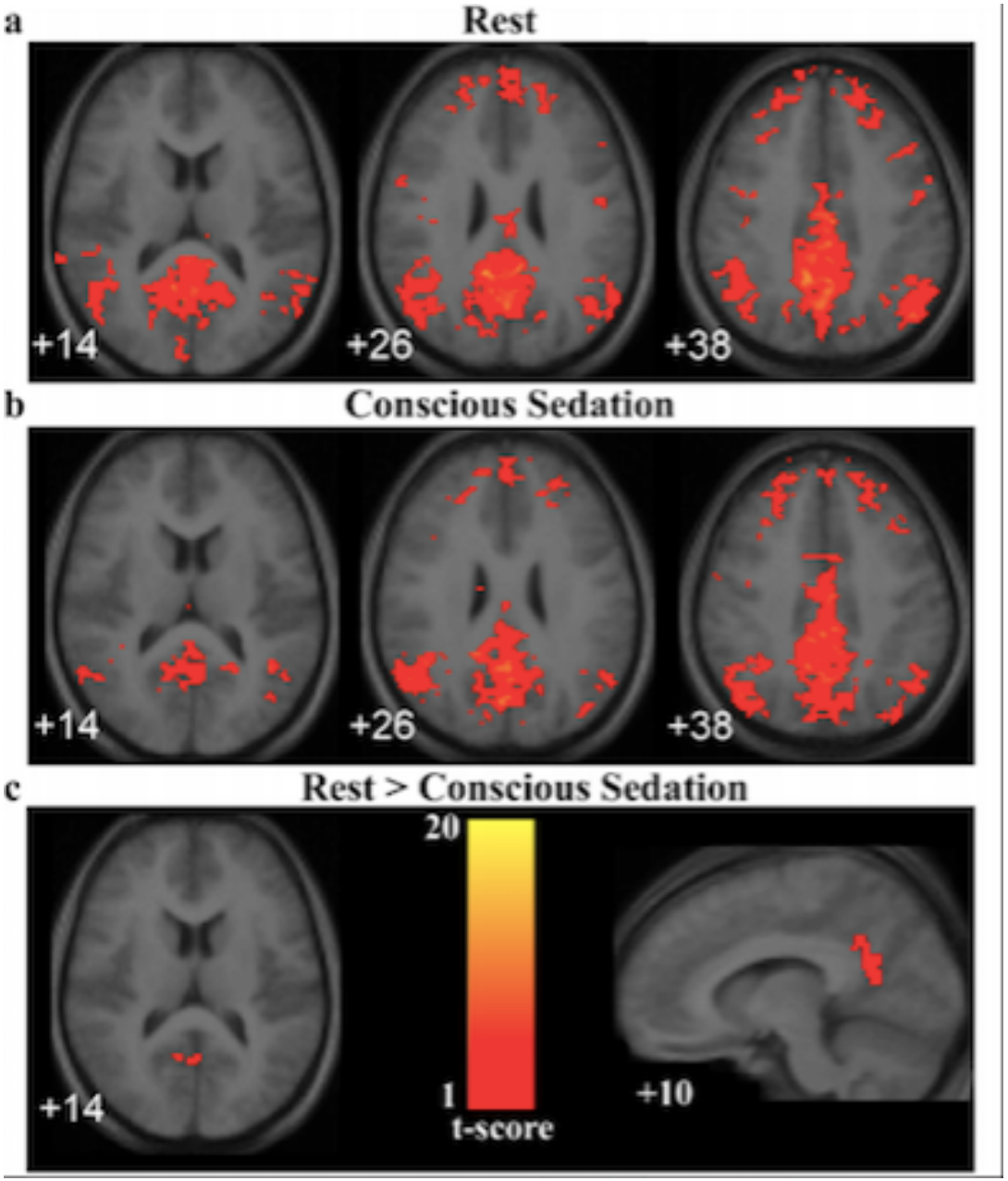


Punto crítico -> reproducción de redes de estado de reposo a partir de las redes de conectividad estructural del cerebro

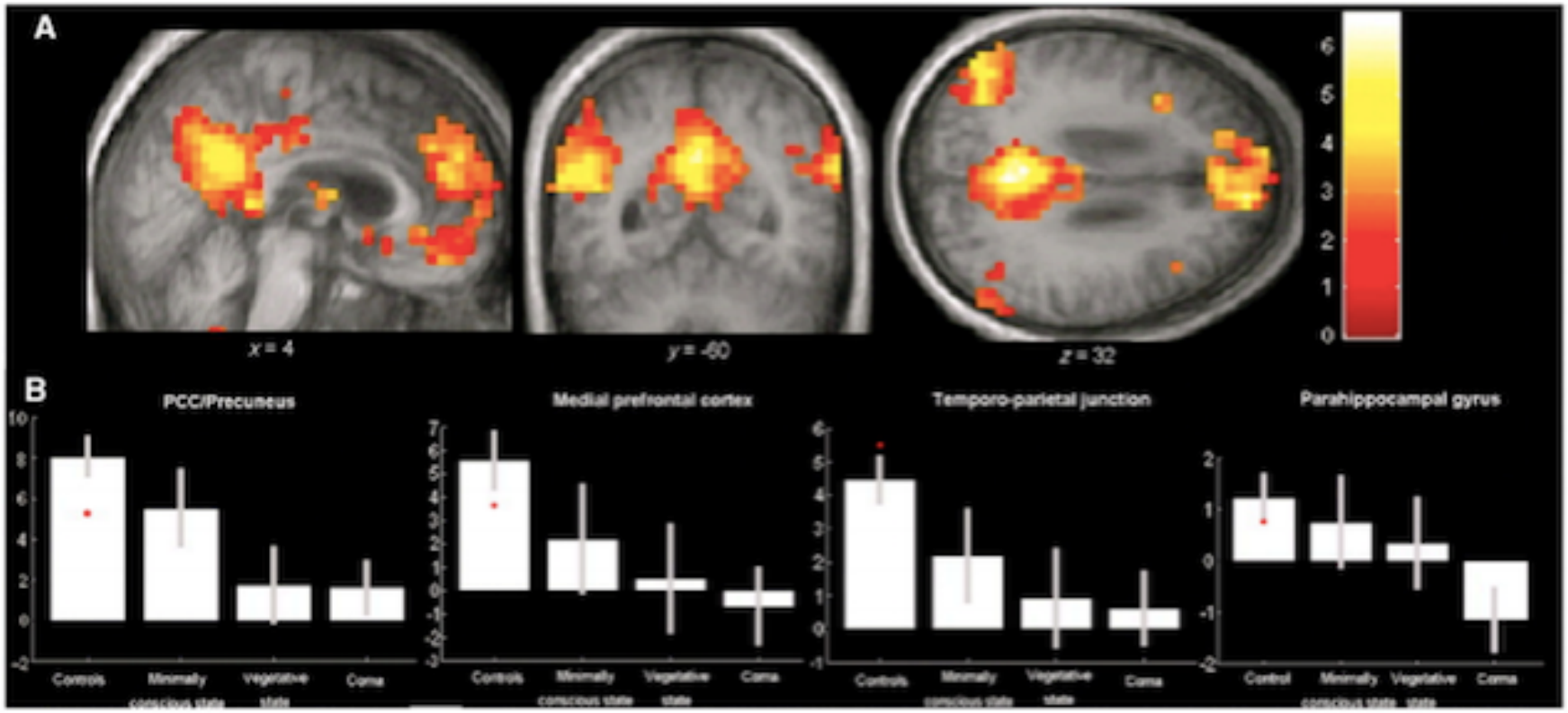
DMN se puede identificar en monos anestesiados



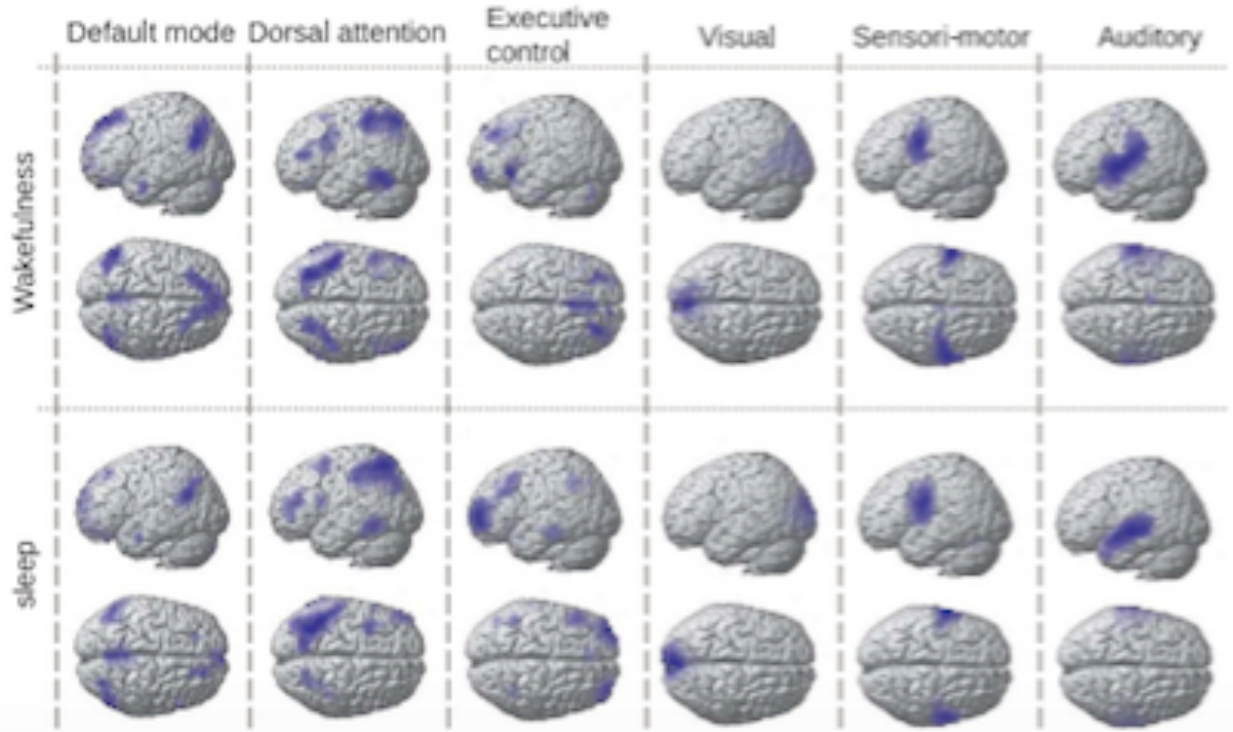
… en humanos sedados…



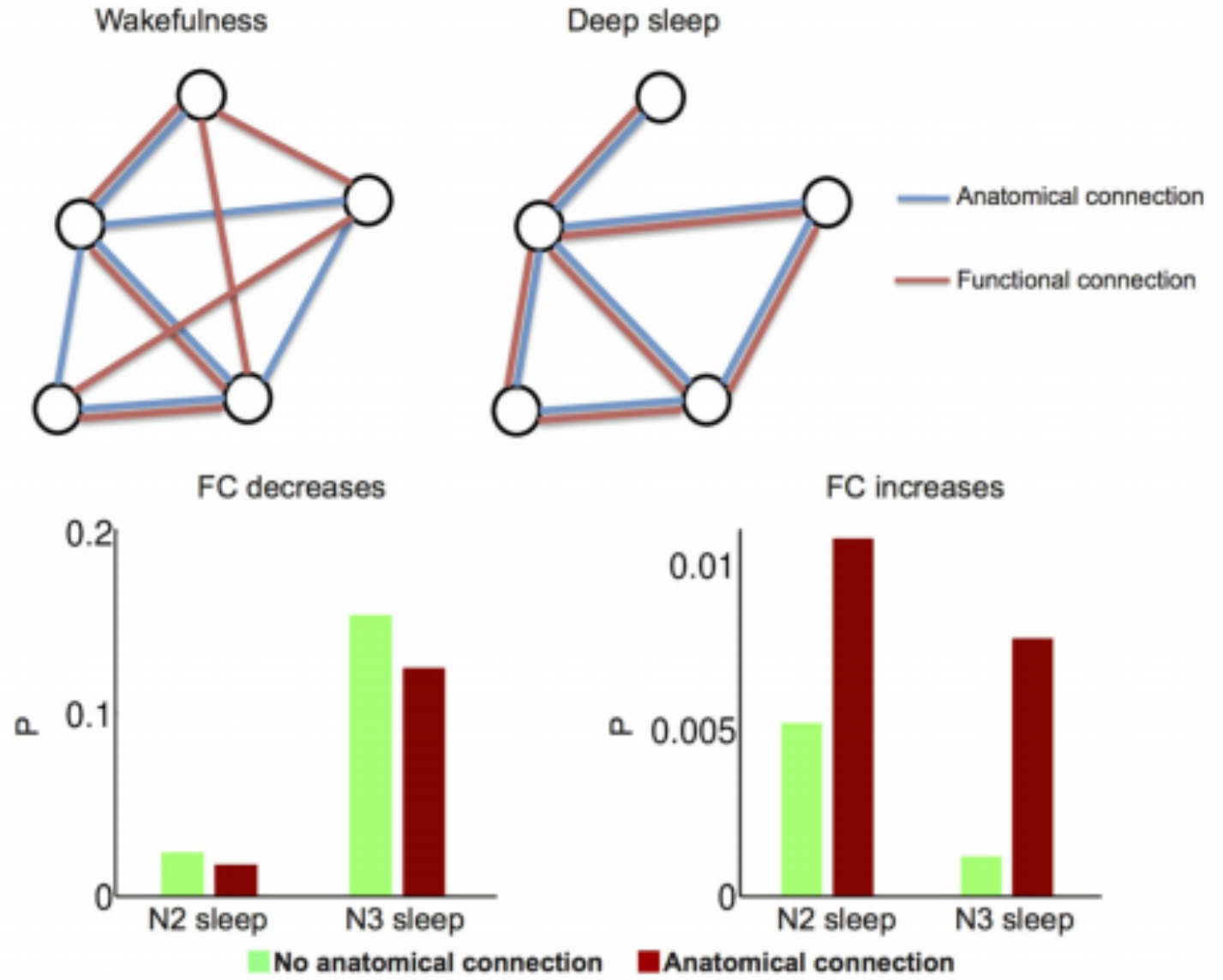
… en humanos en coma…



… en humanos durmiendo.



El nucleo estructural “mantiene” la conectividad



Proxima clase: metodos para detectar cambios en el estado cerebral a partir de cambios mas sutiles en la conectividad funcional