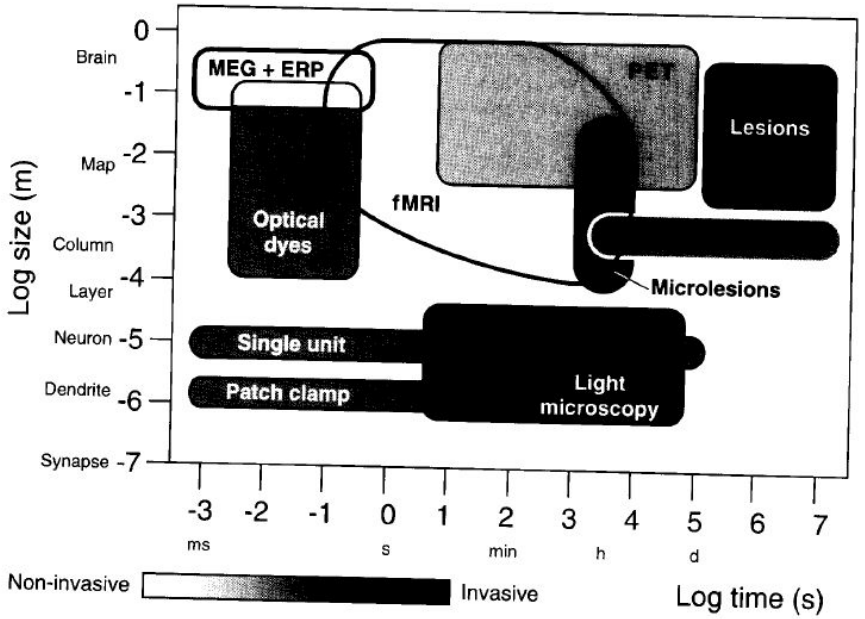
Redes en el cerebro

Data Mining en Ciencia y Tecnología
Maestría de Explotación de Datos y el Descubrimiento de Conocimiento
Octubre 2019

Métodos para medir actividad cerebral



1. Estimulación
   - 1.1. TMS (Transcranial Magnetic Stimulation)
   - 1.2. tDCS (Transcranial Direct Current Stimulation)
   - 1.3. BDS (Deep Brain Stimulation)
2. Registro
   - 2.1. MRI
   - 2.2. fMRI
   - 2.3. DTI
   - 2.4. fNIRS
   - 2.5. PET
   - 2.6. EEG
   - 2.7. MEG
   - 2.8. iEEG
   - 2.9. LFP
   - 2.10. Single-Cell Recordings

Cohen MS and Bookheimer SY (1994) Localization of brain function using magnetic resonance imaging. Trends in Neuroscience

Electroencefalografía (EEG)

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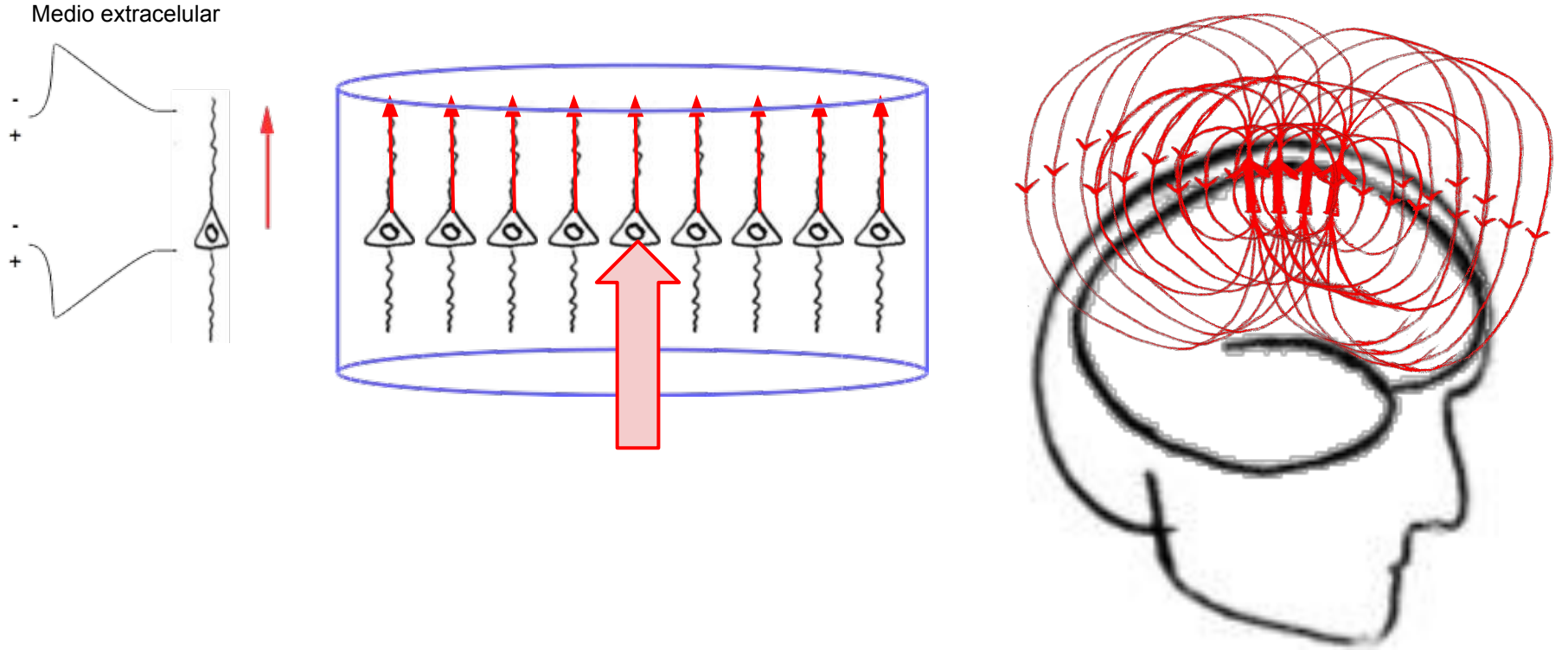

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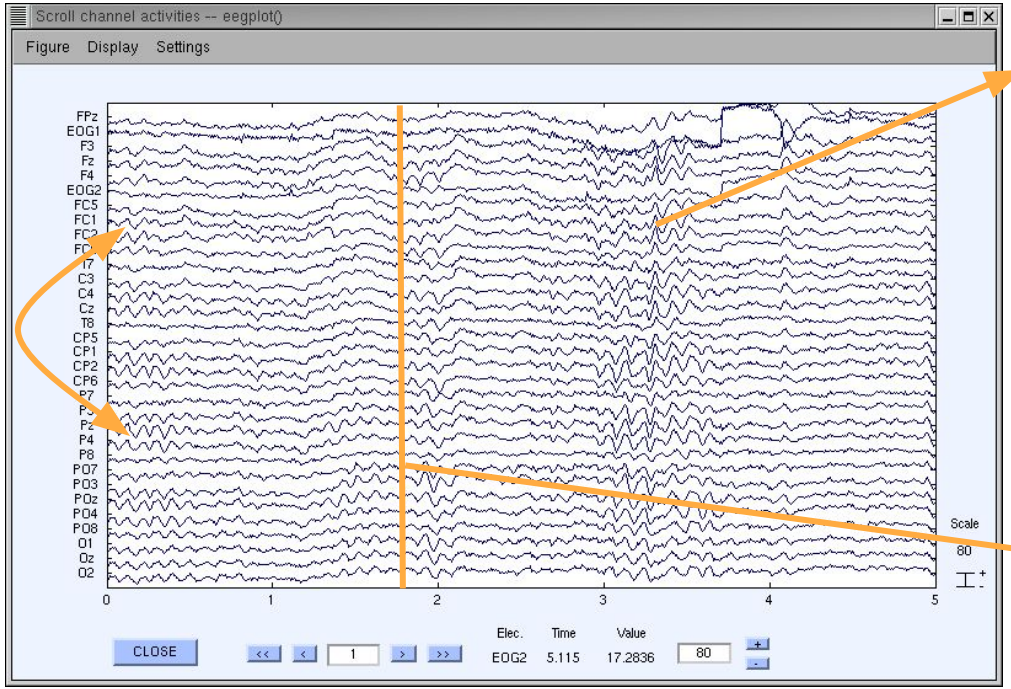
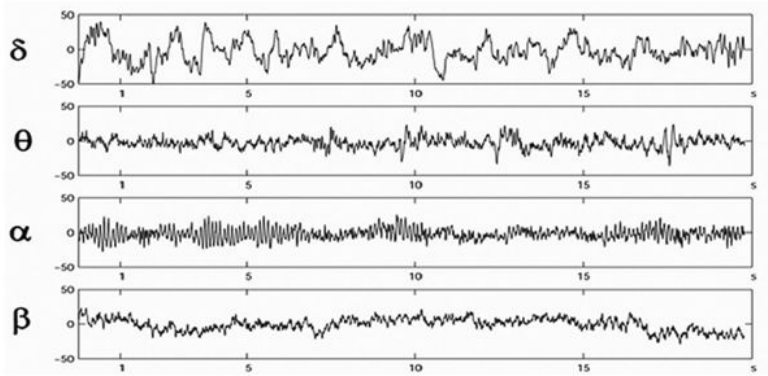
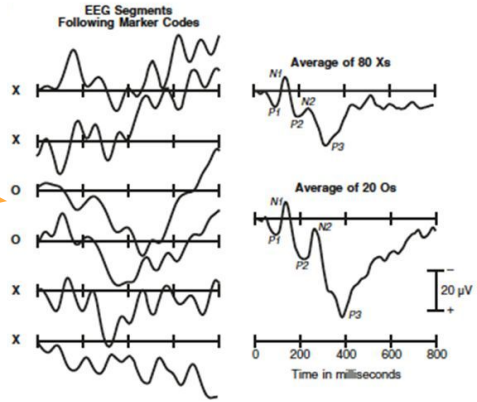


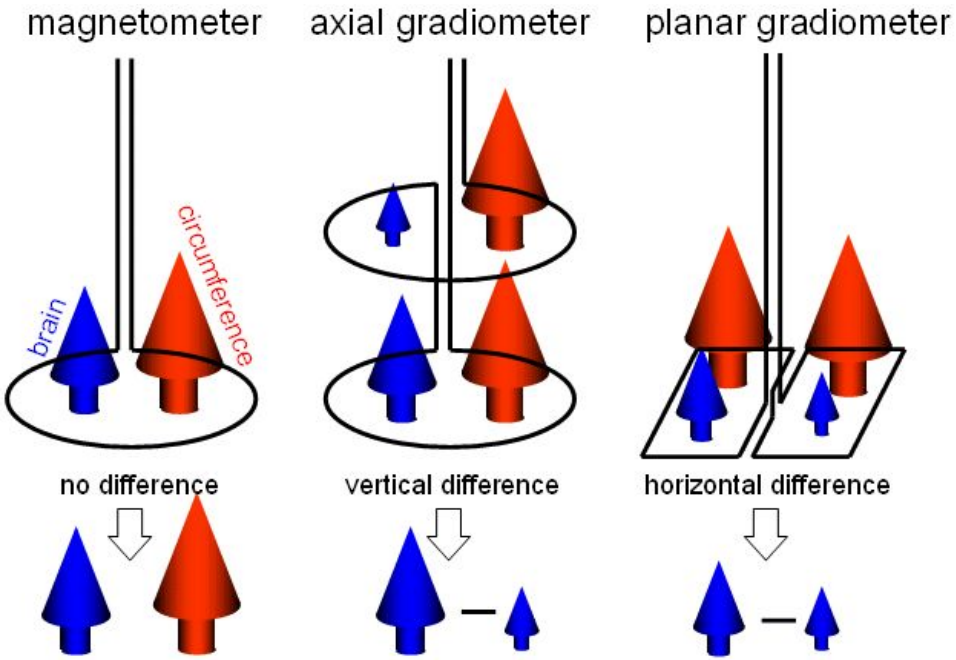
r(x,y)





ERP Components:
P = Positive
N = Negative
P1 = P100
P2 = P200
P3 = P300
etc.

Magnetoencefalografía (MEG)



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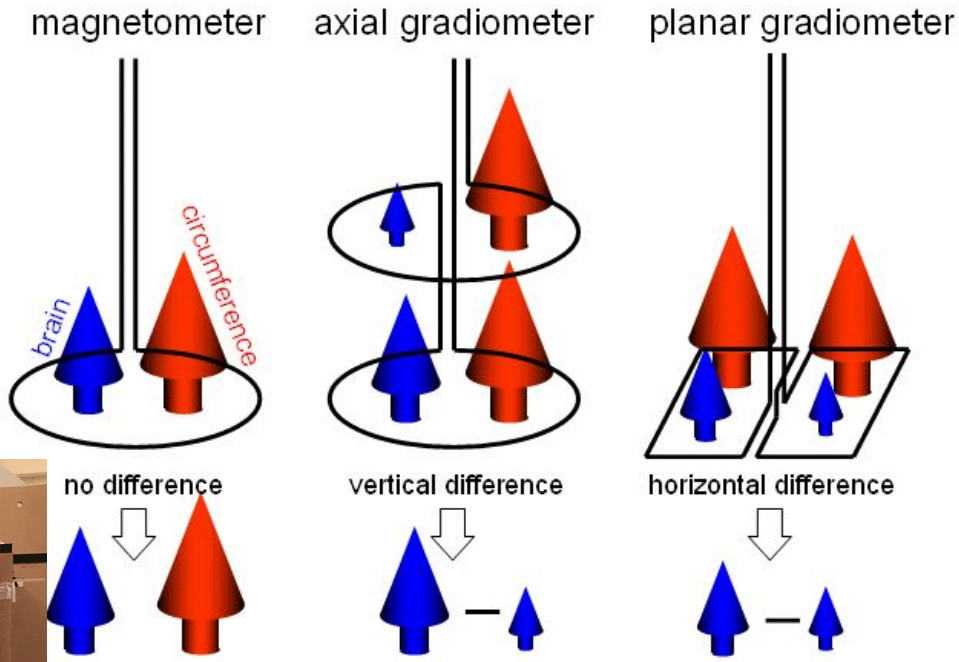
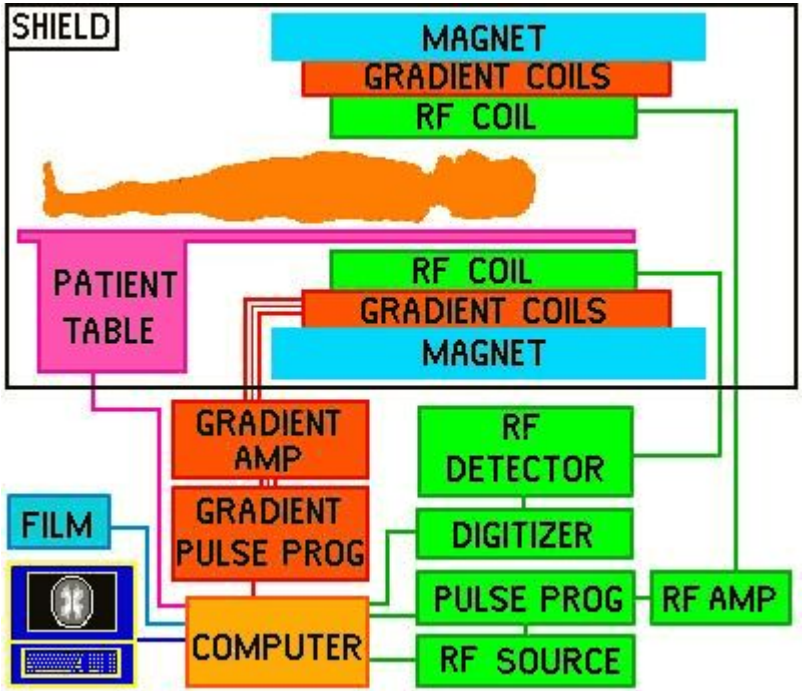


Resonancia Magnética Funcional (fMRI)



http://www.mri-physics.net/bin/mri-physics-en-rev1.3.pdf

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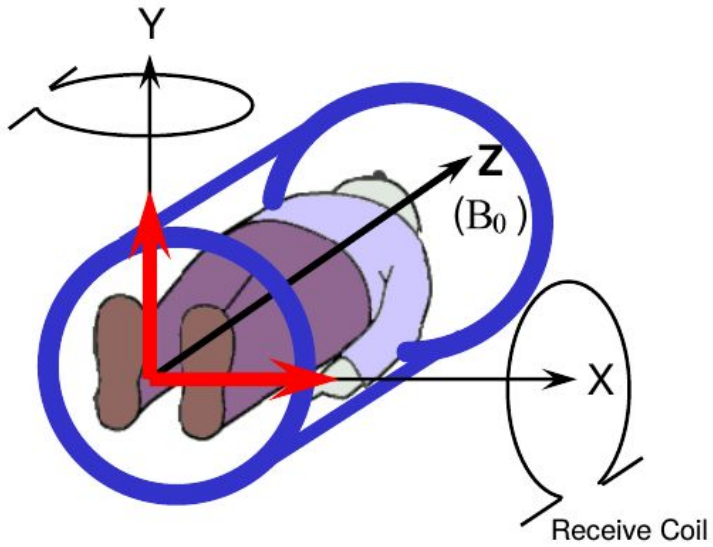

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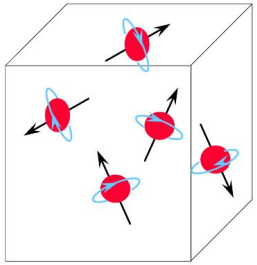

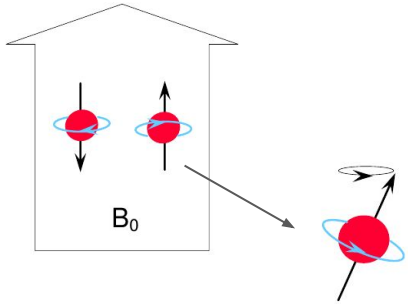

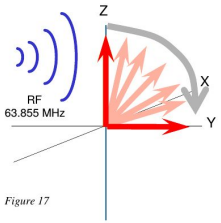

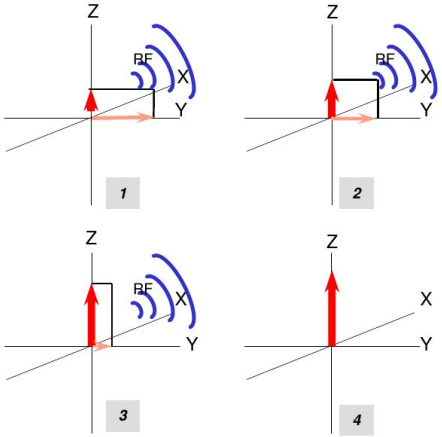

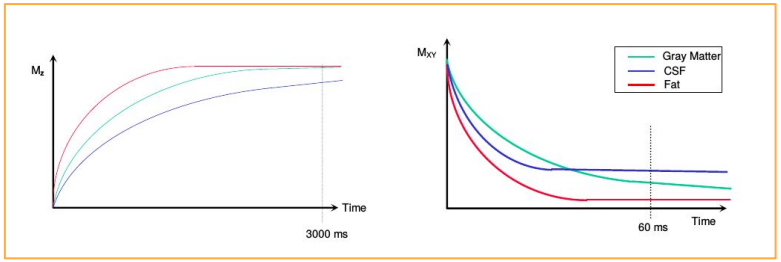

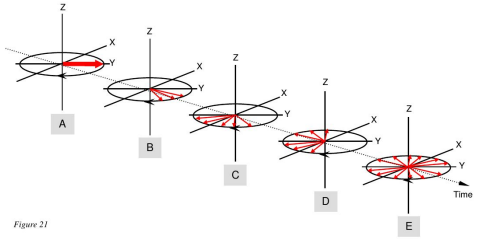

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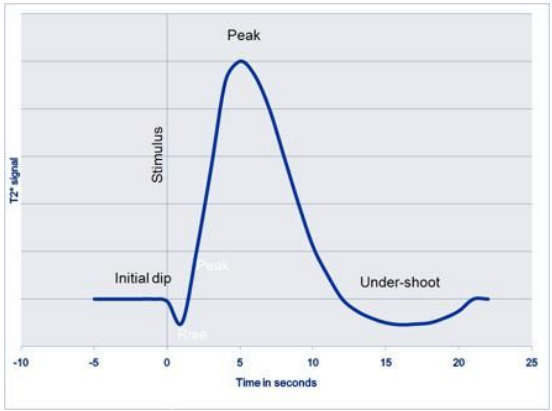

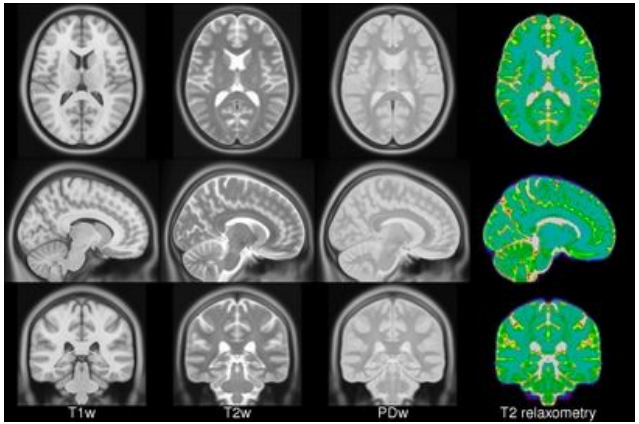

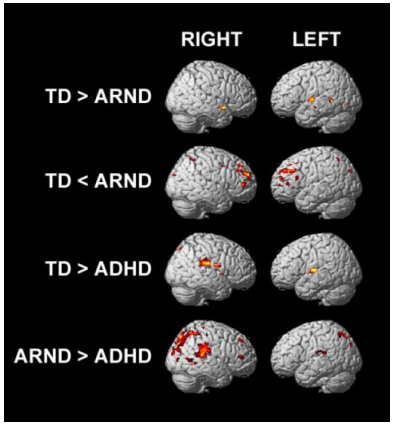

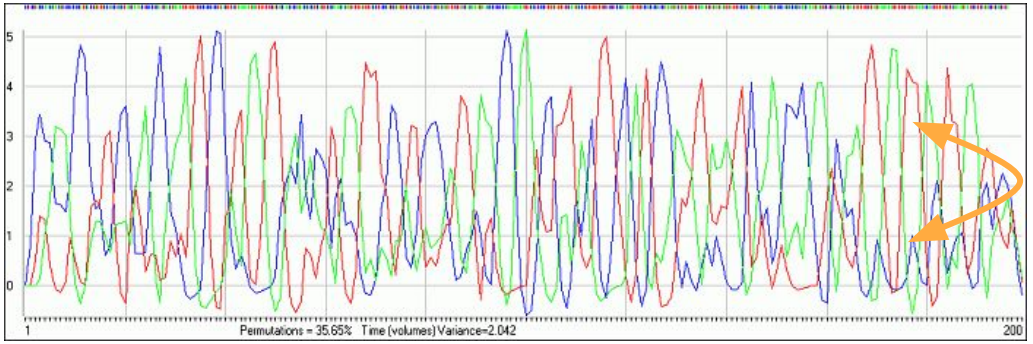

$r(x,y)$

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Cognición: Global Workspace

Dehaene, S., Lau, H., & Kouider, S. (2017). What is consciousness, and could machines have it?. *Science*, *358*(6362), 486-492.

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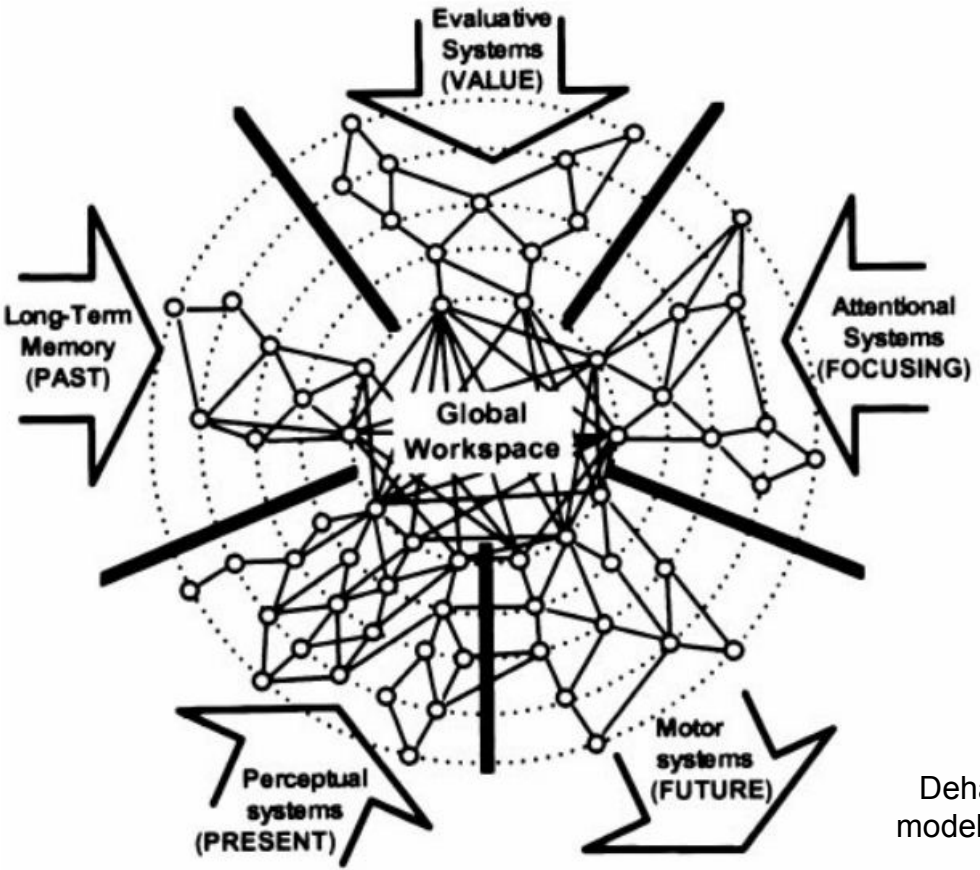

Dehaene, S., Kerszberg, M., & Changeux, J. P. (1998). A neuronal model of a global workspace in effortful cognitive tasks. Proceedings of the National Academy of Sciences

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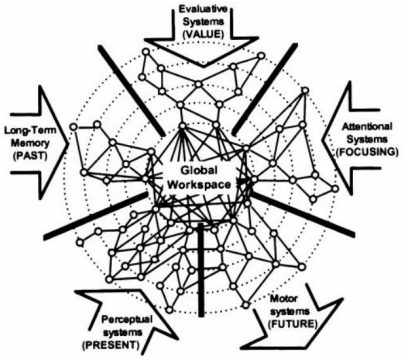

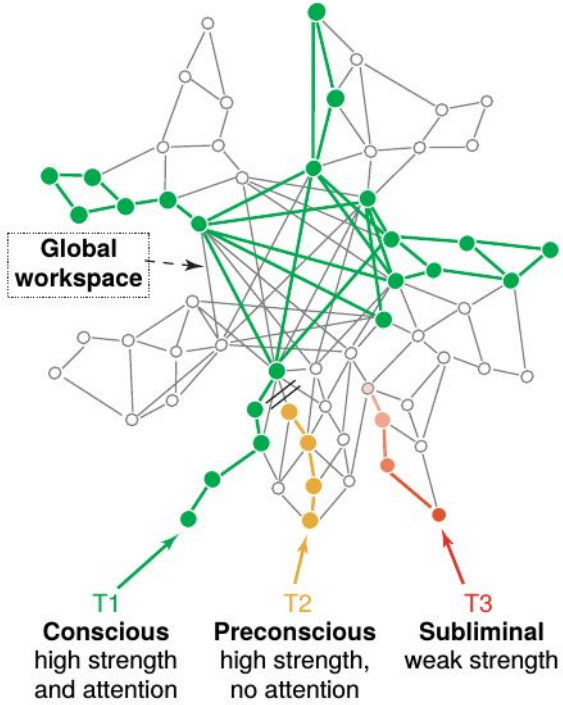

Del Cul, A., Baillet, S., & Dehaene, S. (2007). Brain dynamics underlying the nonlinear threshold for access to consciousness. PLoS biology

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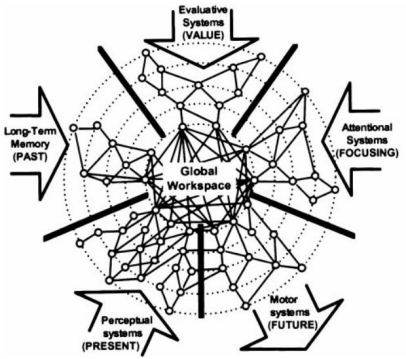

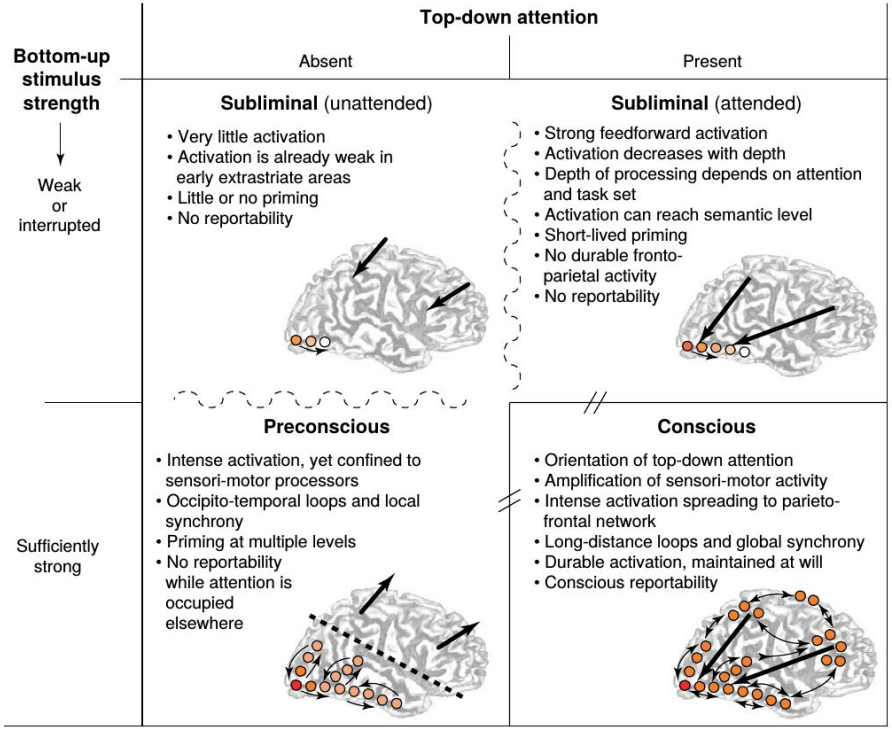

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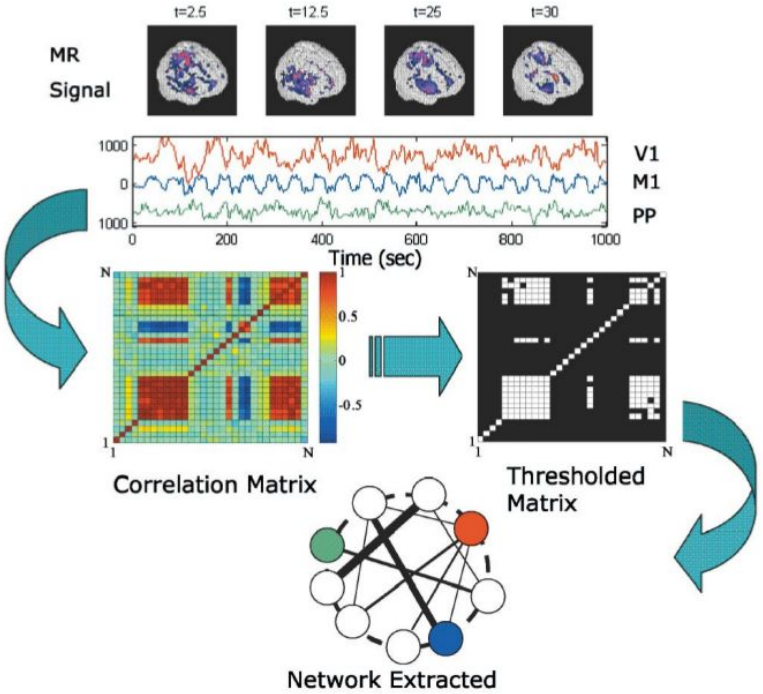
Redes en el cerebro: De small-worlds a Networks-of-Networks

De small-worlds a Networks-of-Networks



Eguiluz, Chialvo, Cecchi, Baliki, & Apkarian (2005). Scale-free brain functional networks. *Phys. Rev. Lett.*

Gallos, Makse, & Sigman (2012). A small world of weak ties provides optimal global integration of self-similar modules in functional brain networks. *PNAS*

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Redes en el cerebro: De Small-Worlds a Networks-of-Networks

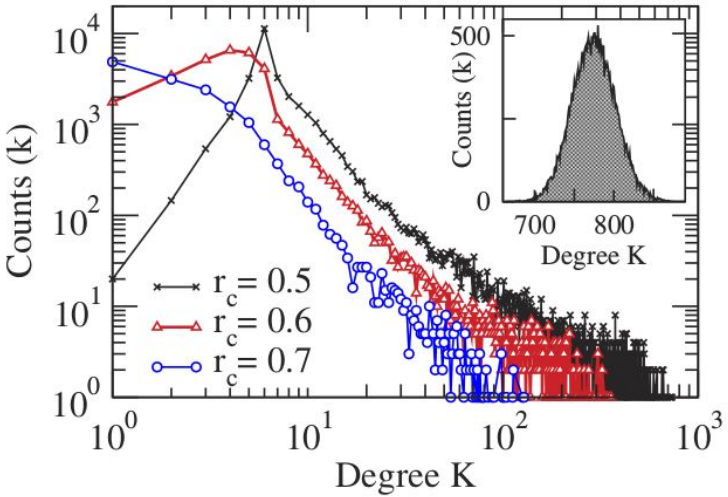

FIG. 2 (color online). Degree distribution for three values of the correlation threshold. The inset depicts the degree distribution for an equivalent randomly connected network.

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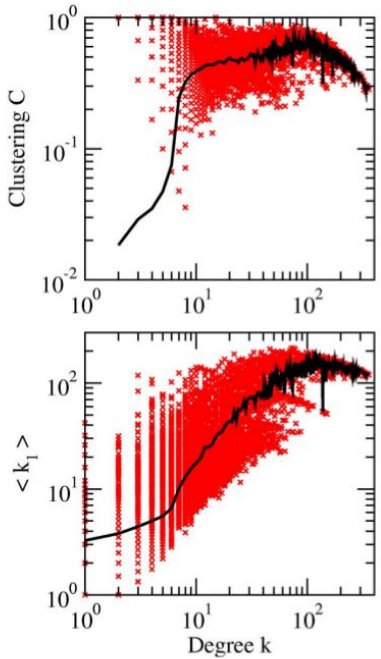

FIG. 5 (color online). Top Panel: Plot of clustering versus degree. Bottom panel: Plot of a neighboring node's degree versus degree illustrates the assortative feature. Symbols represents individual data and continuous lines the average values for nodes with the same degree. (Same subject shown in Fig. 2, with r_c=0.6).

Figure 5 illustrates the dependence of two important features upon a voxel's degree. The first is **clustering**, found in many cases to scale as $C(k) \sim k^{-\alpha}$, an indication of hierarchical organization [13,14]. We see, instead, a relative independence of clustering from degree. The second feature is that a highly connected node tends to connect with other well connected nodes. As shown in the bottom panel of Fig. 5, there is a positive **correlation between the degrees of adjacent vertices**. This correlation, also called assortative mixing, is not typical of biological networks, but rather is distinctive of social networks [15]. [...]

In summary, we report statistical measures showing that the functional correlations of the human brain form a scale-free network with small-world properties and assortative mixing. While some of these properties have been informally discussed, this work is the first quantitative description of these large-scale topological properties, as well as the first report of an assortative biological network.

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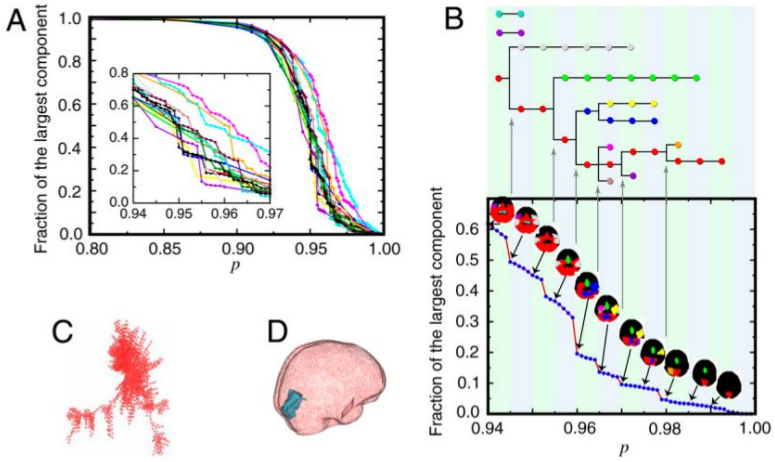
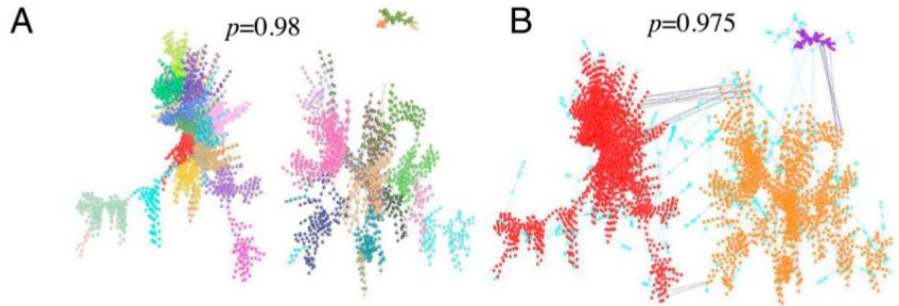


This leads to a basic conundrum of brain networks: Modular processors have to be sufficiently isolated to achieve independent computations, but also globally connected to be integrated in coherent functions (1,2,6). A current view is that small-world networks provide a solution to this puzzle because they combine high local clustering and short path length (7–9). [...]

Although brain networks show small-world properties, several experimental studies have also shown that they are hierarchical, fractal and highly modular (2,3,18). **As there is an intrinsic tension between modular and small-world organization**, the main aim of this study is to reconcile these ubiquitous and seemingly contradictory topological properties. Indeed, traditional models of small-world networks cannot fully capture the coexistence of highly modular structure with broad global integration.



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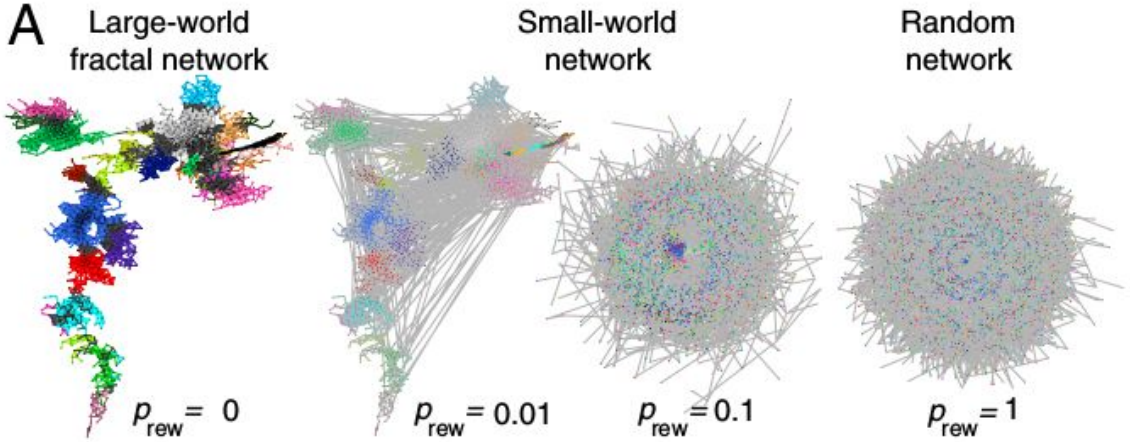

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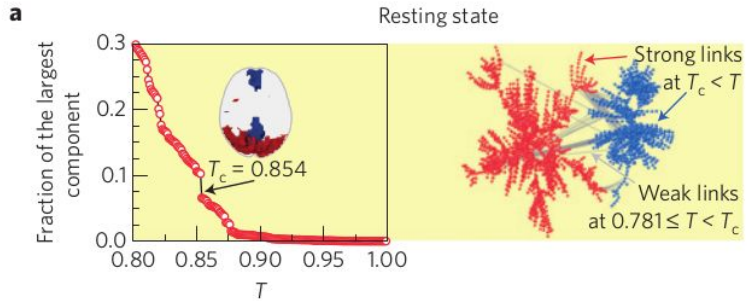

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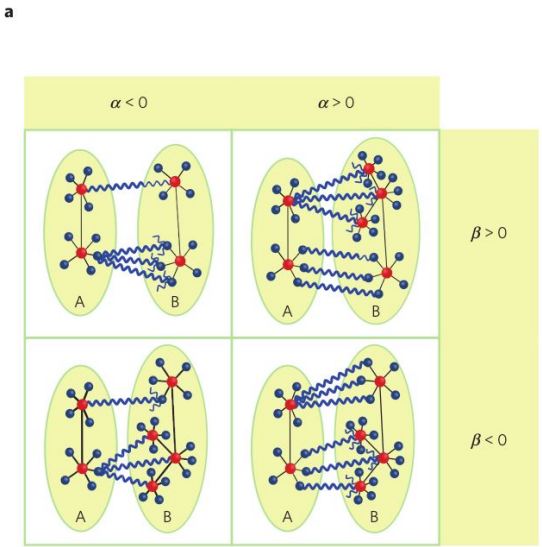

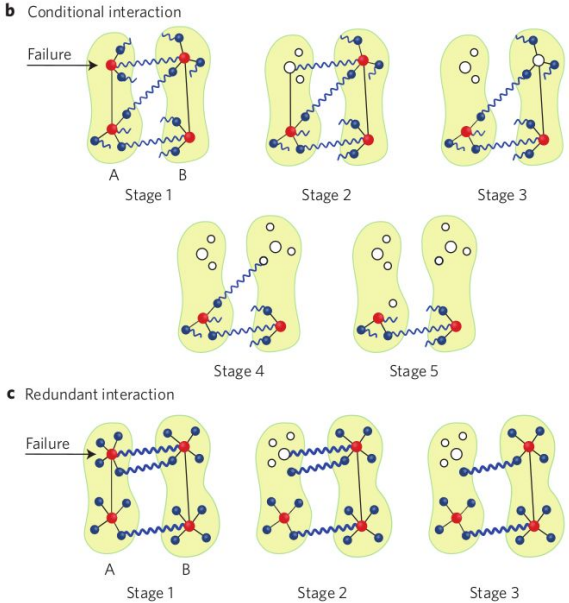

$$k_{entre} \sim k_{int}^{\alpha}$$

$$k_{int}^{nn} \sim k_{int}^{\beta}$$

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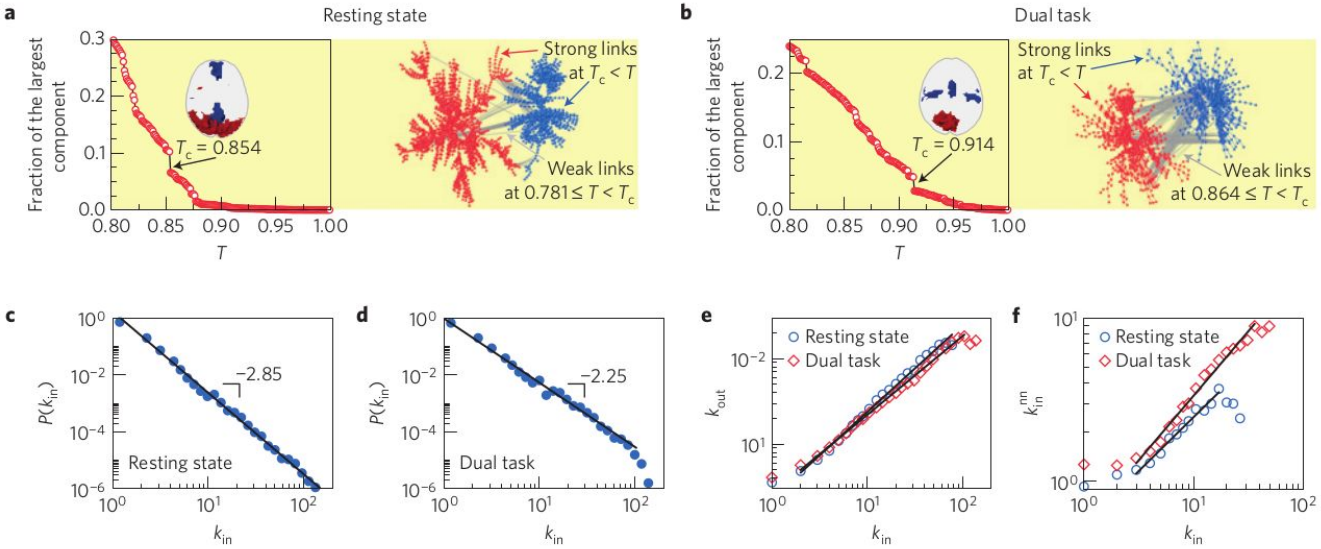

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Desarrollo: Segregación e Integración

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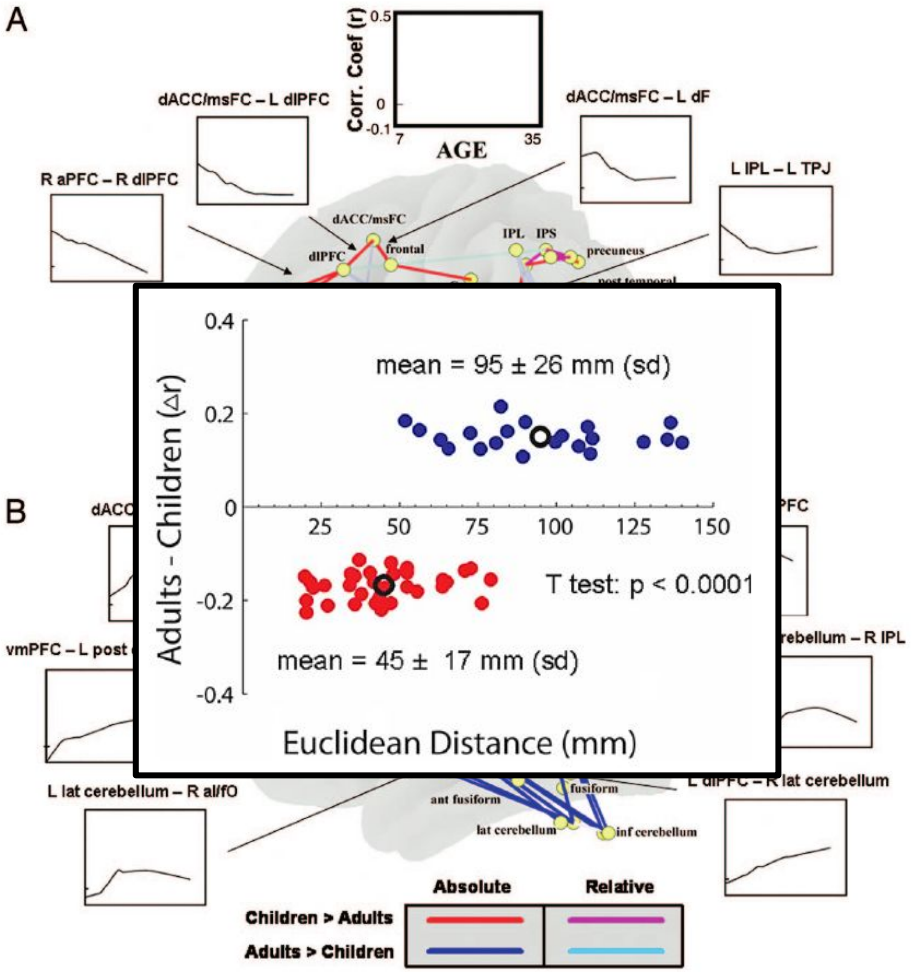


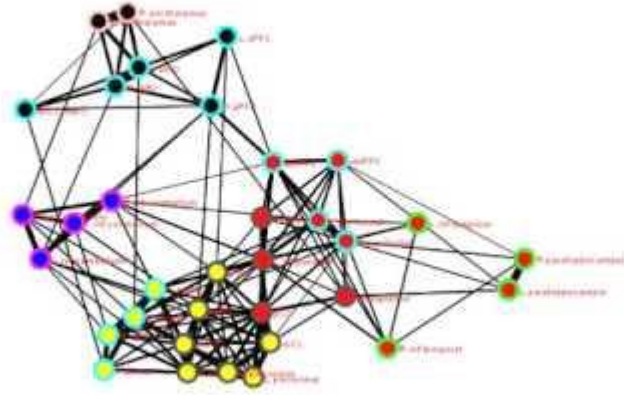
Fair, D. A., Dosenbach, N. U. ... & Schlaggar, B. L. (2007). Development of distinct control networks through segregation and integration. Proceedings of the National Academy of Sciences, 104(33), 13507-13512.

Fair, D. A., Cohen, A. L., ... & Schlaggar, B. L. (2008). The maturing architecture of the brain's default network. Proceedings of the National Academy of Sciences, 105(10), 4028-4032.

Fair, D. A., Cohen, A. L., Power, J. D., Dosenbach, N. U., Church, J. A., Miezin, F. M., ... & Petersen, S. E. (2009). Functional brain networks develop from a “local to distributed” organization. *PLoS comput biol*, *5*(5), e1000381.

Dosenbach, N. U., ... & Schlaggar, B. L. (2010). Prediction of individual brain maturity using fMRI. Science, 329(5997), 1358-1361.

Desarrollo: Segregación e Integración



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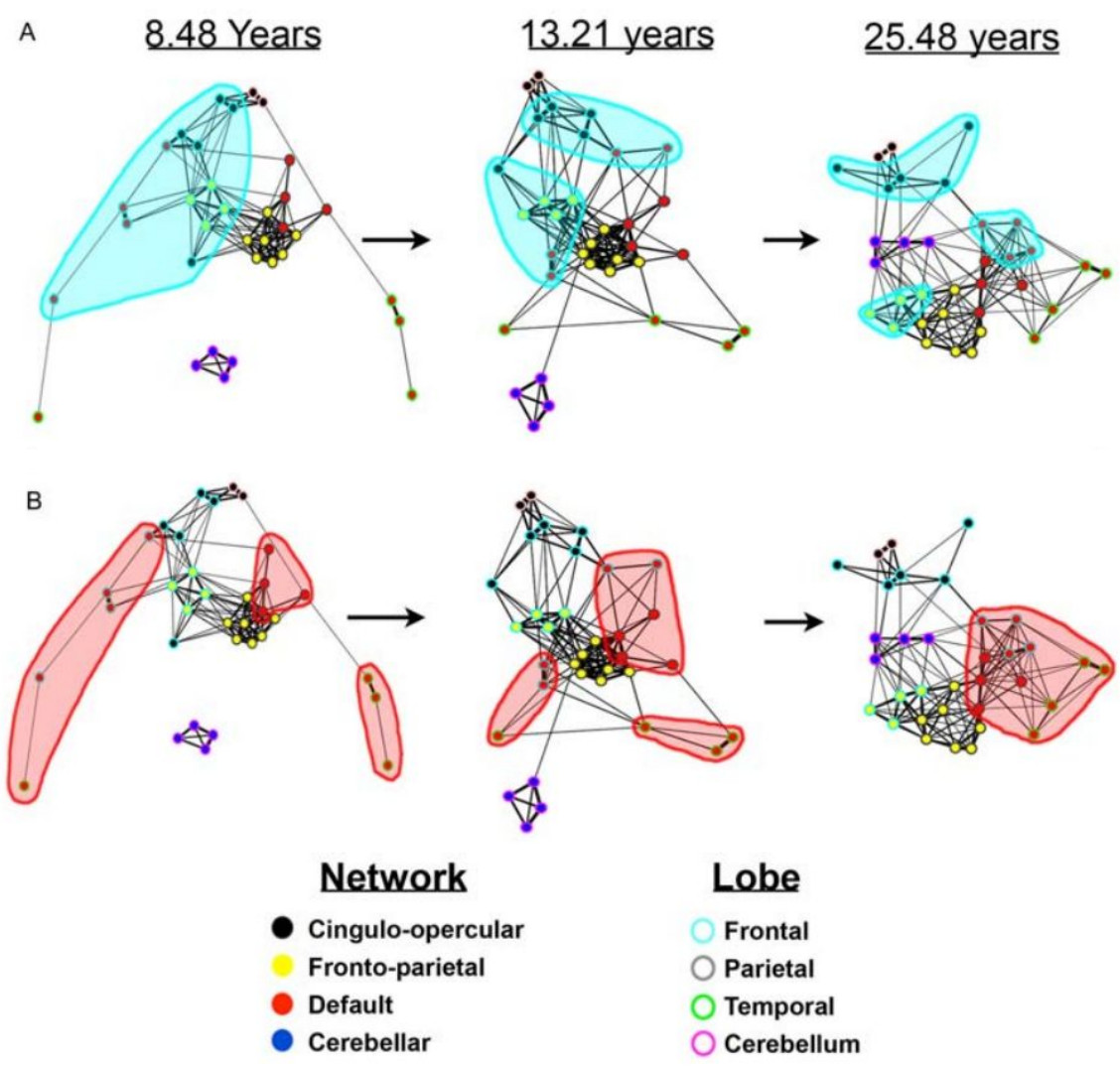

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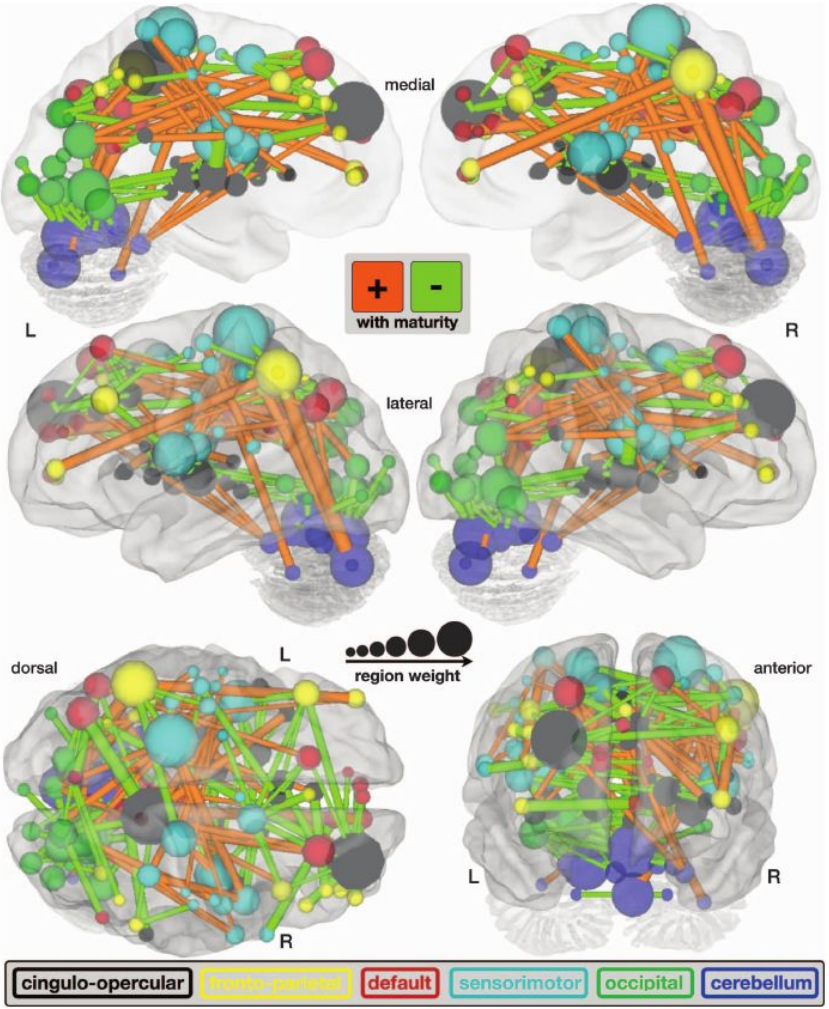

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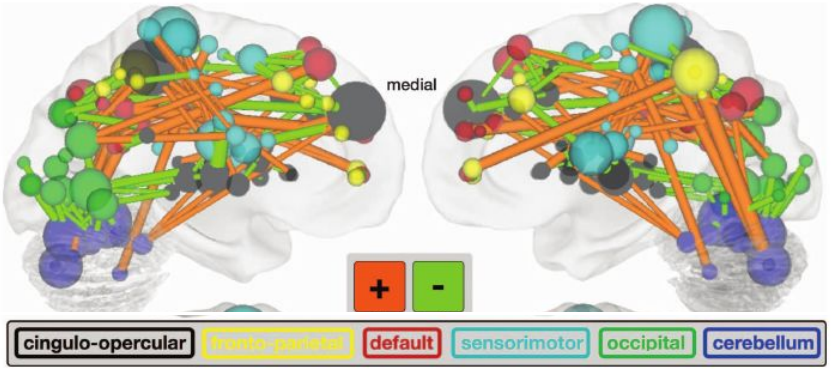
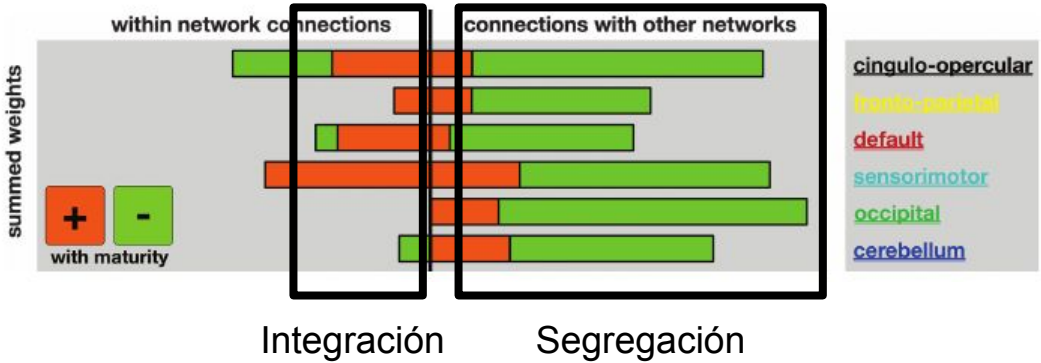
Desarrollo: Segregación e Integración





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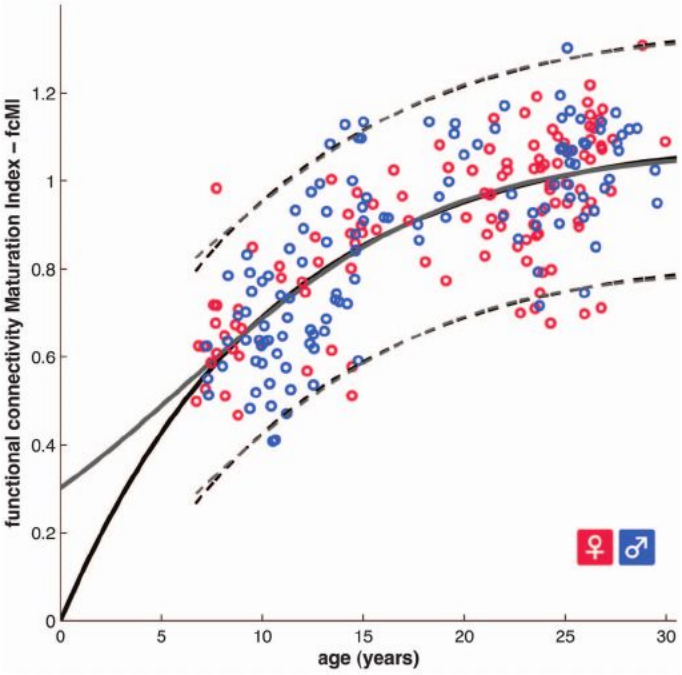
Desarrollo: Segregación e Integración



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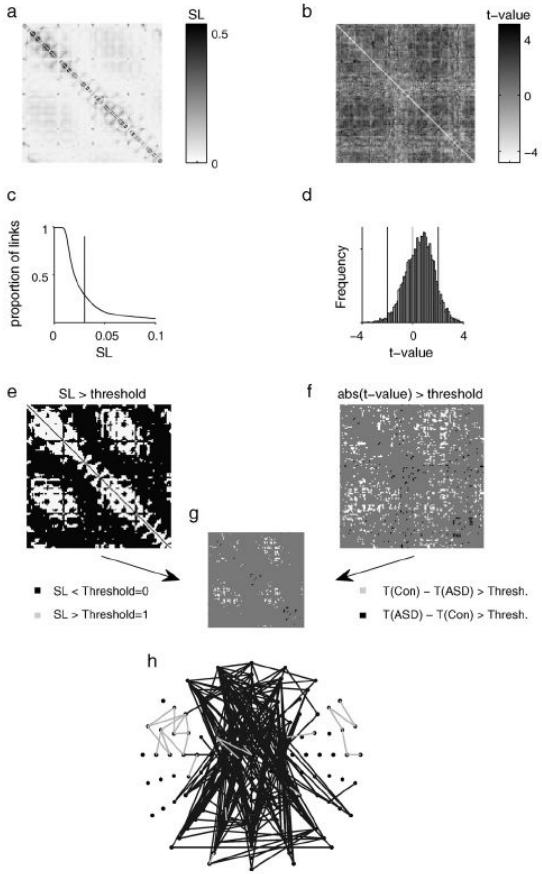
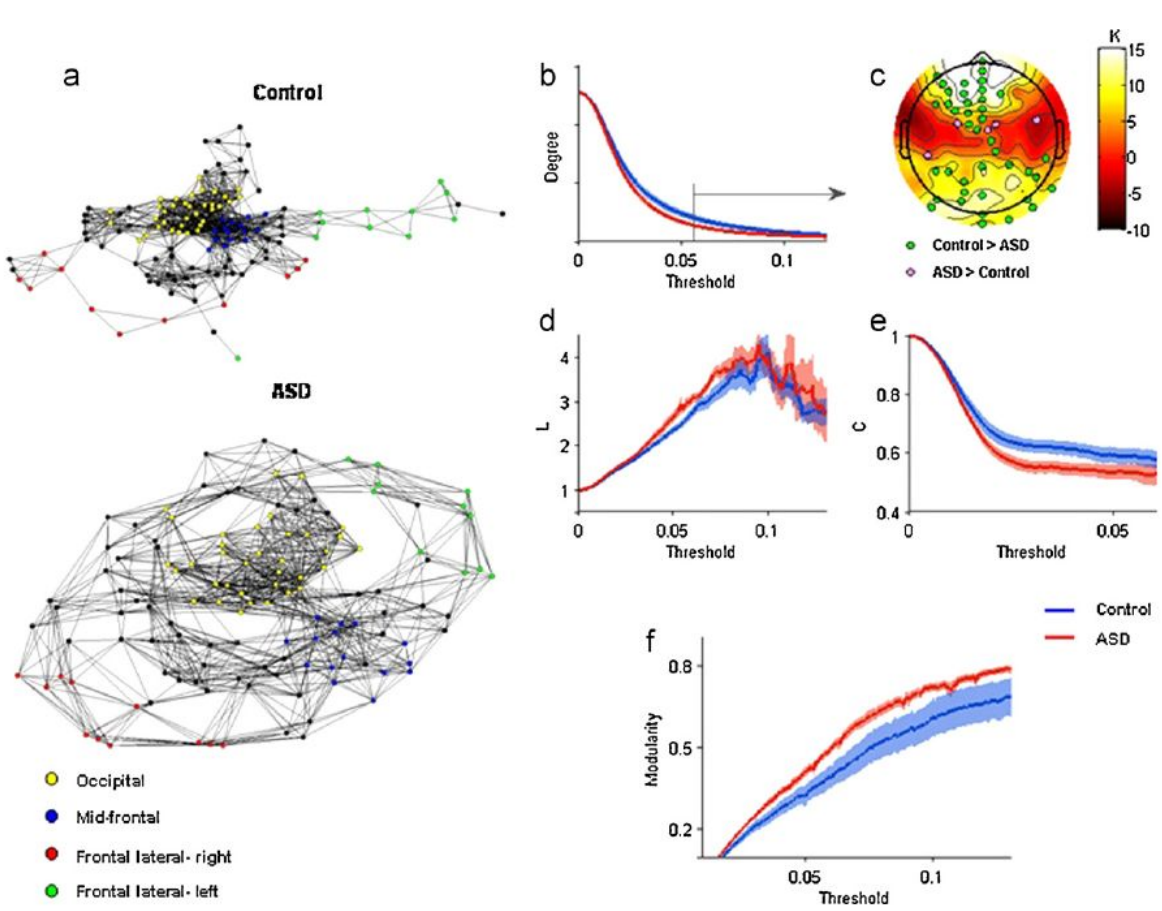
Autismo

Autismo



Barttfeld, P., Wicker, B., Cukier, S., Navarta, S., Lew, S., & Sigman, M. (2011). A big-world network in ASD: dynamical connectivity analysis reflects a deficit in long-range connections and an excess of short-range connections. Neuropsychologia

Autismo



Clustering coefficient:

$$C_i = \frac{2N_i}{k_i(k_i-1)}$$

Ni = Número de aristas entre vecinos

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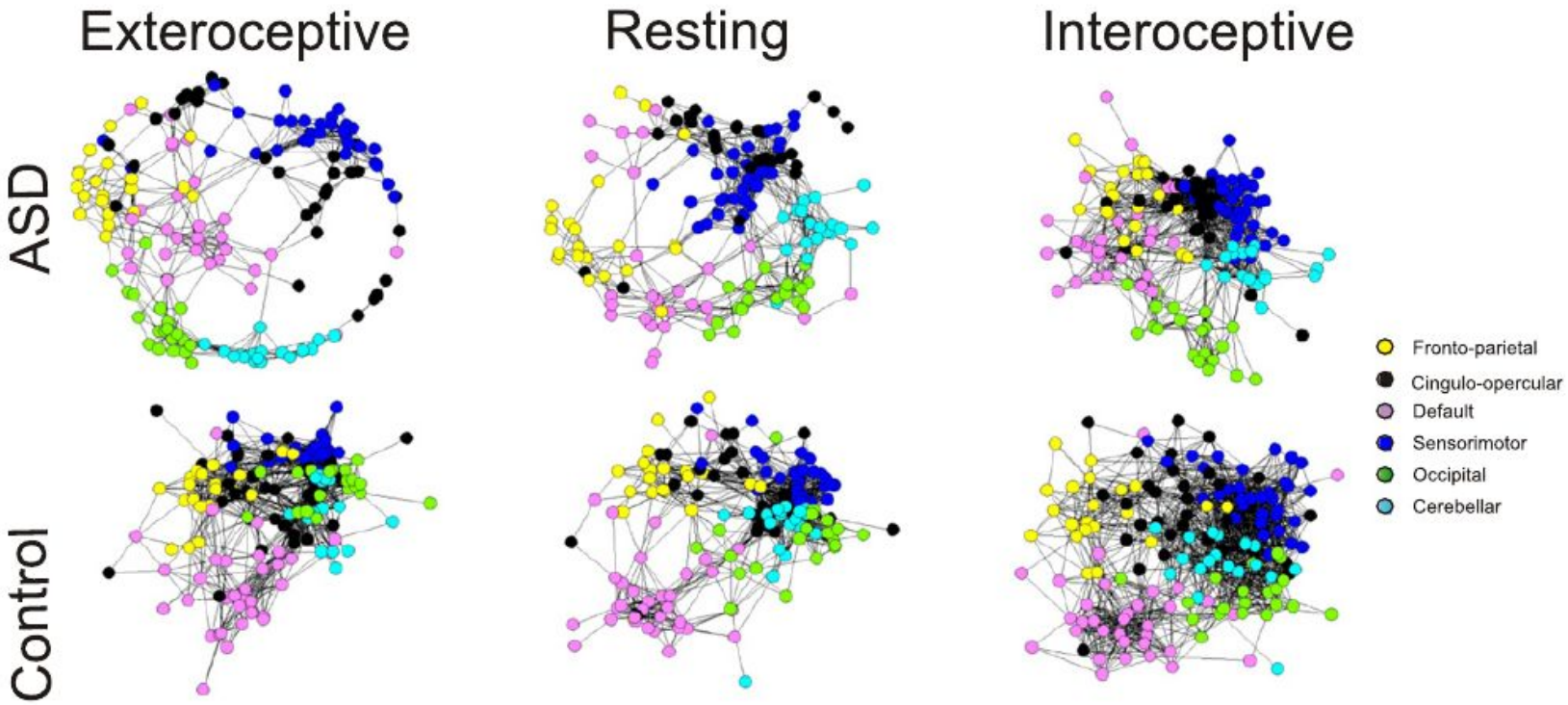
Autismo



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Estados de conciencia: Sueño

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Contents lists available at SciVerse ScienceDirect

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Large-scale brain functional modularity is reflected in slow electroencephalographic rhythms across the human non-rapid eye movement sleep cycle

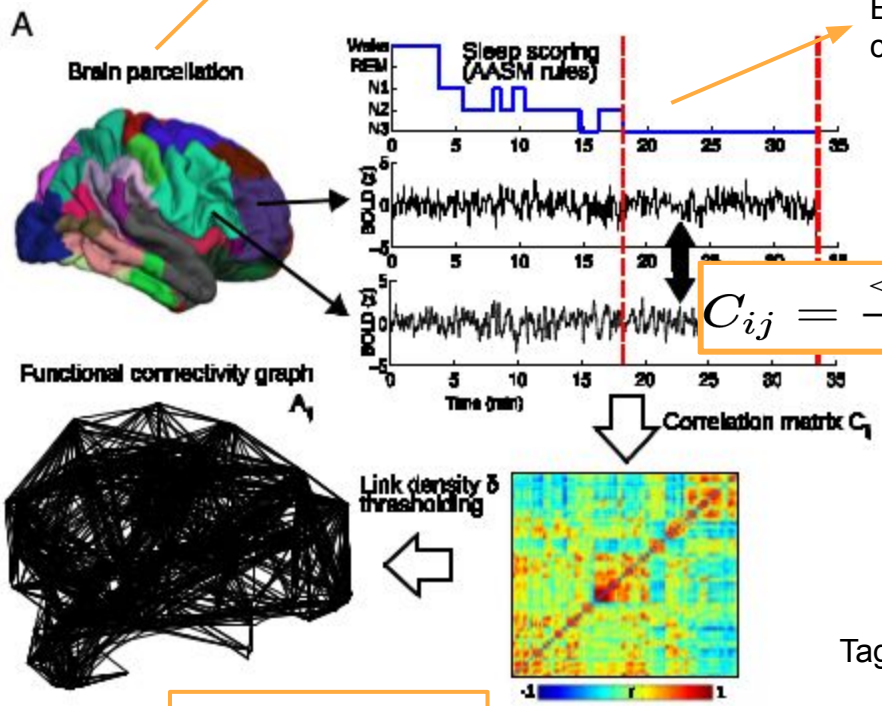
Enzo Tagliazucchi *, Frederic von Wegner, Astrid Morzelewski, Verena Brodbeck, Sergey Borisov, Kolja Jahnke, Helmut Laufs

Department of Neurology and Brain Imaging Center, Goethe University Frankfurt am Main, Schleusenweg 2-16, 60528 Frankfurt am Main, Germany

Sueño

116 regiones definidas a partir del atlas Automatic Anatomical Labeling (AAL) (Tzourio-Mazoyer et al., 2002).

Etapas del sueño definidas manualmente por un experto según el criterio de la American Academy of Sleep Medicine (AASM, 2007).

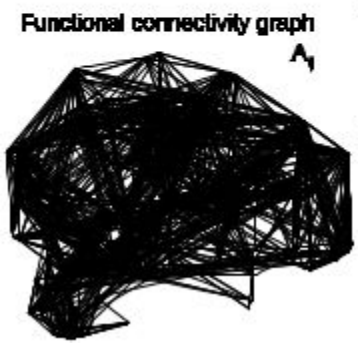


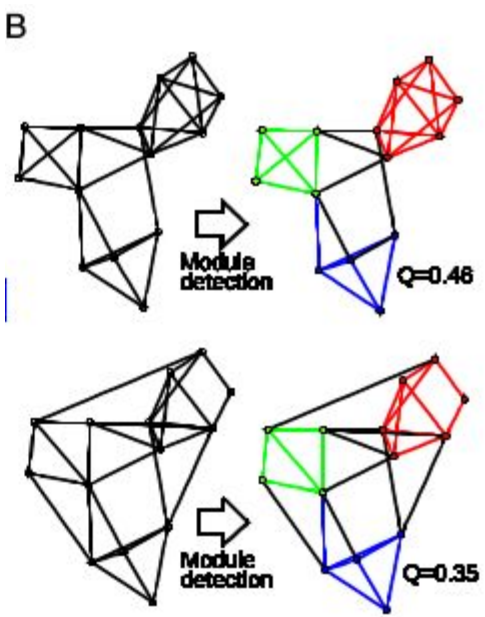
$$C_{ij} = \frac{<(X_i(t)-\mu_i)(X_j(t)-\mu_j)>}{\sigma_i \sigma_i}$$

$$A_{ij} = 1, \; if \; C_{ij} > \rho$$

Tagliazucchi, E., Von Wegner, F., Morzelewski, A., Brodbeck, V., Borisov, S., Jahnke, K., & Laufs, H. (2013). Large-scale brain functional modularity is reflected in slow electroencephalographic rhythms across the human non-rapid eye movement sleep cycle. Neuroimage

Sueño





Definir módulos / comunidades:

- Objetivo: Maximizar Q
- Heurística para la búsqueda óptima: Algoritmo de Louvain (Blondel et al., 2008).
- Una fase del algoritmo es estocástica ⇒ Repiten la búsqueda 1000 veces, y se quedan con el que tiene Q máximo.

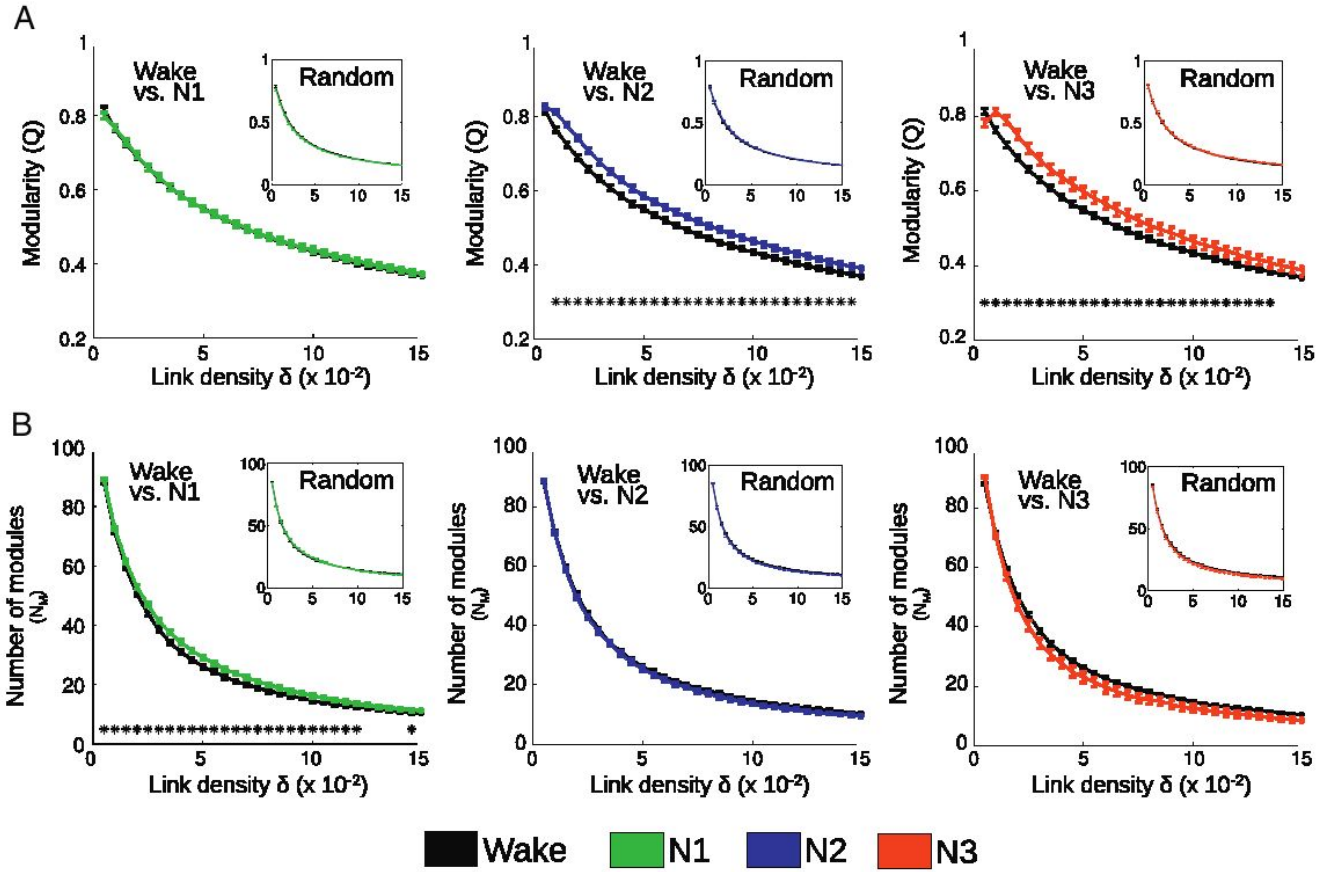
$$Q = \frac{1}{2L} \sum_{ij} \delta(i,j)[A_{ij} - \frac{k_i k_j}{2L}]$$

http://igraph.org/r/doc/cluster_louvain.html

https://perso.uclouvain.be/vincent.blondel/research/louvain.html

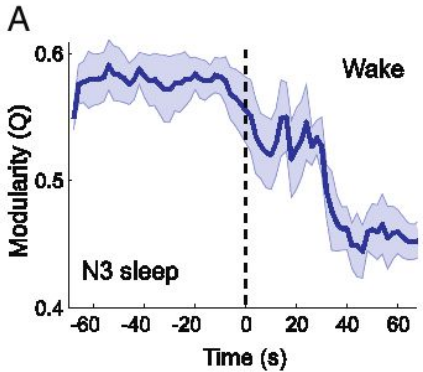
https://arxiv.org/abs/0803.0476

Sueño: Modularidad

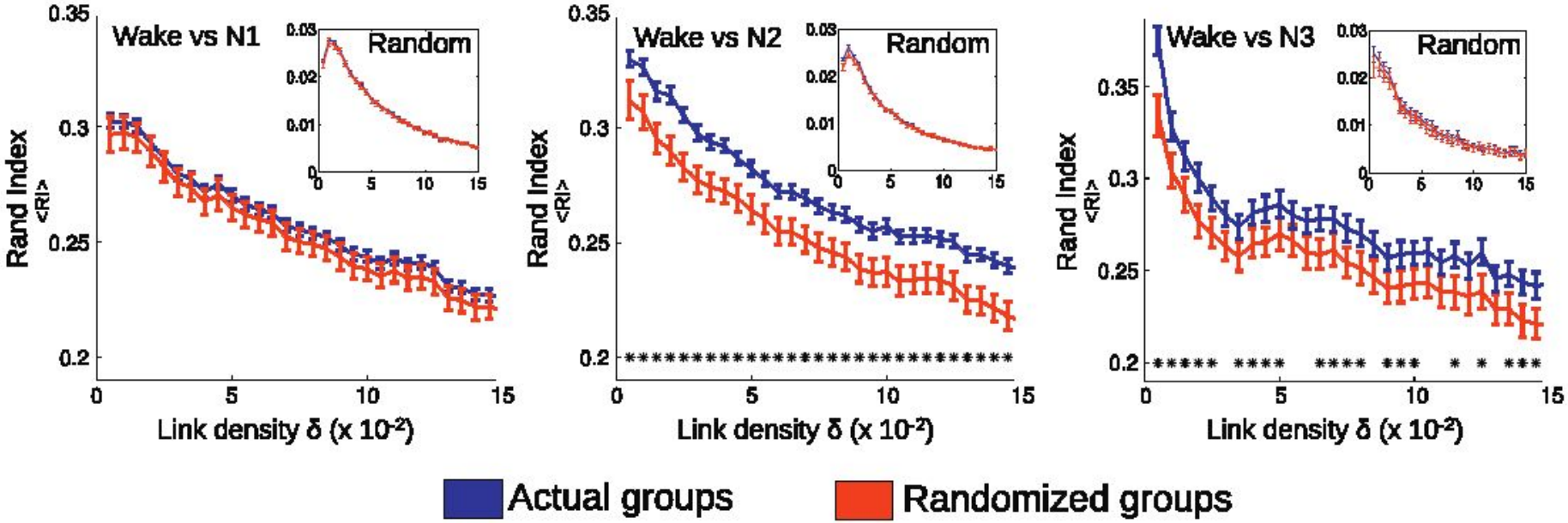


Modularidad

módulos



Sueño


Wake vs N1
Random
Rand Index
<RI>
Link density δ (x 10-2)
Wake vs N2
Random
Rand Index
<RI>
Link density δ (x 10-2)
Wake vs N3
Random
Rand Index
<RI>
Link density δ (x 10-2)
Actual groups
Randomized groups

Sueño: Roles de los nodos

Intra-modular degree:

$$z_i = \frac{k_i - <k>}{\sigma_k}$$

ki: Grado intra-módulo
<k>, σ: Promedio y desvío de los grados intra-módulo

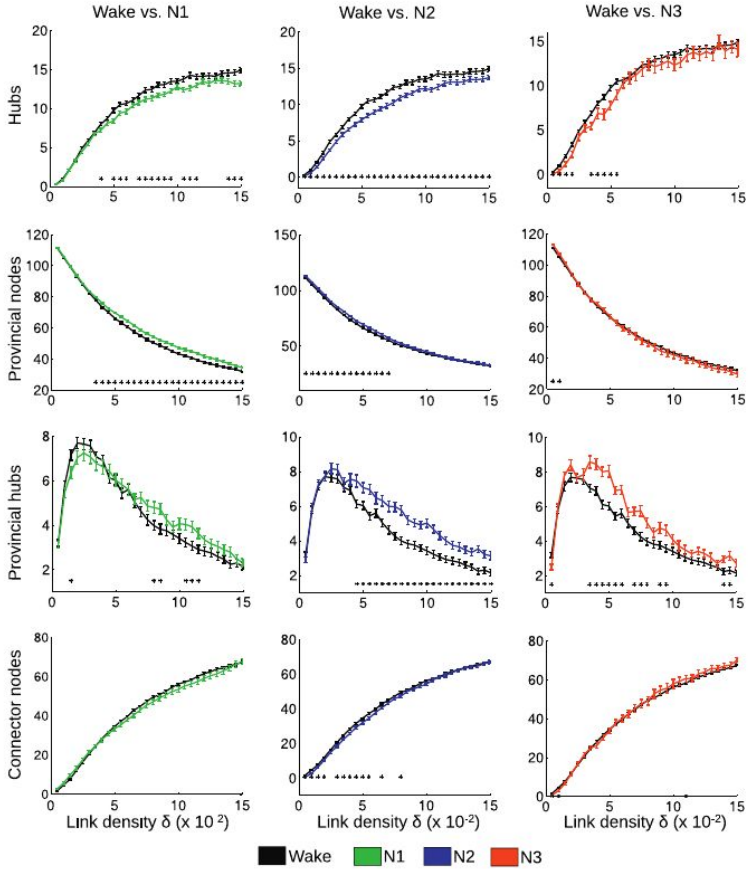
Participation coefficient:

$$P_i = \sum_{j}^{N_M} \left(\frac{k_i^{U_j}}{k_i} \right)^2$$

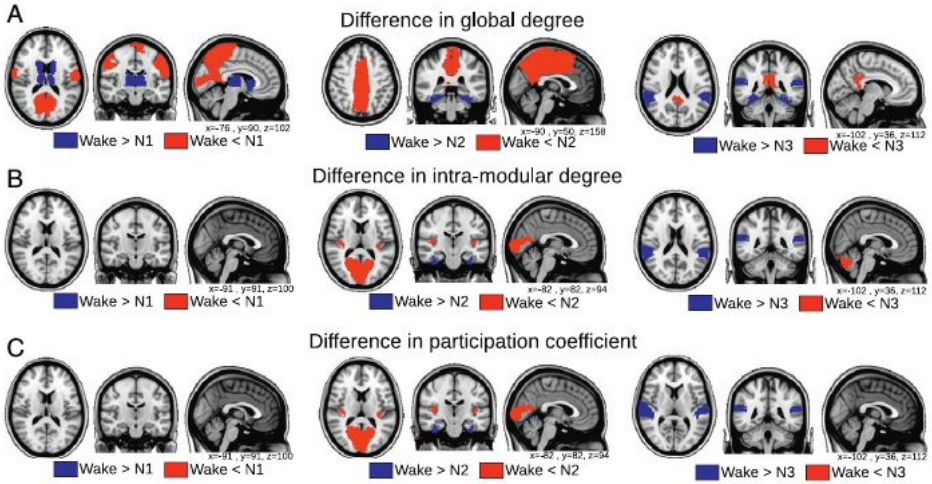
k_i: Grado global
k_i^{Uj}: Número de aristas de i al módulo j

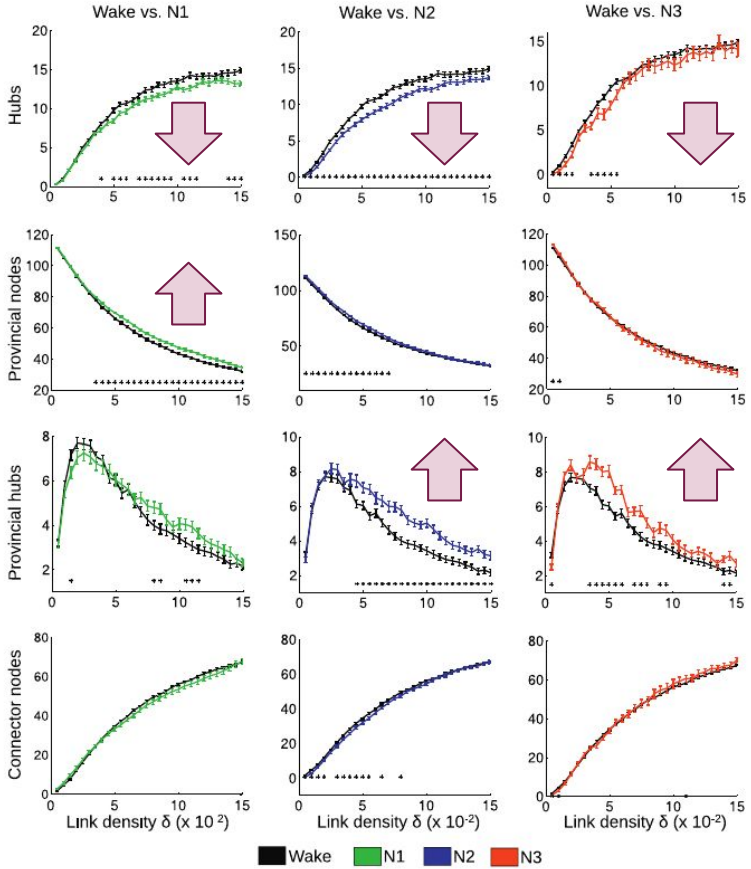
Hubs:	$\uparrow z_i , \uparrow P_i$
Provincial Hubs:	$\uparrow z_i , \downarrow P_i$
Provincial Nodes:	$\downarrow z_i , \downarrow P_i$
Connector Nodes:	$\downarrow z_i , \uparrow P_i$

($z_C = 1$, $P_C = 0.05$)

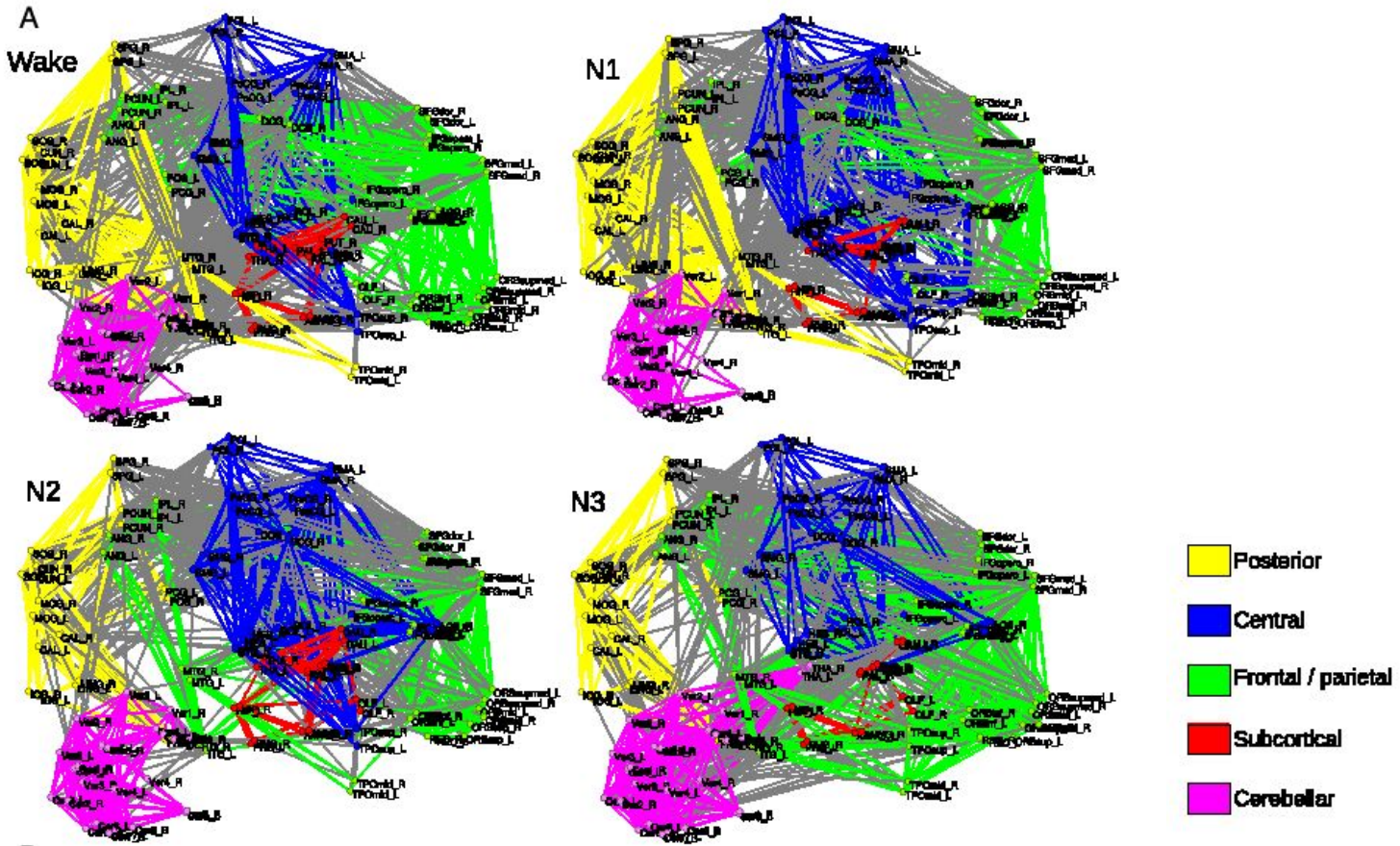


Sueño: Roles de los nodos

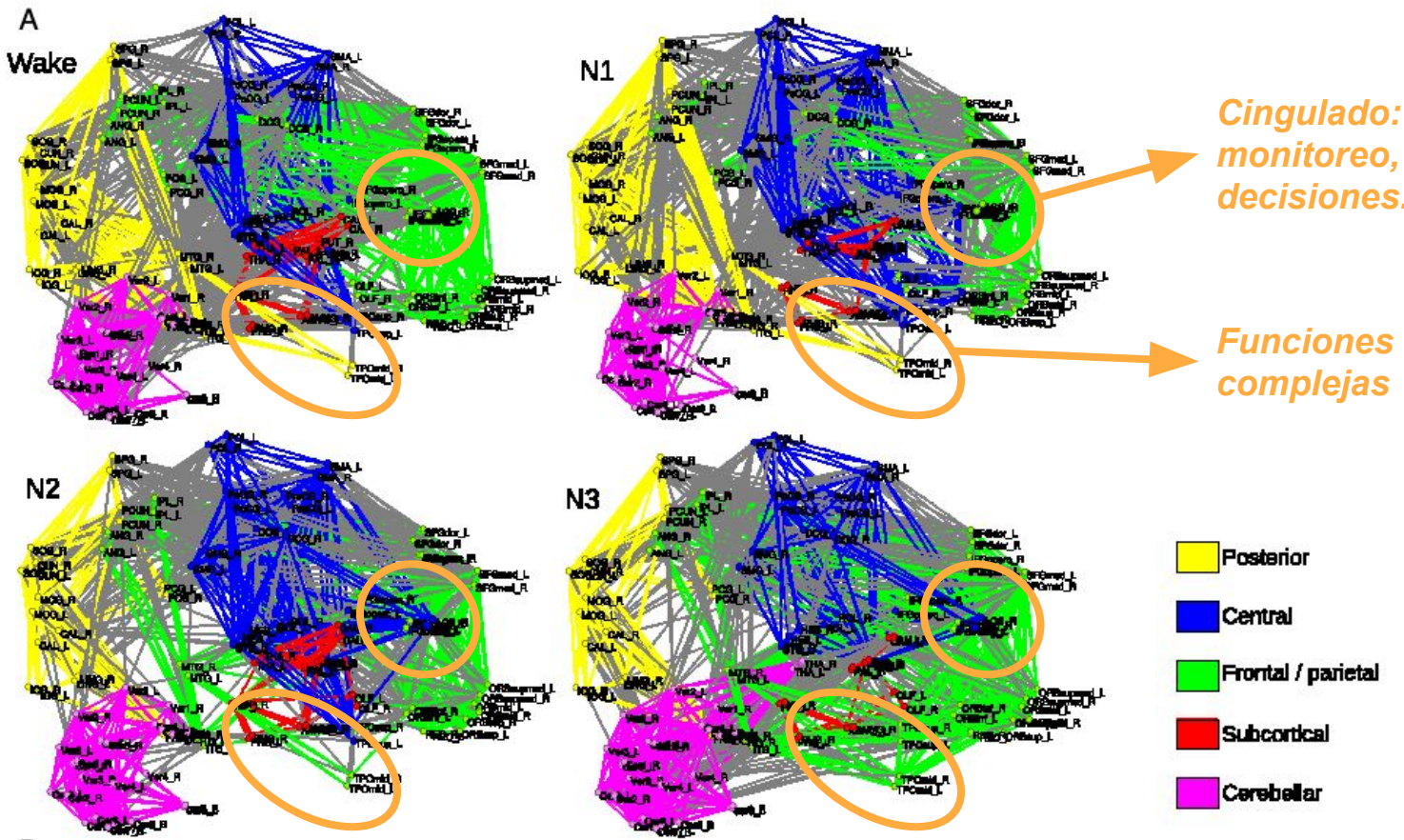




Sueño: Redes

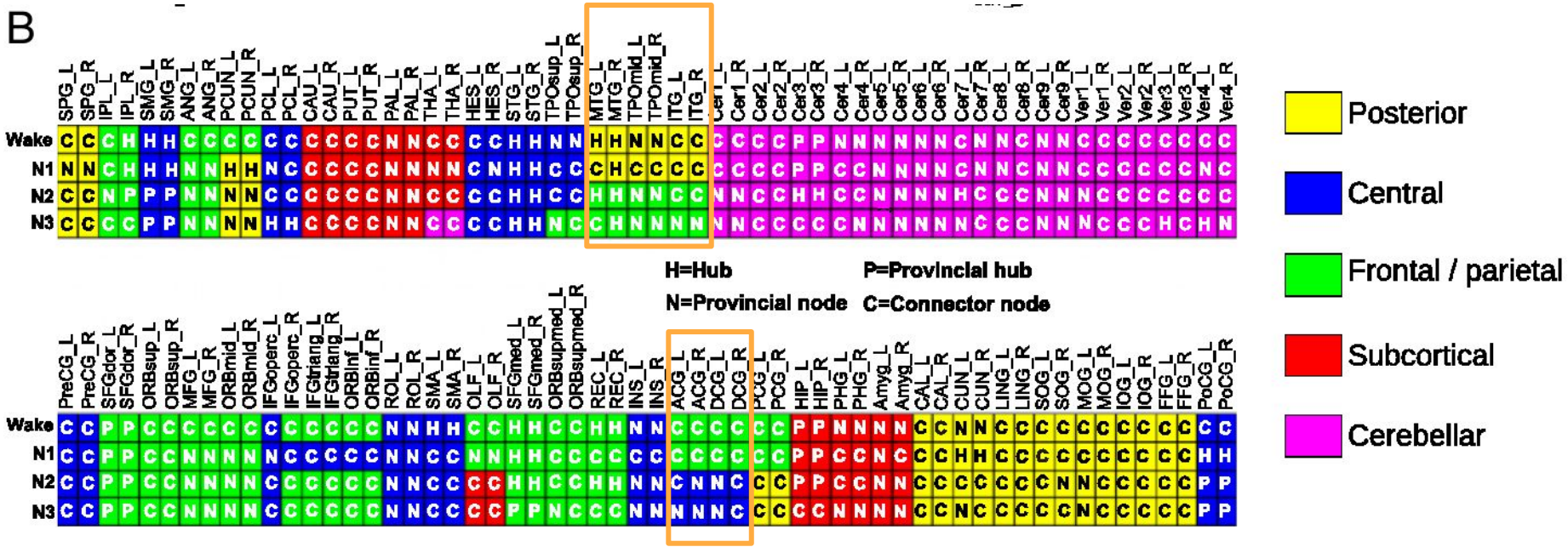

A
Wake
N1
N2
N3
Posterior
Central
Frontal / parietal
Subcortical
Cerebellar

Sueño: Redes


A
Wake
N1
N2
N3
Cingulado: Control, monitoreo, toma de decisiones...
Funciones visuales complejas
Posterior
Central
Frontal / parietal
Subcortical
Cerebellar

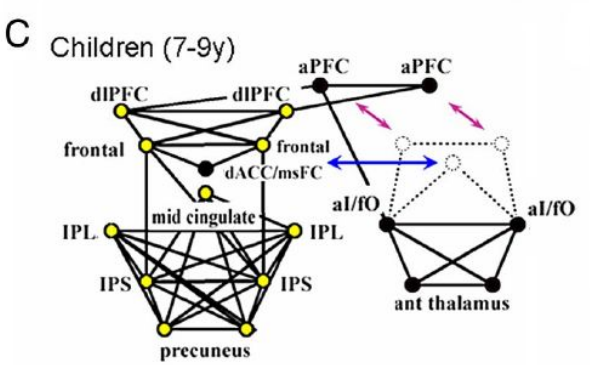
EXTRA

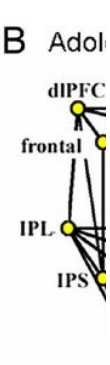
Funciones visuales complejas

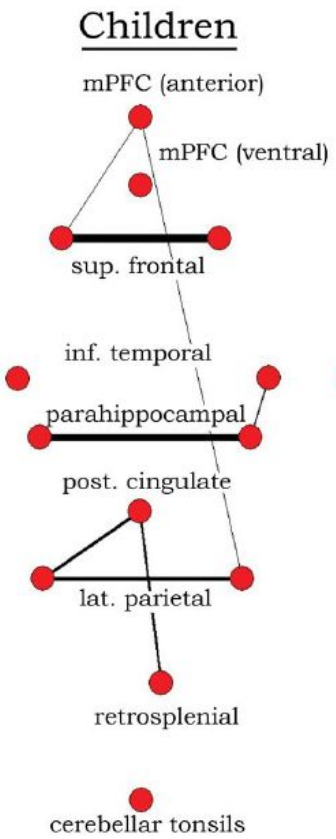


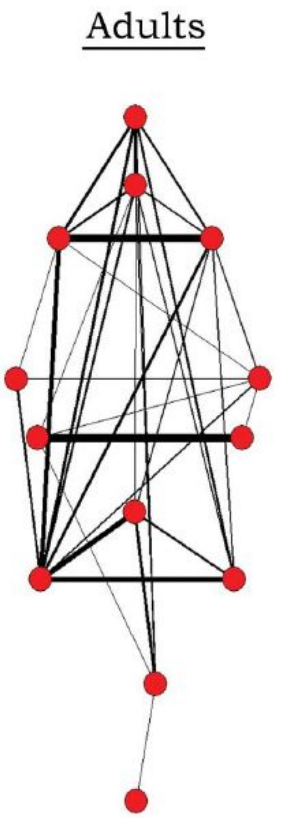
Cingulado: Control, monitoreo, toma de decisiones...

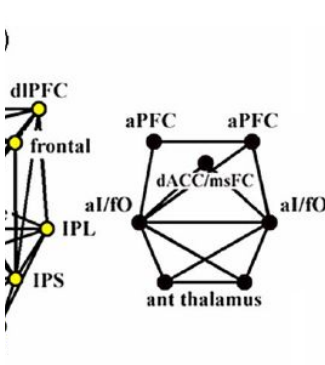
Redes: Segregación e Integración











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