

# Neurociencia cognitiva

2do cuatrimestre 2024

Práctica 3: fMRI

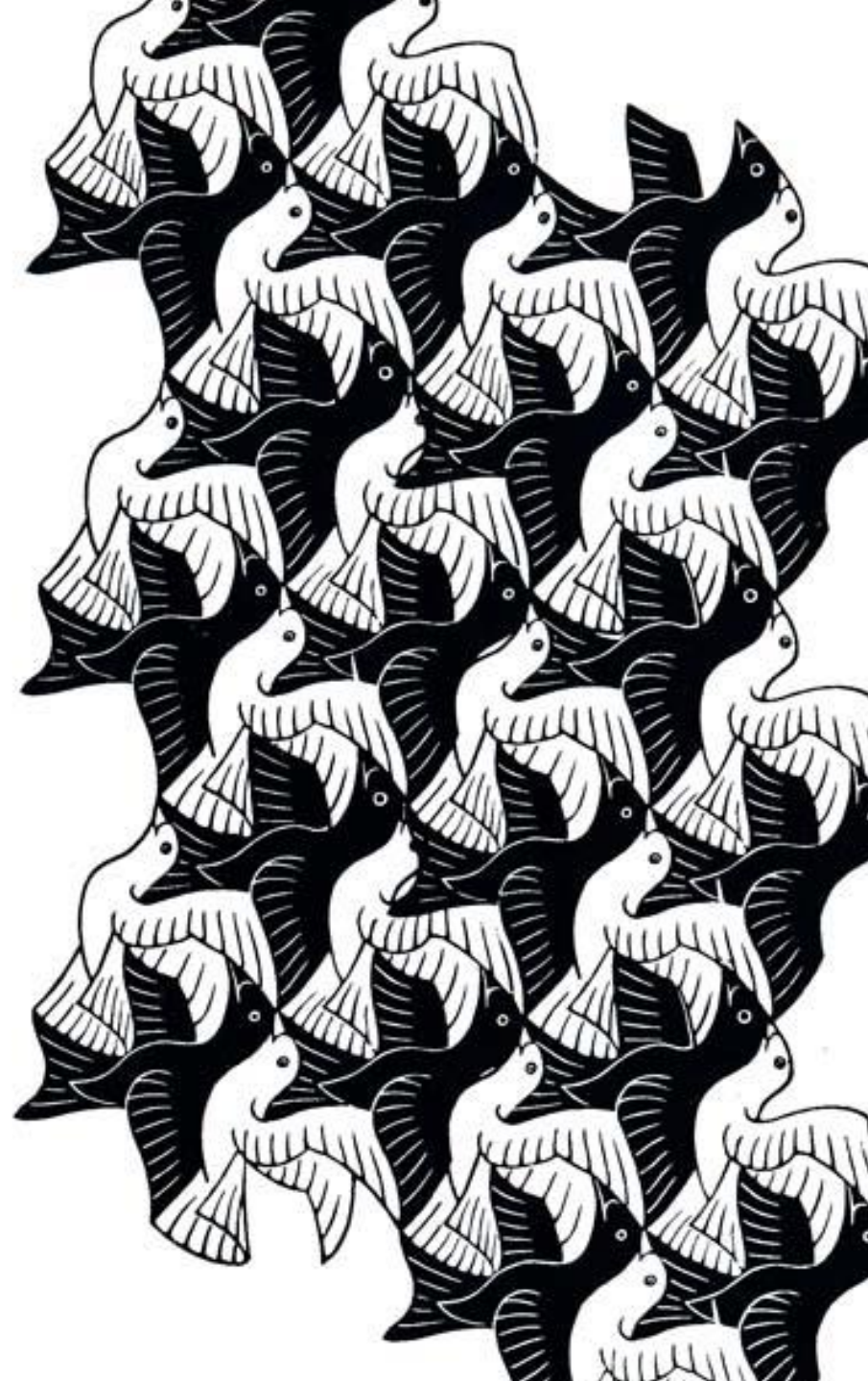
<http://materias.df.uba.ar/nca2024c2/>

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Enzo Tagliazucchi

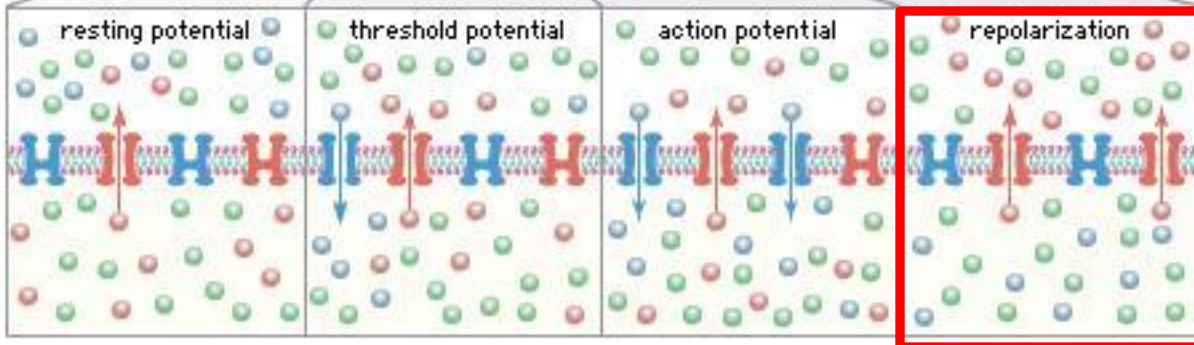
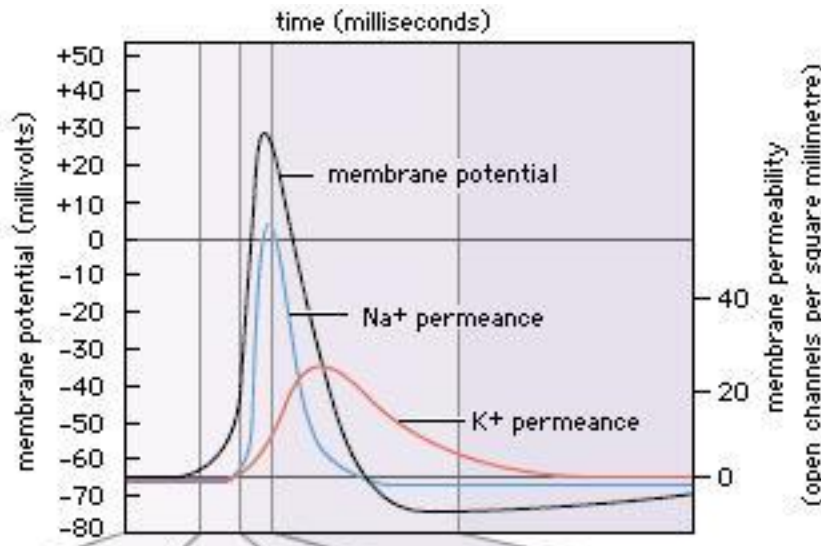
[tagliazucchi.enzo@gmail.com](mailto:tagliazucchi.enzo@gmail.com)



**Primera parte:**

Introducción a fMRI

# Generación del potencial de acción

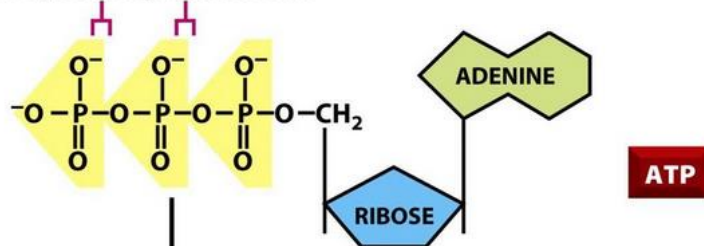


1. El interior de la célula tiene más carga negativa que el exterior
2. Los neurotransmisores abren canales de Na<sup>+</sup> que ingresan a la célula llevando la diferencia de potencial más cerca de 0.
3. Se da origen a un proceso exponencial (*depolarización*, inicio del potencial de acción).
4. La apertura de canales de K<sup>+</sup> vuelve a disminuir la carga negativa dentro de la célula.
5. La acción de “bombas” de Na<sup>+</sup> y K<sup>+</sup> reestablece el equilibrio.

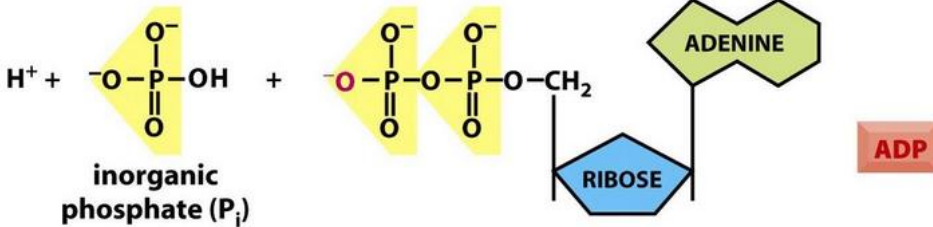
**Consumo de energía (ATP)**  
**3 Na<sup>+</sup> por 2 K<sup>+</sup> = 1 ATP**

# Cómo se suministra esa energía?

phosphoanhydride bonds



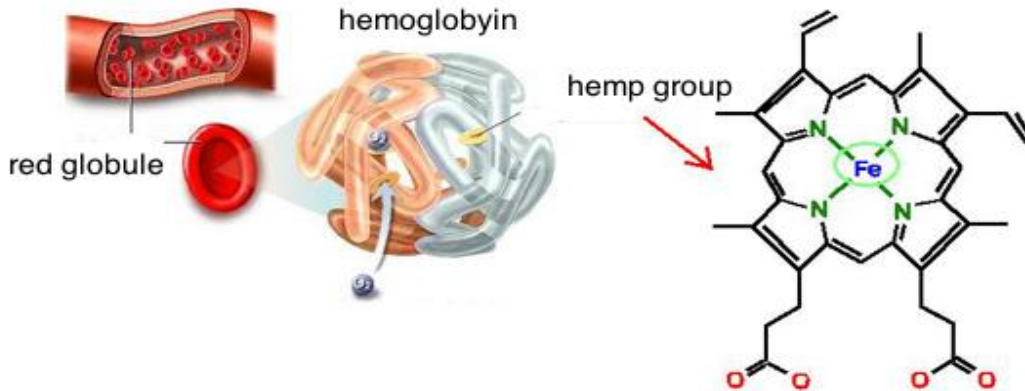
H<sub>2</sub>O



**Hidrólisis del adenosín trifosfato (ATP)**

(Approx. 30 KJ/mol)

**Requiere oxígeno**



**Hemoglobina oxigenada:**

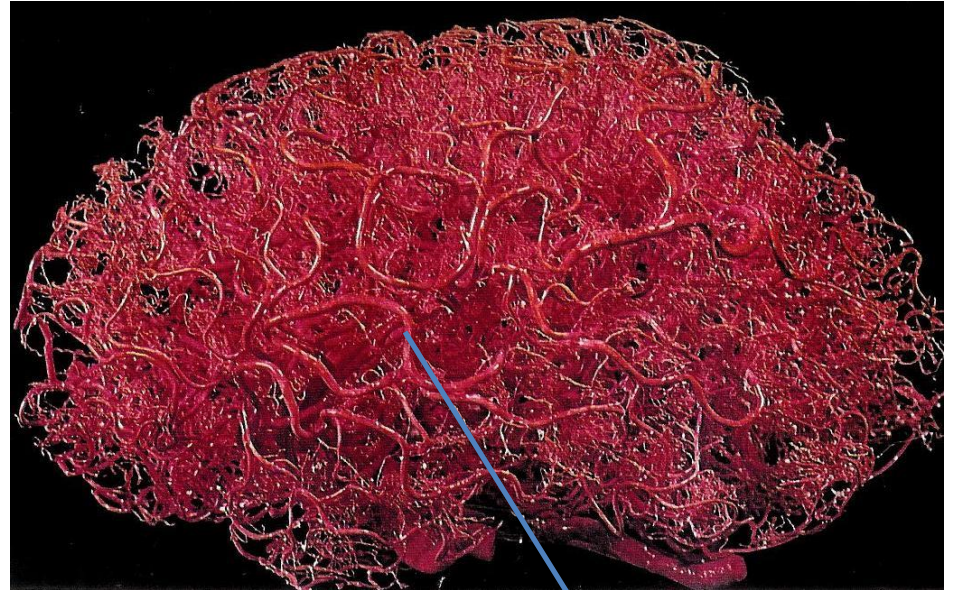
*diamagnética* (repelida por campos magnéticos).

**Hemoglobina no-oxigenada:**

*paramagnética* (atraída por campos magnéticos).

# Hipótesis:

- ↗ Actividad neuronal
- ↗ Requerimiento energético
- ↗ Hidrólisis de ATP
- ↗ Requerimiento de oxígeno
- ↗ Glóbulos rojos (hemoglobina)
- ↗ Flujo sanguíneo

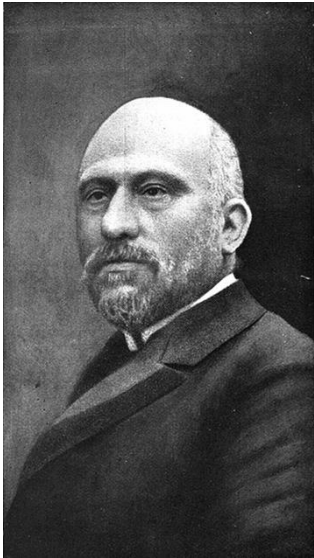


Si medimos el flujo de sangre puede indicarnos la actividad neuronal en esa zona del cerebro.

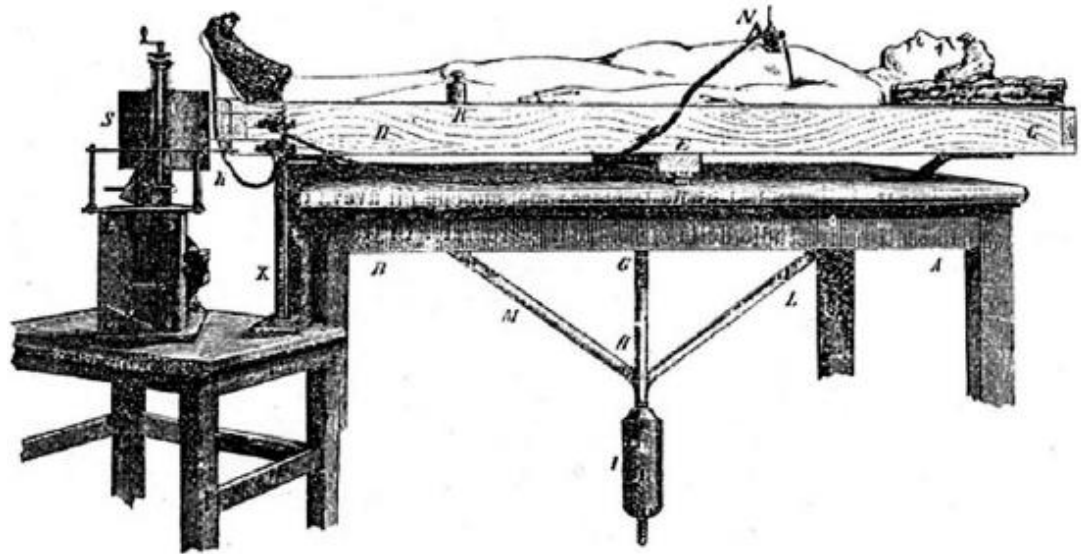
*Alta resolución espacial*

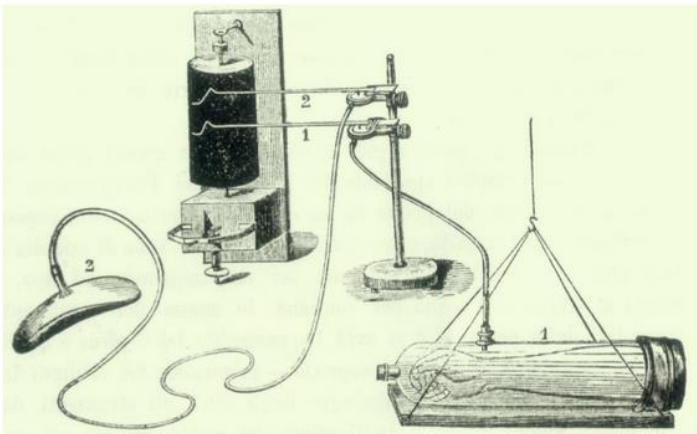
*Baja resolución temporal*

# ¿Es posible “pesar el pensamiento”?

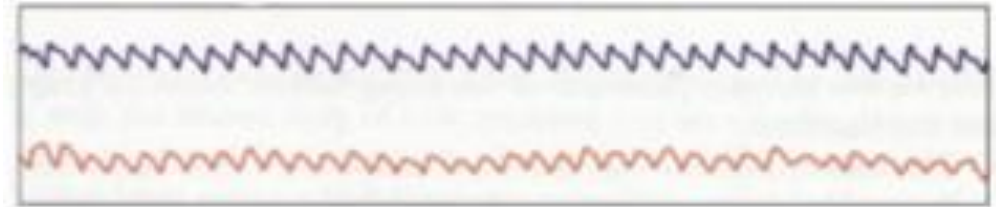


Angelo Mosso  
(1846 – 1910)

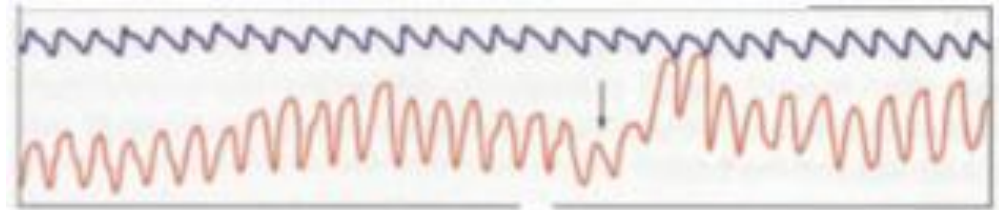




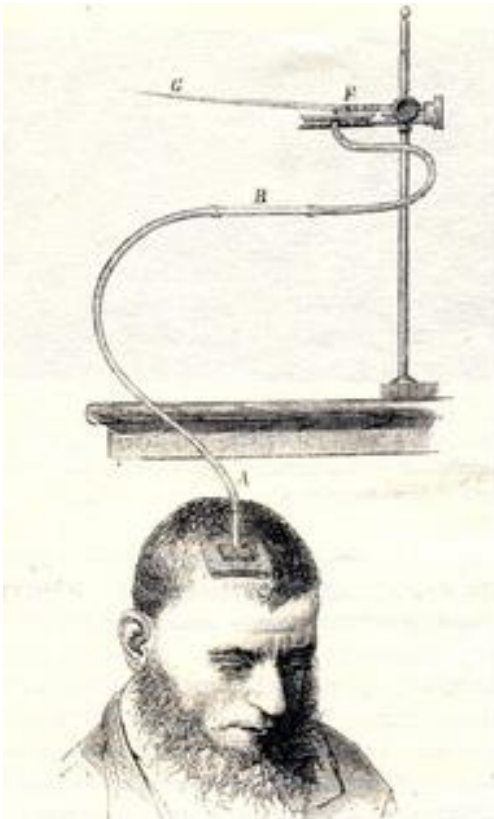
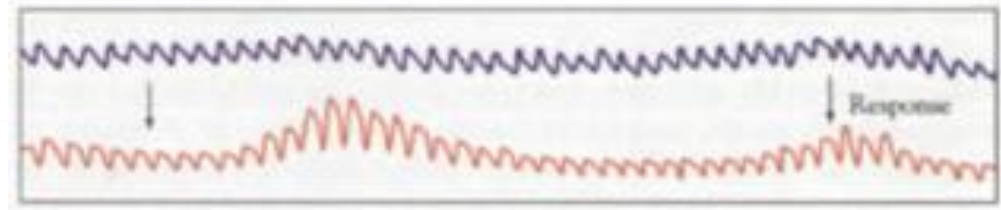
Descanso



Campanas de la iglesia



Aritmética mental (8 x 12?)



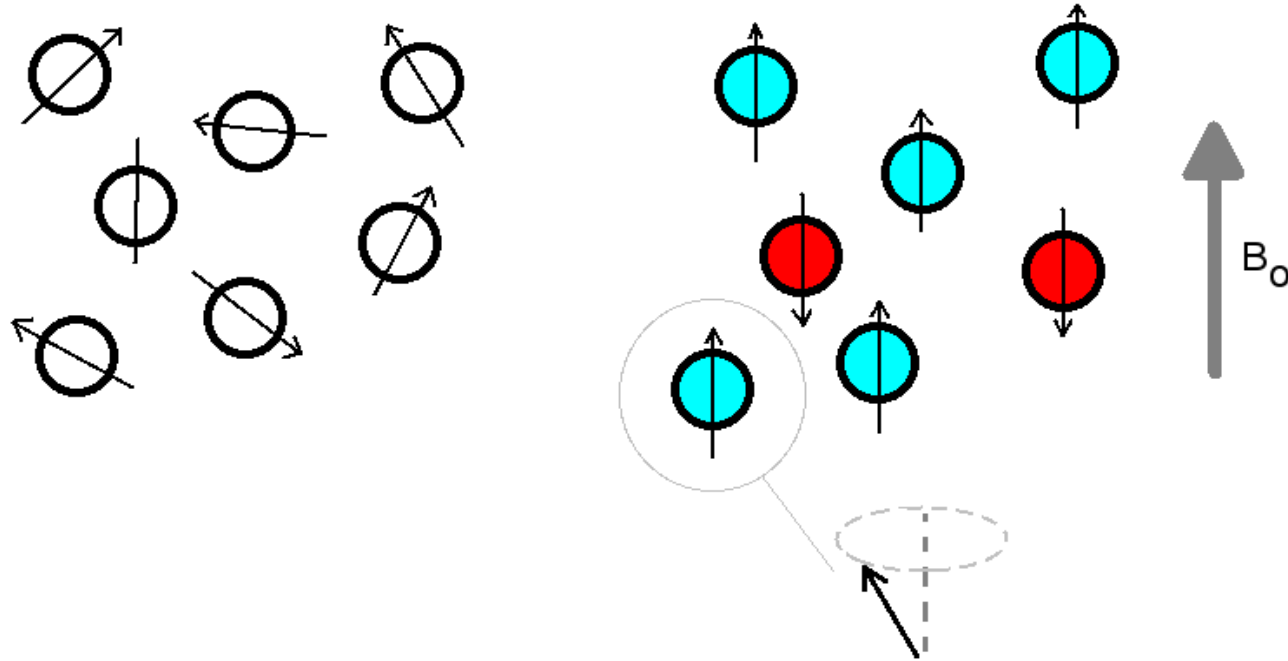
**La conclusión de Mosso: la estimulación sensorial y la actividad cognitiva cambian el flujo sanguíneo en el cerebro**

# 100 años en el futuro





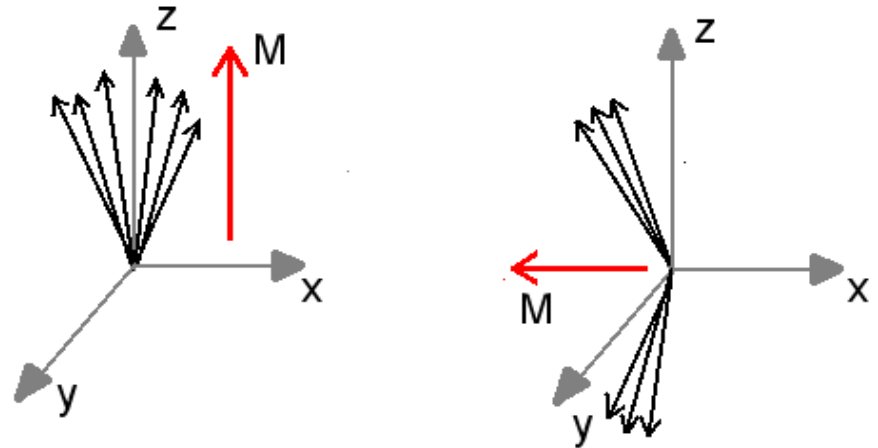
# Introducción a la física de la resonancia nuclear



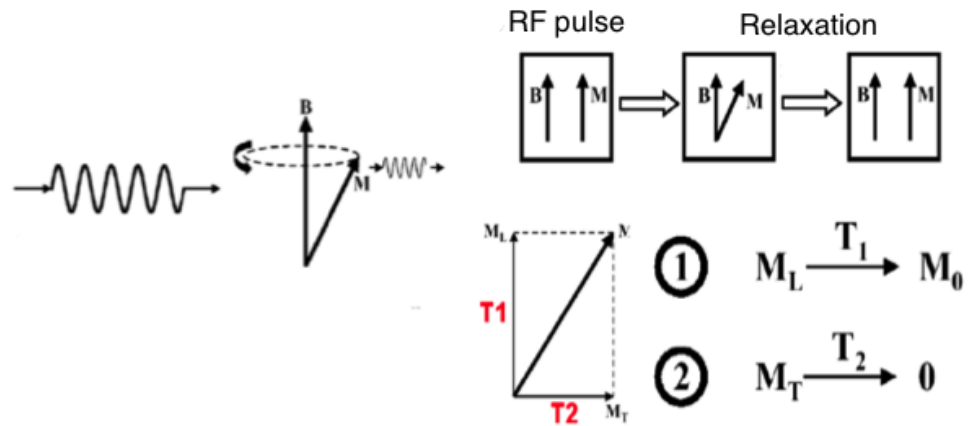
Los protones son pequeños imanes que se alinean con un campo magnético externo y “preceden”

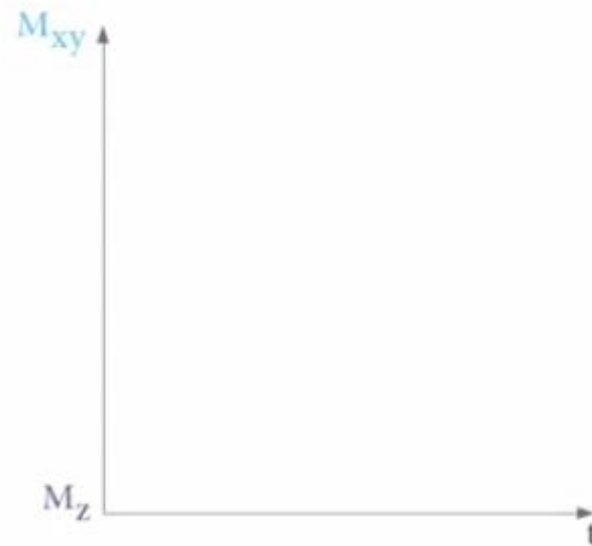
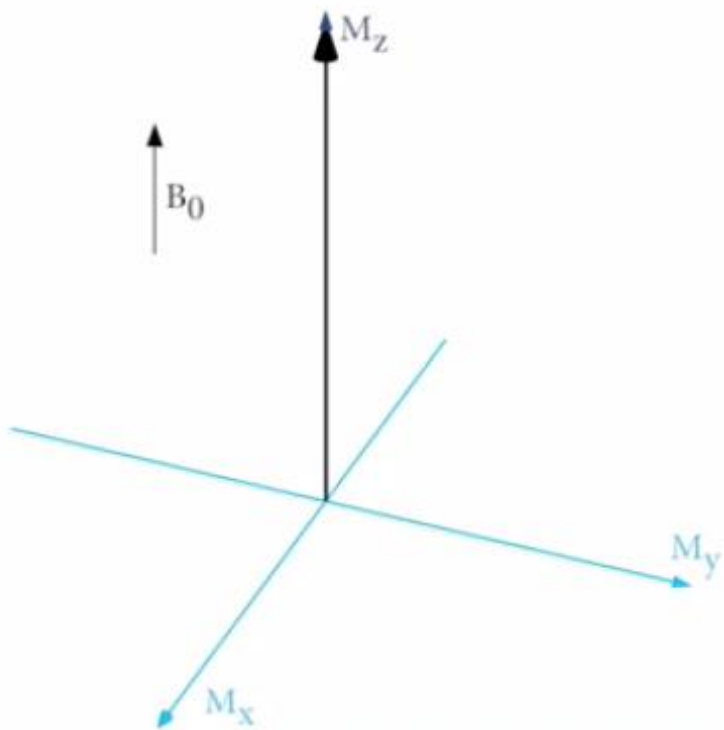
Frecuencia de precesión  $\leftarrow \nu = \gamma B_0$

La aplicación de un pulso de radiofrecuencia *inclina* a los spines en la dirección del pulso

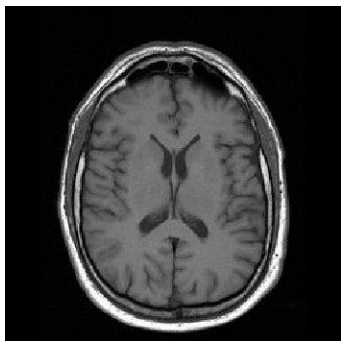
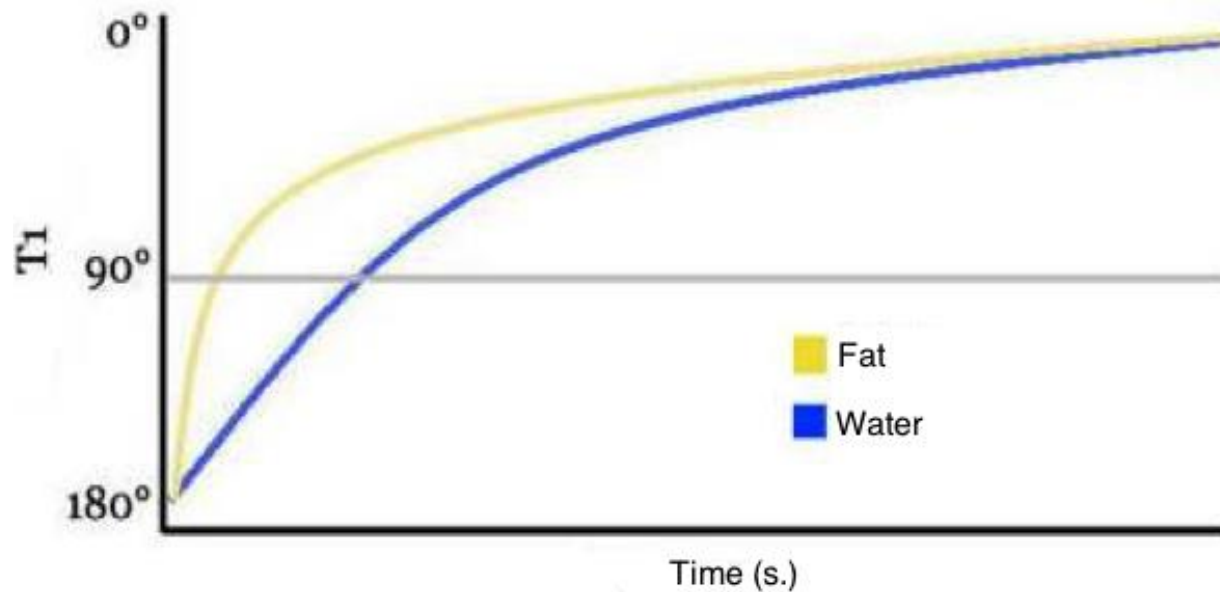


Al terminar el pulso los spines vuelven a alinearse con el campo  $B_0$ , devolviendo la energía en forma de ondas de radio





Midiendo las constantes de decaimiento longitudinal y transversal ( $T_1$  y  $T_2$ ) es posible determinar la densidad de protones



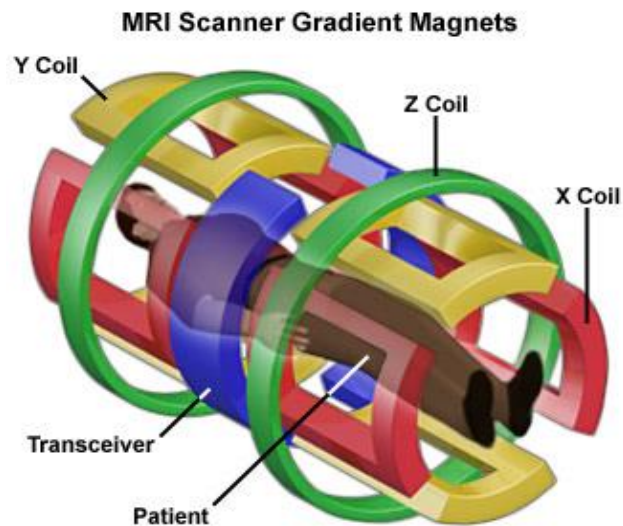
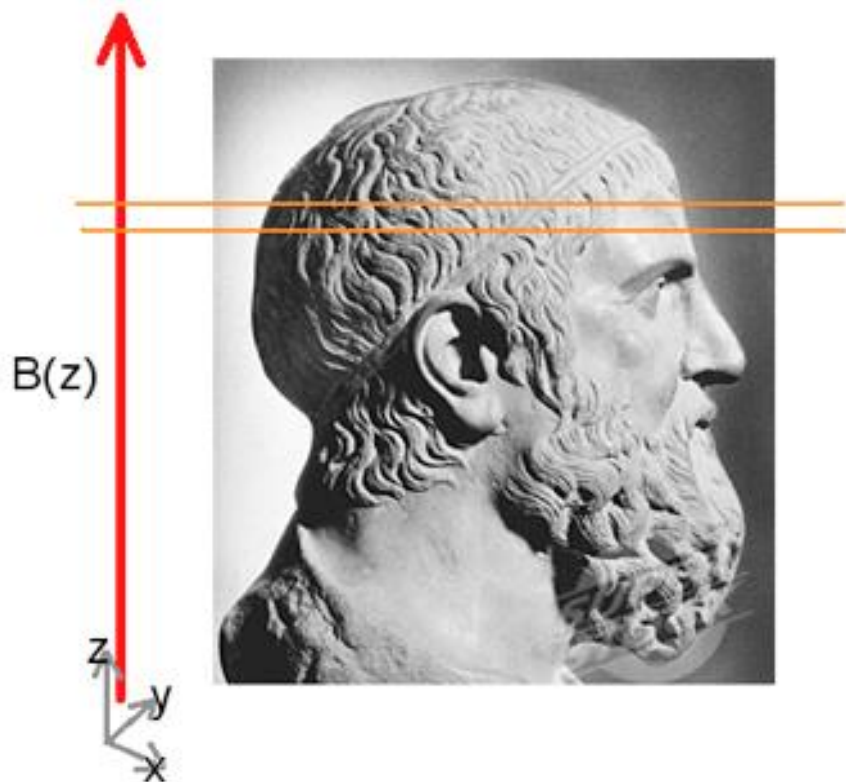
T1 (izquierda) y T2 (derecha)

En principio, deberíamos poder obtener mapas espaciales que indiquen para cada punto del espacio las constantes de decaimiento

## Solución: introducir un gradiente

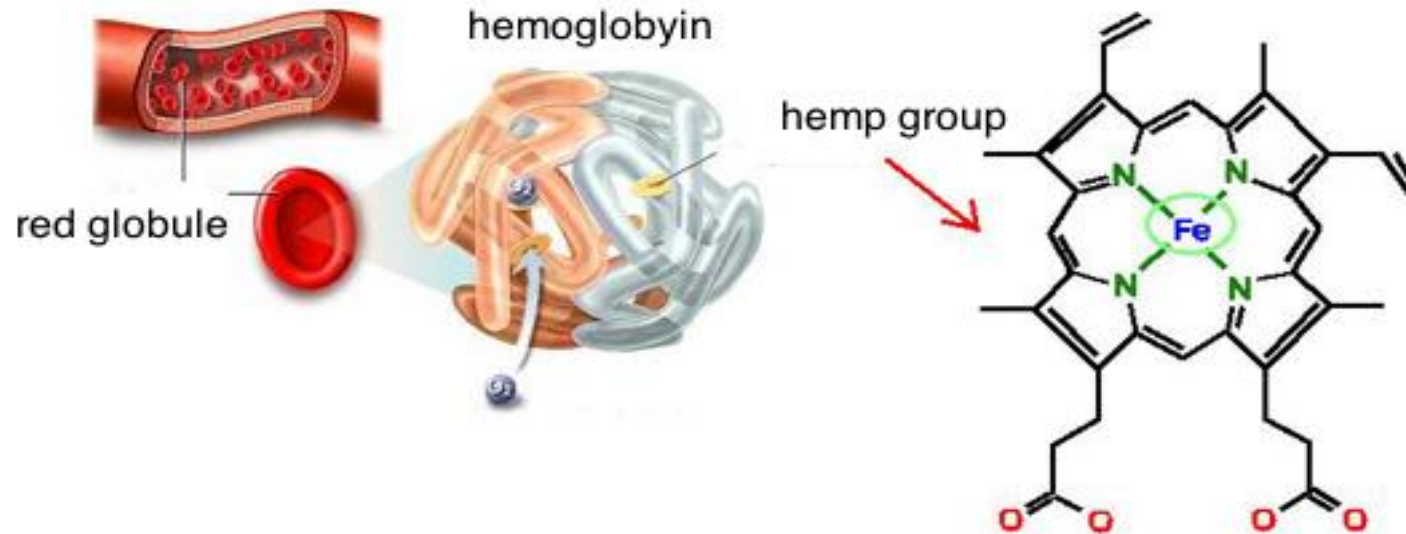
Ahora la frecuencia de resonancia depende de la coordenada  $z$  y es posible excitar solo los protones que estén en esa *rebanada*

$$\nu(z) = \gamma B(z)$$

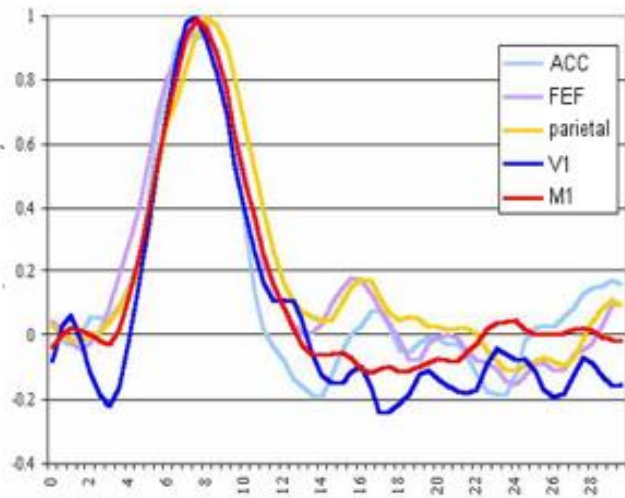




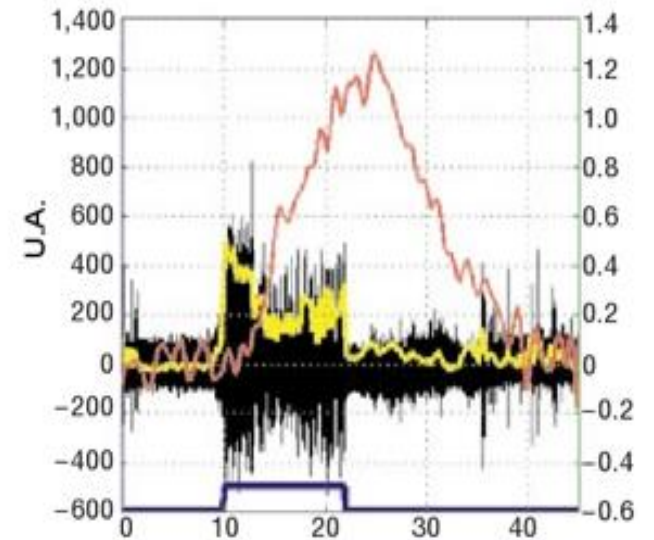
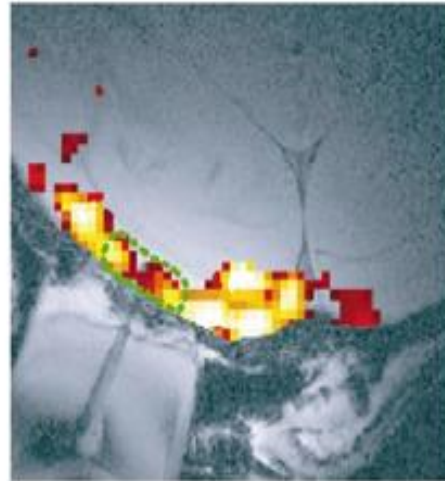
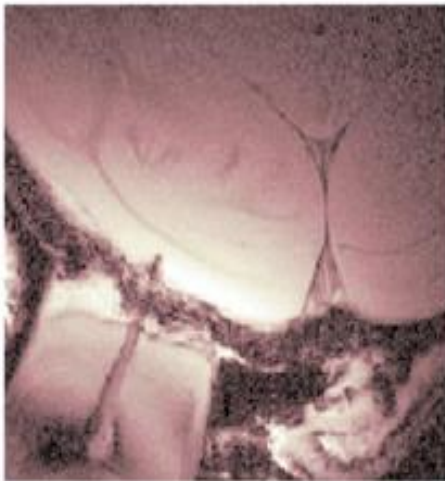
# De la física a la neurociencia



El cambio en las propiedades magnéticas de la hemoglobina oxigenada afecta el campo magnético del resonador y la constante de decaimiento transversal ( $T2^*$ )



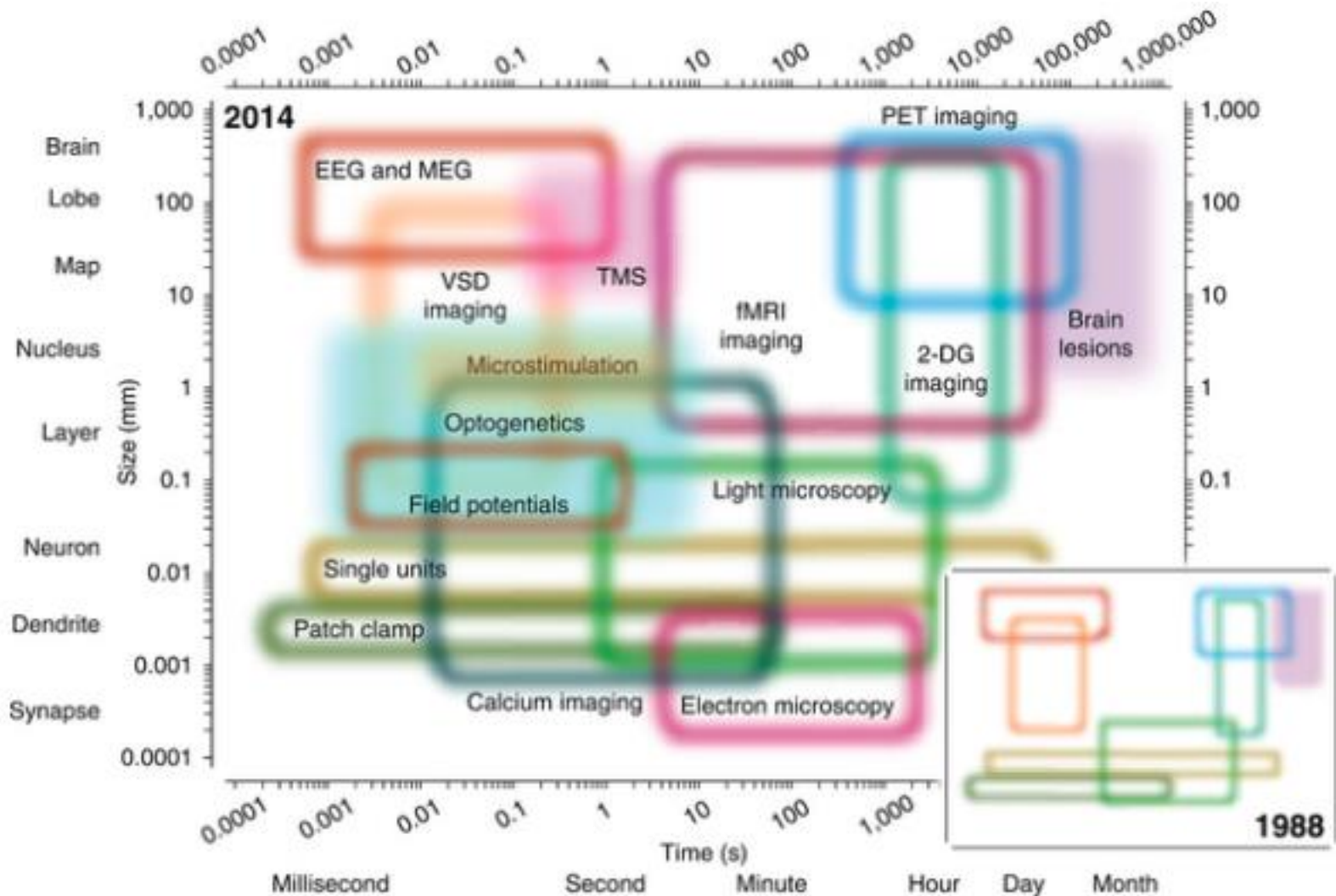
**Función de respuesta hemodinámica**  
*(hemodynamic response function)*



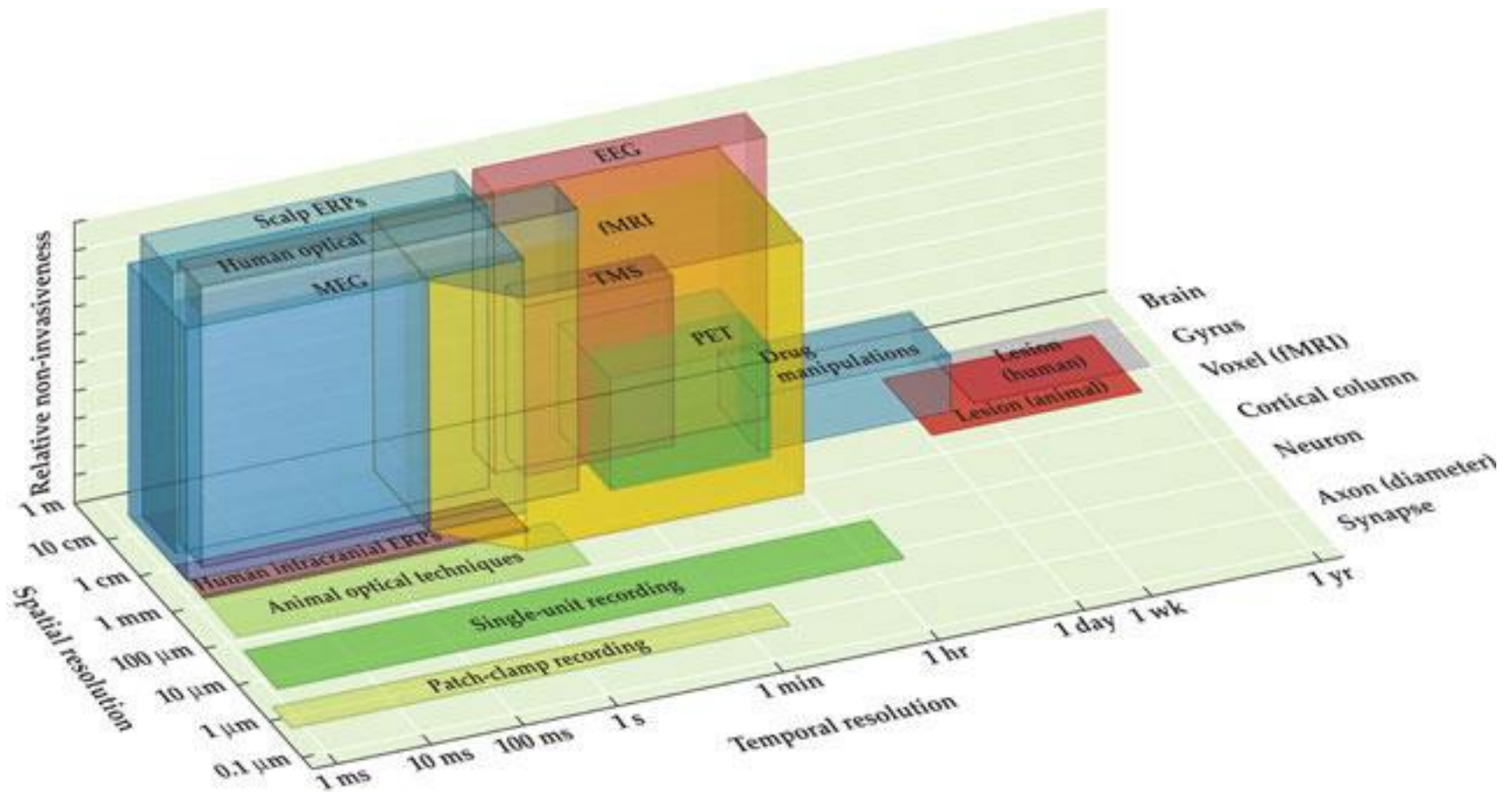
**Alta resolución espacial (1 mm)**  
**Relativamente baja resolución temporal (1 s.)**



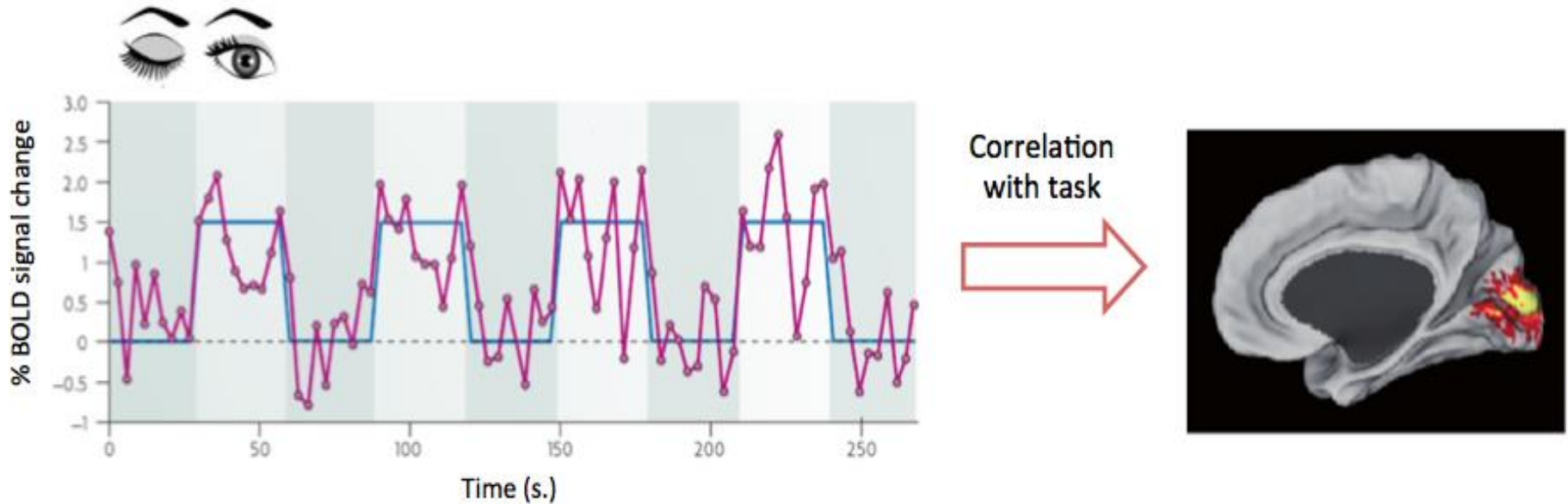
# Resoluciones



# Qué tan invasivas son las técnicas (limitación en humanos)

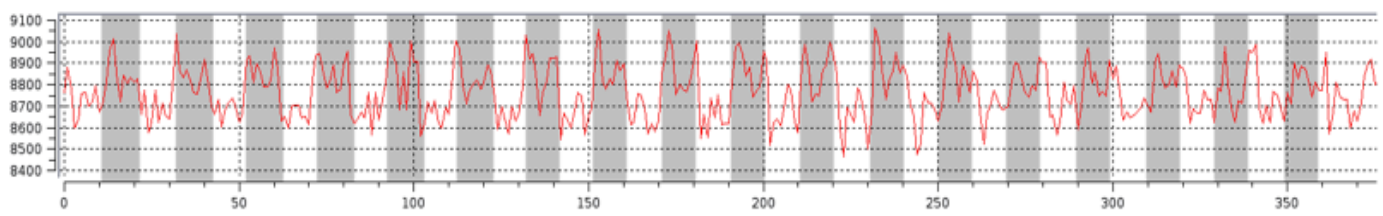
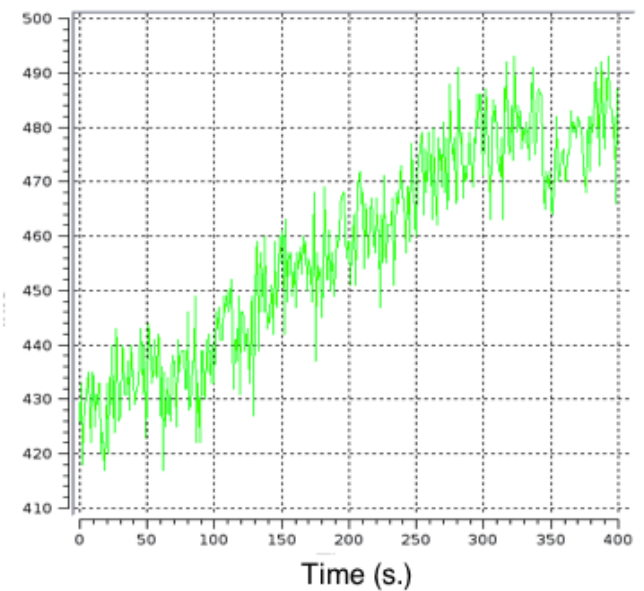
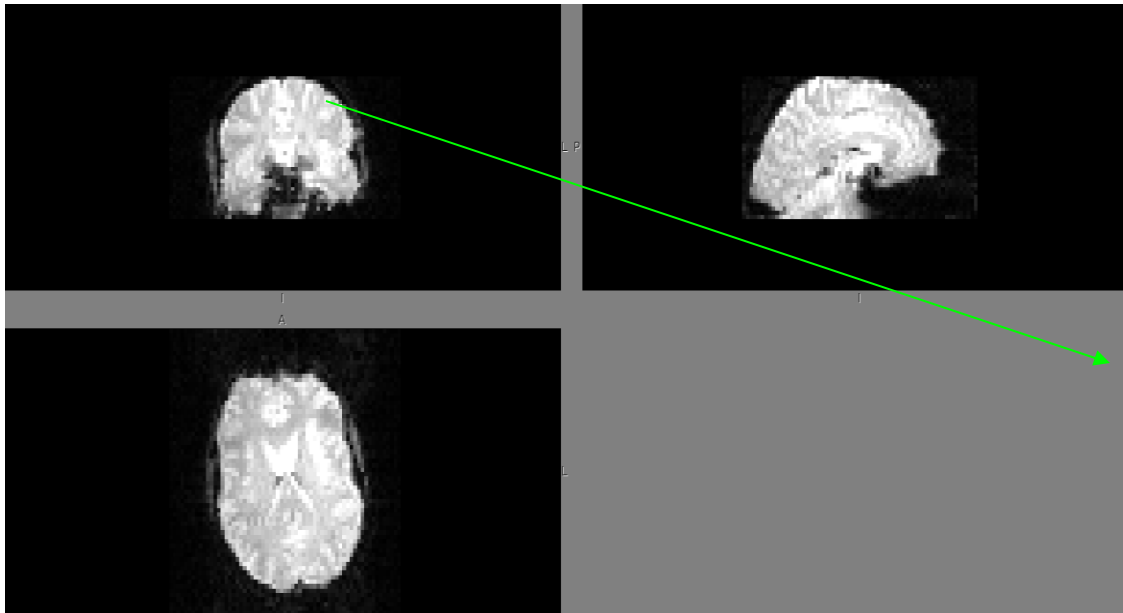


## Mapeando funciones a zonas cerebrales utilizando fMRI



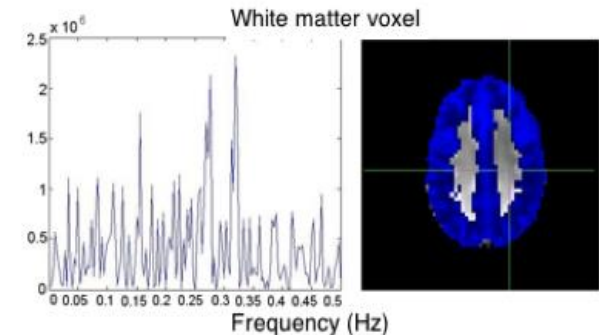
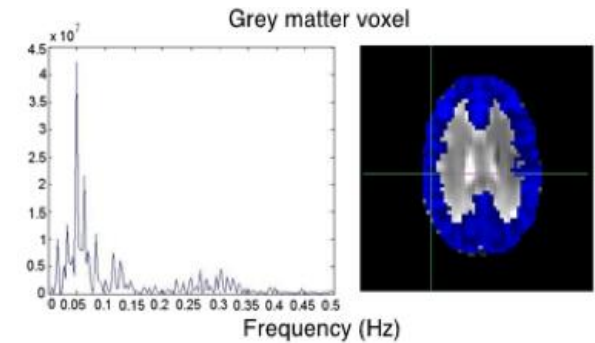
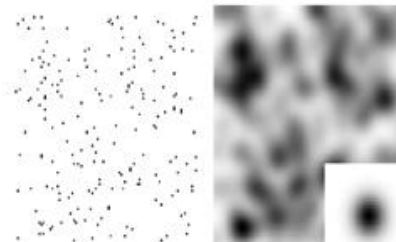
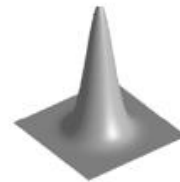
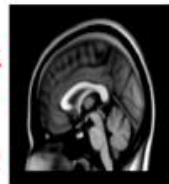
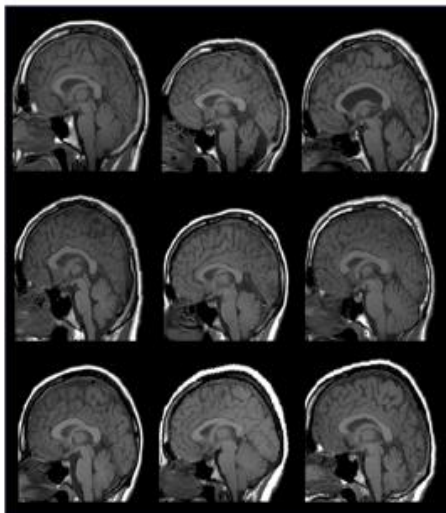
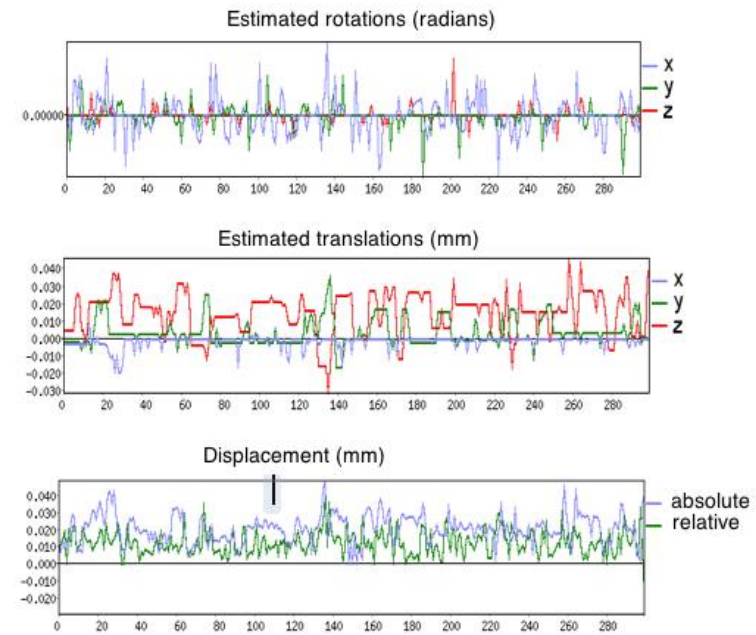
*Objetivo:* Inferir la correlación entre la serie temporal del modelo y la serie temporal empírica para cada *voxel* (mínima unidad de resolución del aparato)

# Datos crudos en una tarea de *finger tapping*



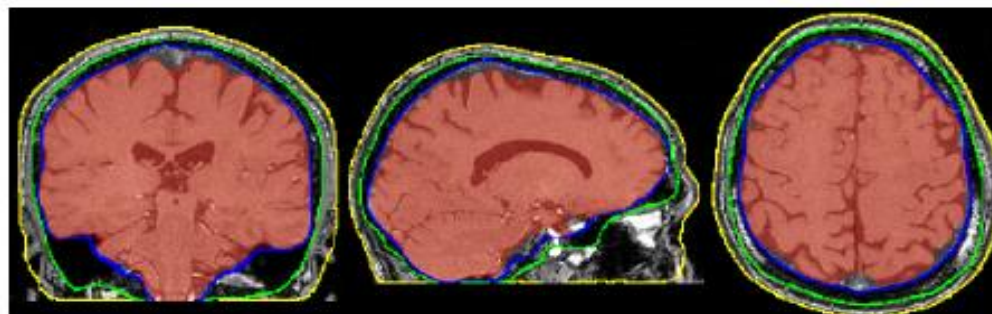
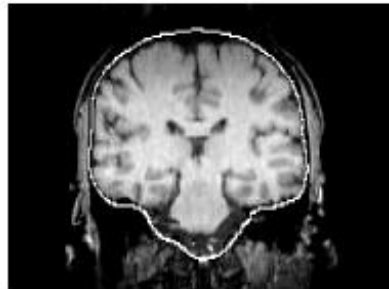
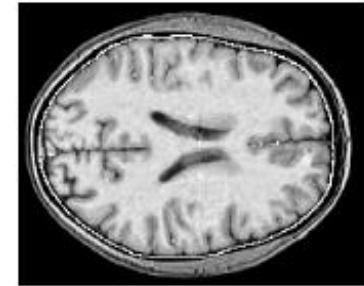
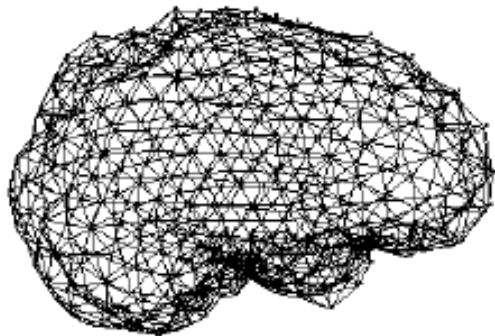
# Preprocesado

- Corrección de movimiento
- Filtrado temporal
- Segmentación
- Suavizado espacial
- Normalización



# Extracción de cerebro

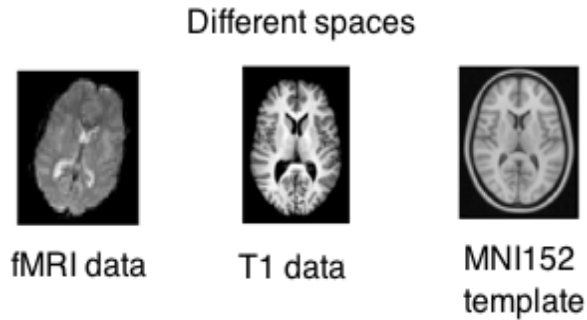
E.g. Empezar con una "malla" en forma de esfera y agregar nodos hasta expandir y ajustar sobre la superficie donde cambia la intensidad de la imagen



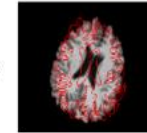
# Normalización / corrección de movimiento

O bien, aplicar distintos tipos de transformaciones para llevar las imágenes de un espacio a otro

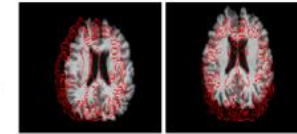
Llevar las imágenes de un mismo sujeto en un tiempo dado a otro tiempo (corrección de movimiento)



Rigid body transformations  
3 degrees of freedom (free parameters)  
3 rotations



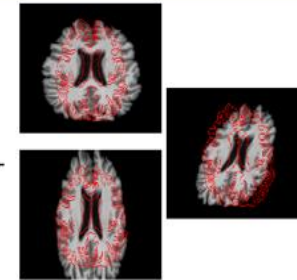
or 6 degrees of freedom  
3 rotations + rigid translations



Intra-subject registration  
(head motion)

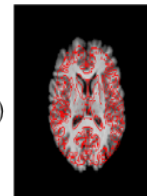
Affine transformations

12 degrees of freedom  
(6 from before plus 3 scale changes -  
multiplying by a constant in x,y,z +  
shearing in 3 directions).



Registration to standard space

Non-linear transformations  
(more than 16 degrees of freedom)



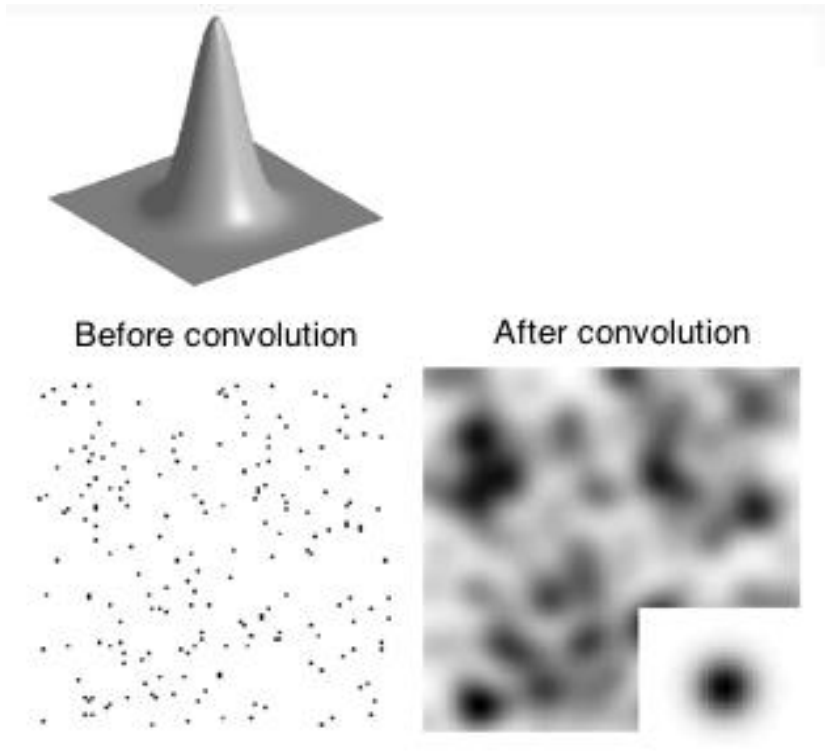
Registering a high resolution brain  
to another high resolution brain

# Suavizado espacial

- 1) Reduce la influencia del ruido (el promediado elimina el ruido)
- 2) Suaviza los datos y mejora el *matcheo* entre sujetos
- 3) Requisito teórico para corrección por comparaciones múltiples

**Precaución**

**El diámetro del núcleo de convolución no debe ser mayor que el área del cerebro que nos interesa**

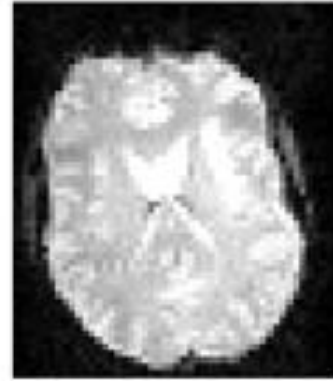
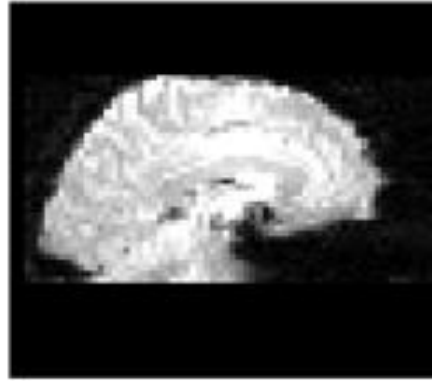


Averaging weights

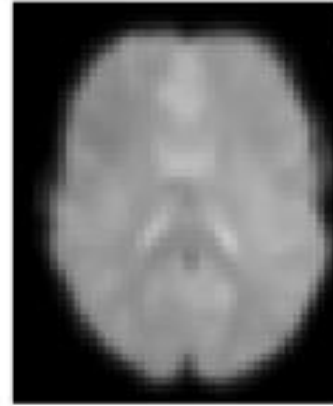
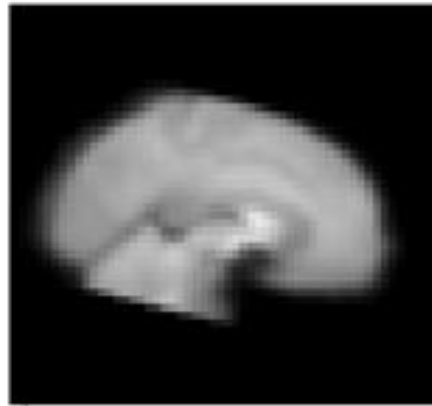
0.1	0.3	0.4	0.3	0.1
0.3	0.6	0.8	0.6	0.3
0.4	0.8	1.0	0.8	0.4
0.3	0.6	0.8	0.6	0.3
0.1	0.3	0.4	0.3	0.1

↔  
FWHM  
(Full Width Half Maximum)





Datos  
crudos



Datos con todos los  
pasos hasta ahora

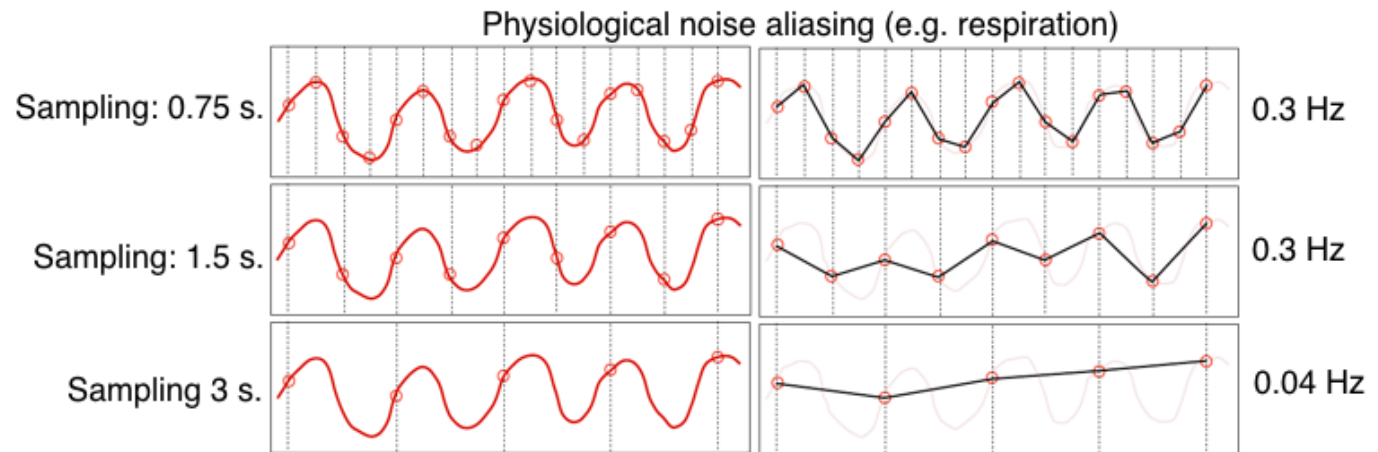
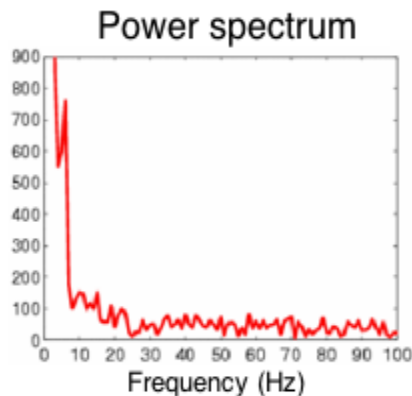
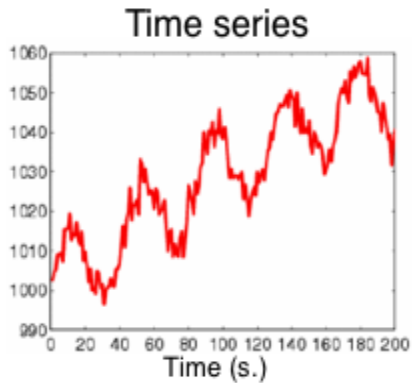
# Filtrado temporal

1) Ruido en bajas frecuencias  
(principalmente el *drift* del scanner)

2) Ruido de alta frecuencia (e.g. movimiento residual)

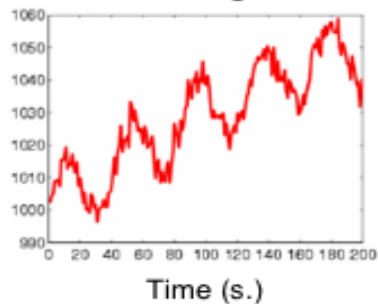
**Precaución**

**El filtro no debe eliminar frecuencias relevantes para el experimento**

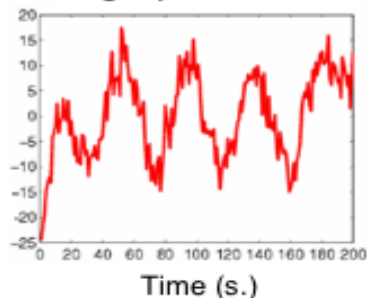


If sampling frequency is below half of the signal we are interested in, the measured signal has very low frequency.

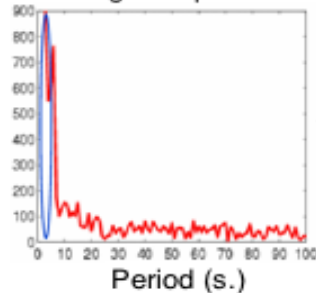
Raw signal



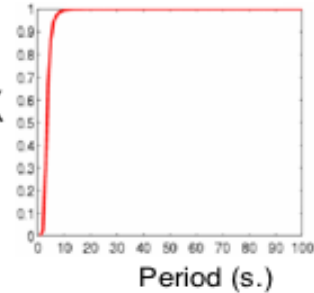
High pass filter



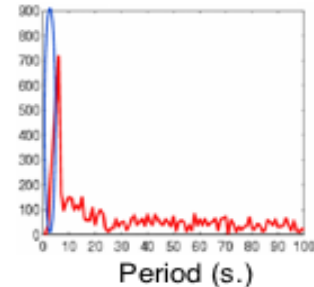
Original spectrum



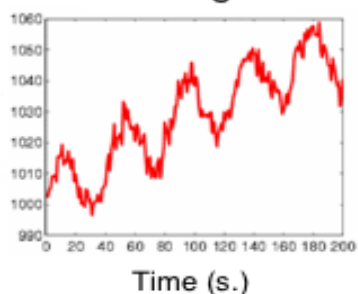
High pass filter



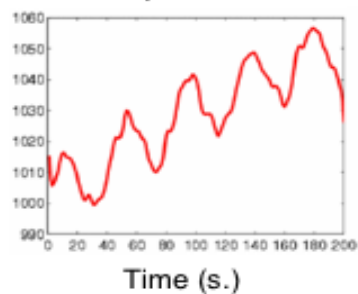
Filtered spectrum



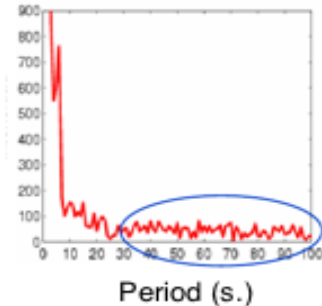
Raw signal



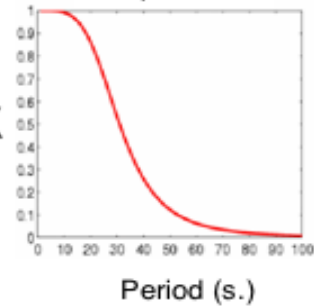
Low pass filter



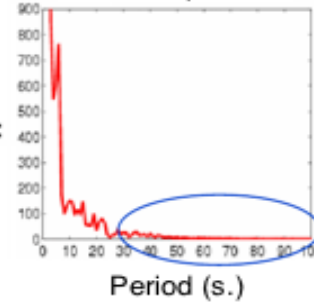
Original spectrum



Low pass filter

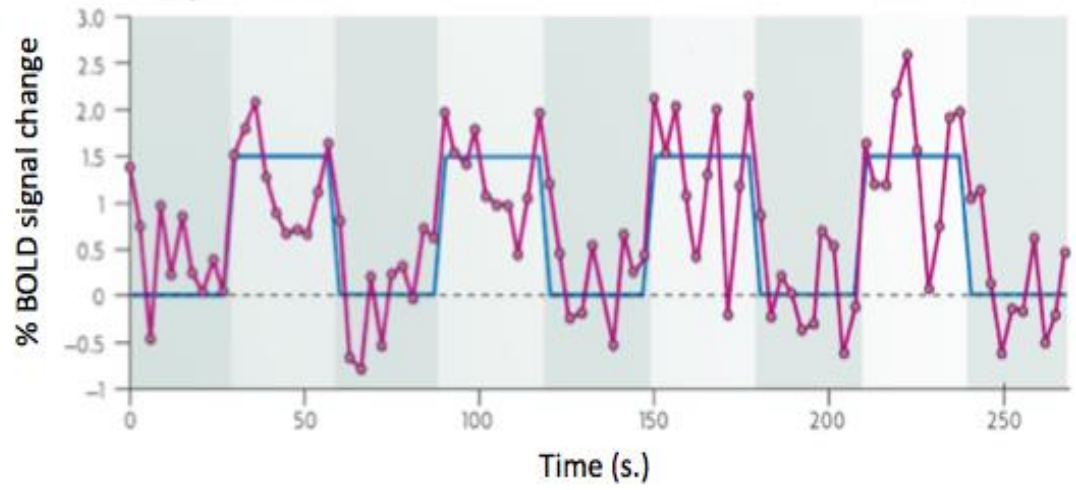


Filtered spectrum

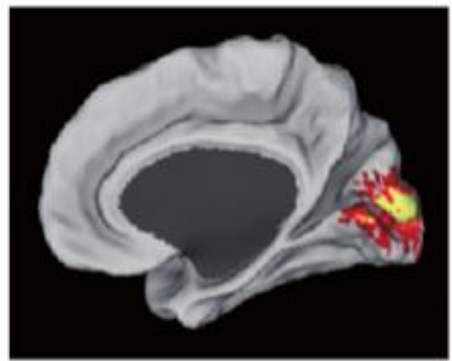


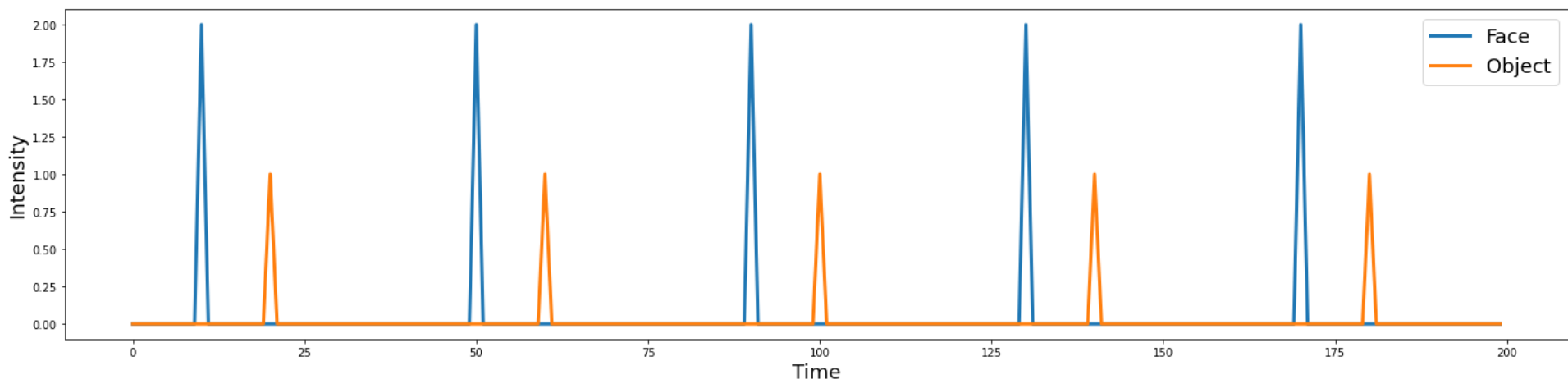
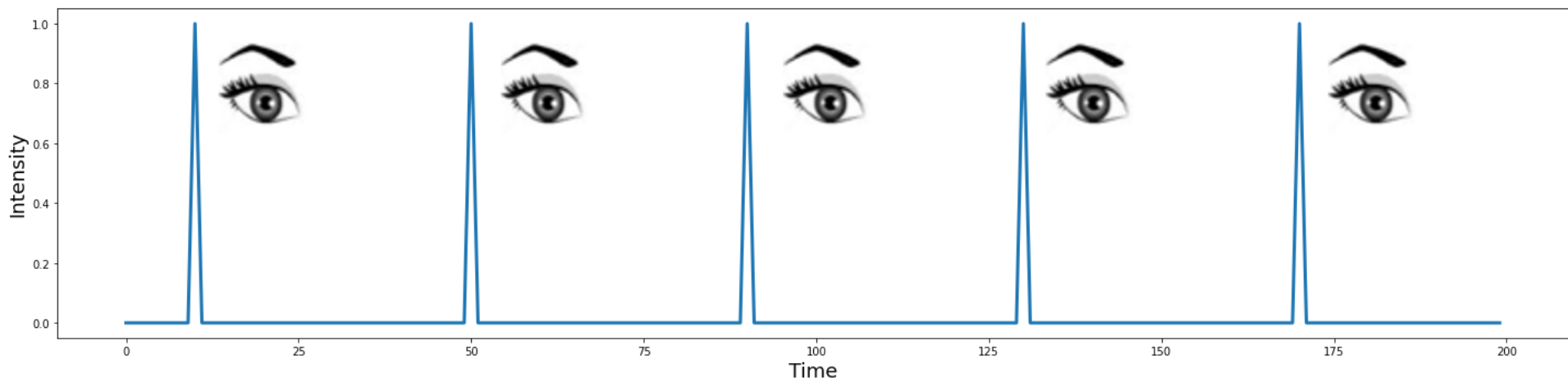
**Segunda parte:**

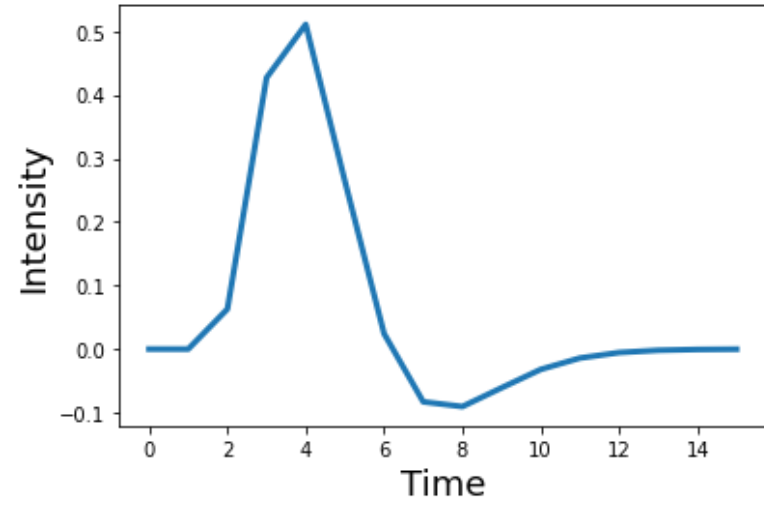
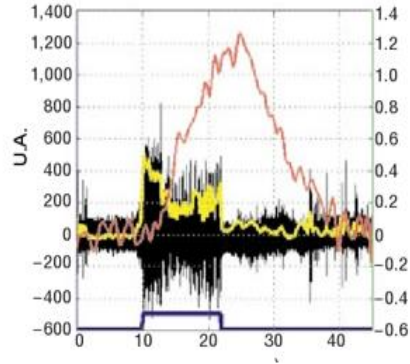
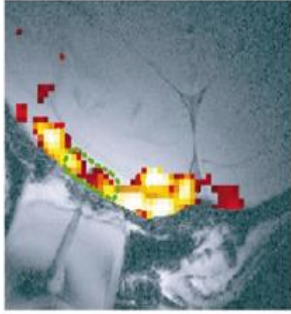
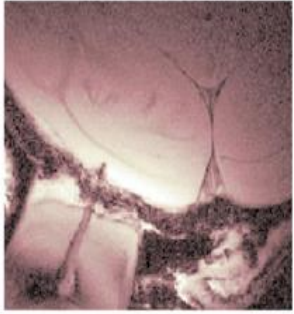
Modelo general lineal



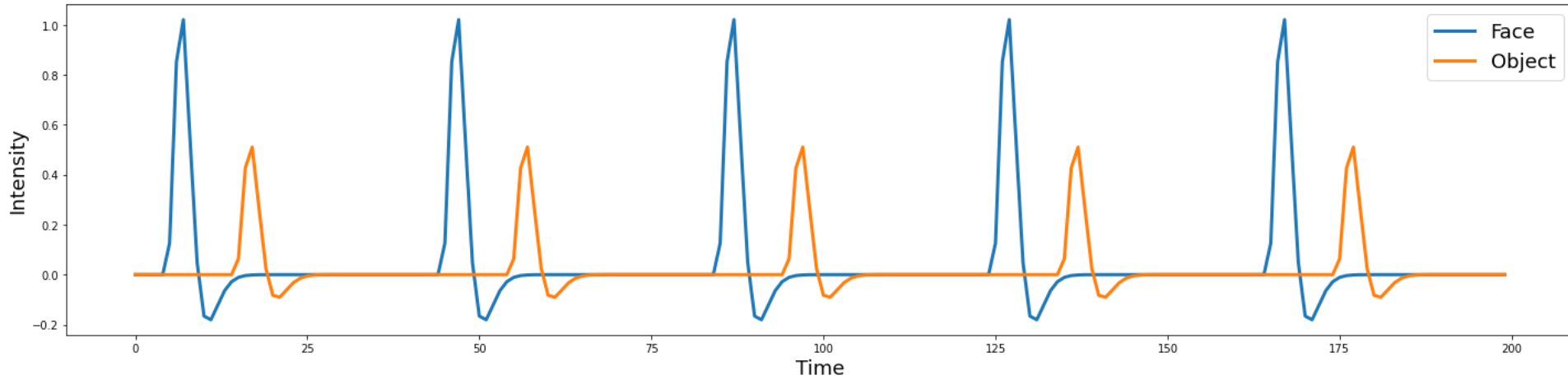
Correlation with task



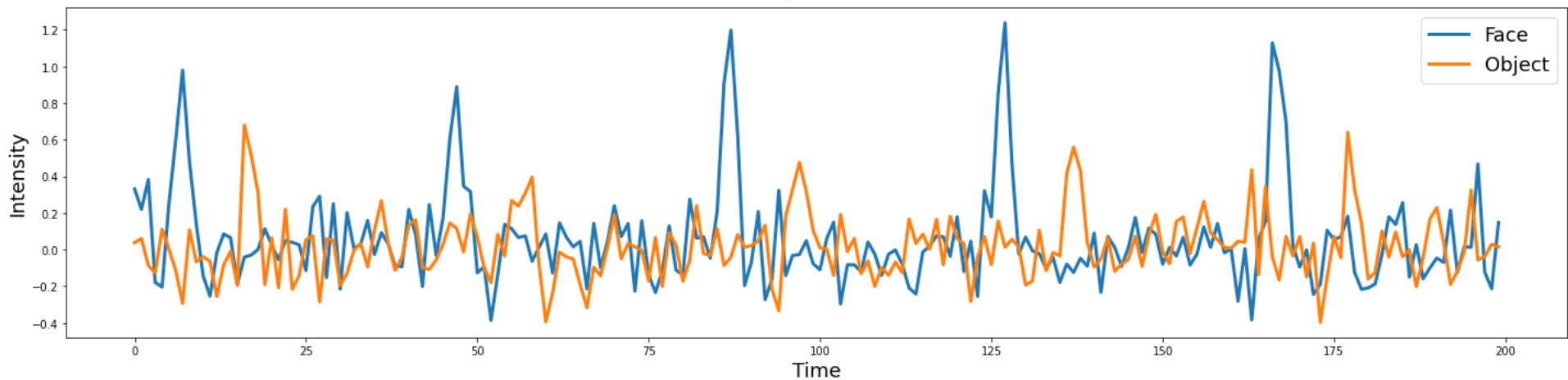




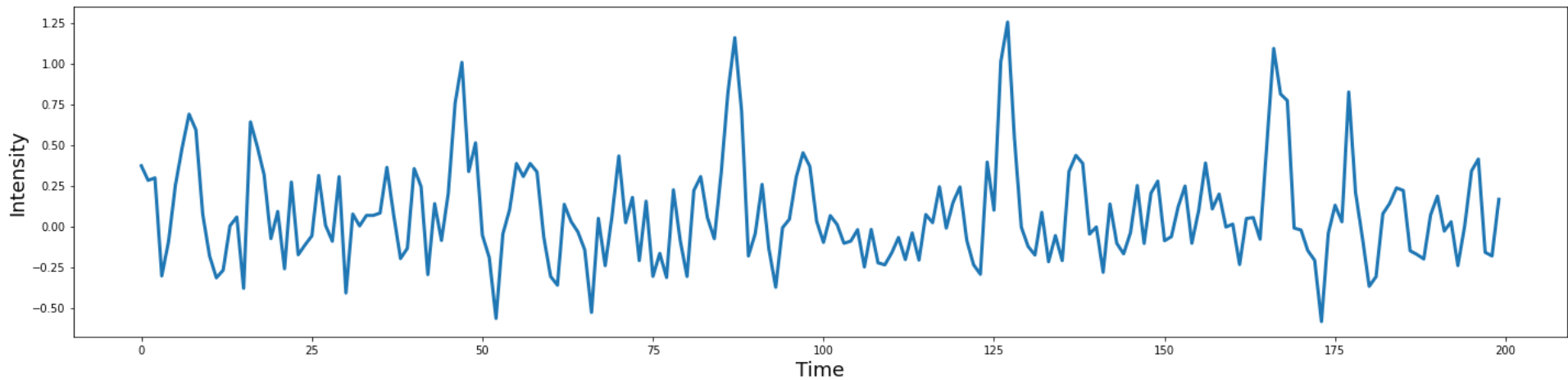
Convolución



$\epsilon \sim \mathcal{N}(\mu, \sigma^2)$



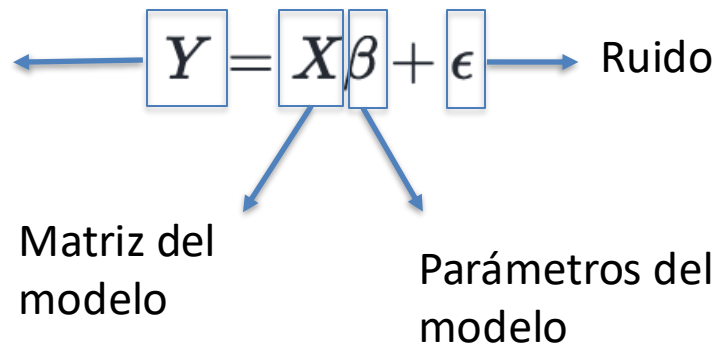
Mezcla (señal simulada)



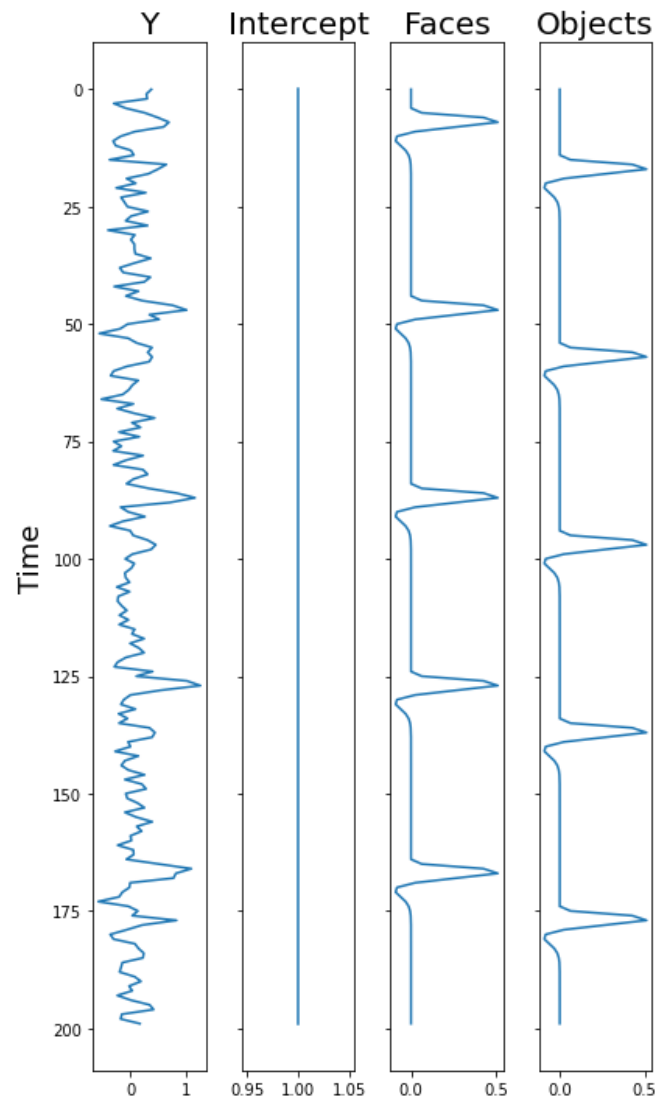


# Modelo general lineal

Series de tiempo  
de voxels



$$\text{Voxel} = \beta_0 \cdot \text{Intercept} + \beta_1 \cdot \text{Faces} + \beta_2 \cdot \text{Objects} + \epsilon$$

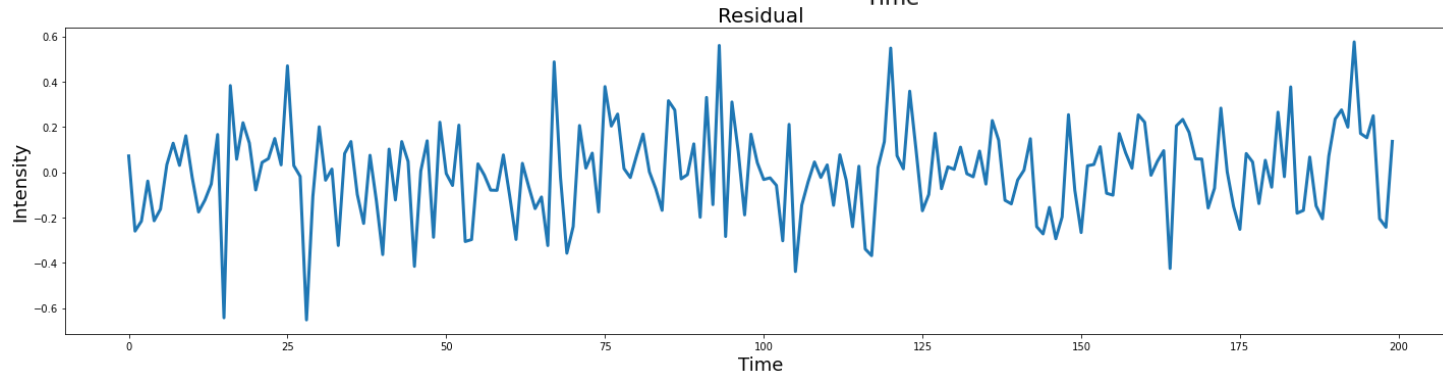
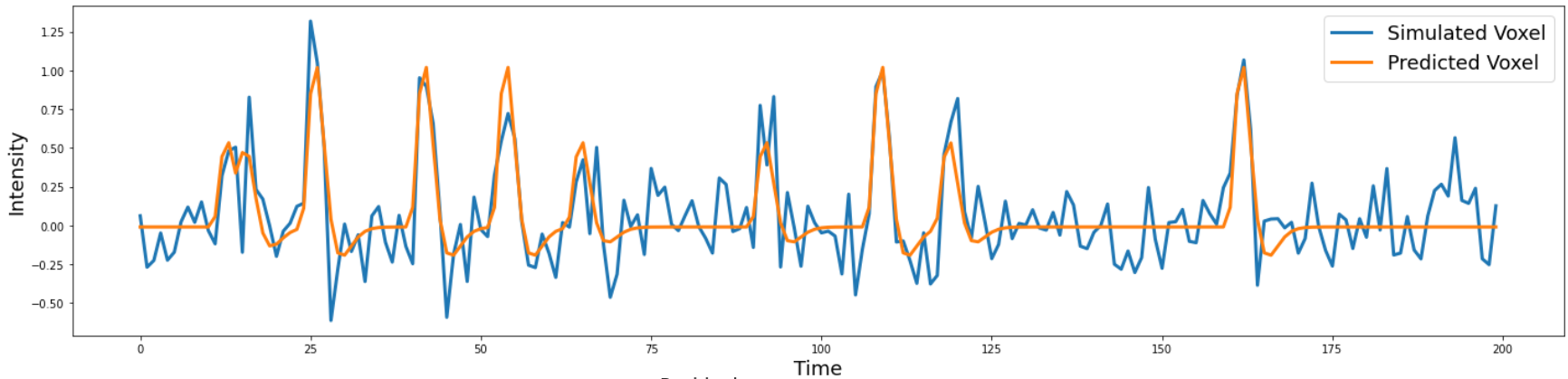
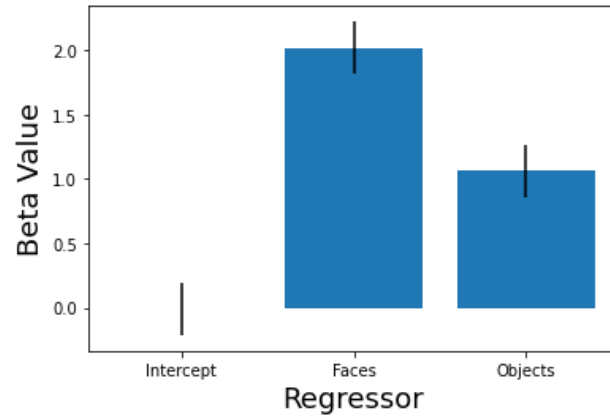


$$Y = X\beta + \epsilon$$

$$\text{Voxel} = \beta_0 \cdot \text{Intercept} + \beta_1 \cdot \text{Faces} + \beta_2 \cdot \text{Objects} + \epsilon$$

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$










$$\text{residual} = Y - \hat{Y}$$

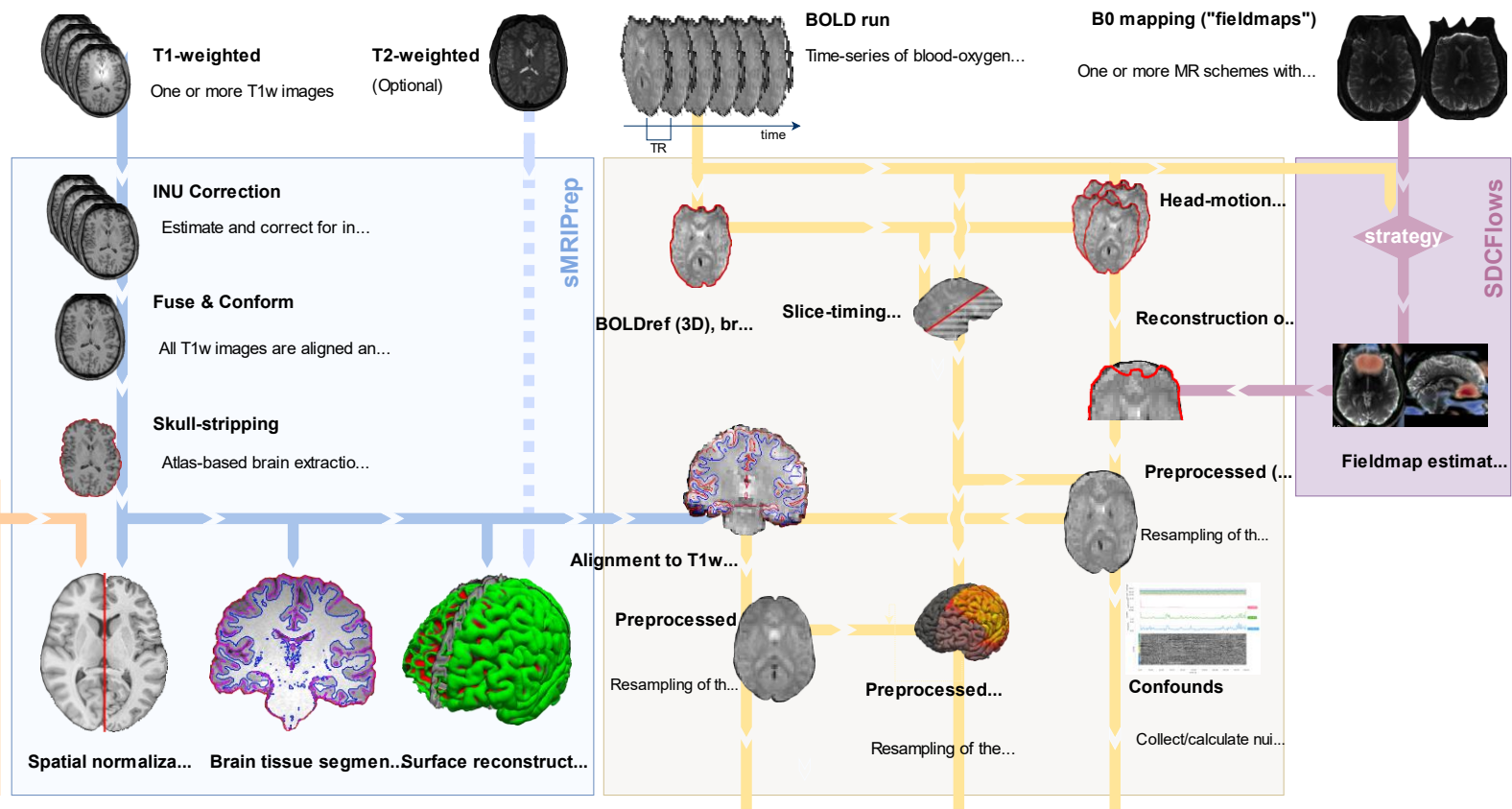


# Tercera parte:

fMRI con Python

# fMRIPrep: a robust preprocessing pipeline for functional MRI

Oscar Esteban <sup>1\*</sup>, Christopher J. Markiewicz <sup>1</sup>, Ross W. Blair<sup>1</sup>, Craig A. Moodie <sup>1</sup>, A. Ilkay Isik <sup>2</sup>, Asier Erramuzpe <sup>3</sup>, James D. Kent<sup>4</sup>, Mathias Goncalves<sup>5</sup>, Elizabeth DuPre <sup>6</sup>, Madeleine Snyder<sup>7</sup>, Hiroyuki Oya<sup>8</sup>, Satrajit S. Ghosh <sup>5,9</sup>, Jessey Wright<sup>1</sup>, Joke Durnez <sup>1</sup>, Russell A. Poldrack<sup>1,10</sup> and Krzysztof J. Gorgolewski <sup>1,10\*</sup>



## OPEN The brain imaging data structure, a format for organizing and describing outputs of neuroimaging experiments

### SUBJECT CATEGORIES

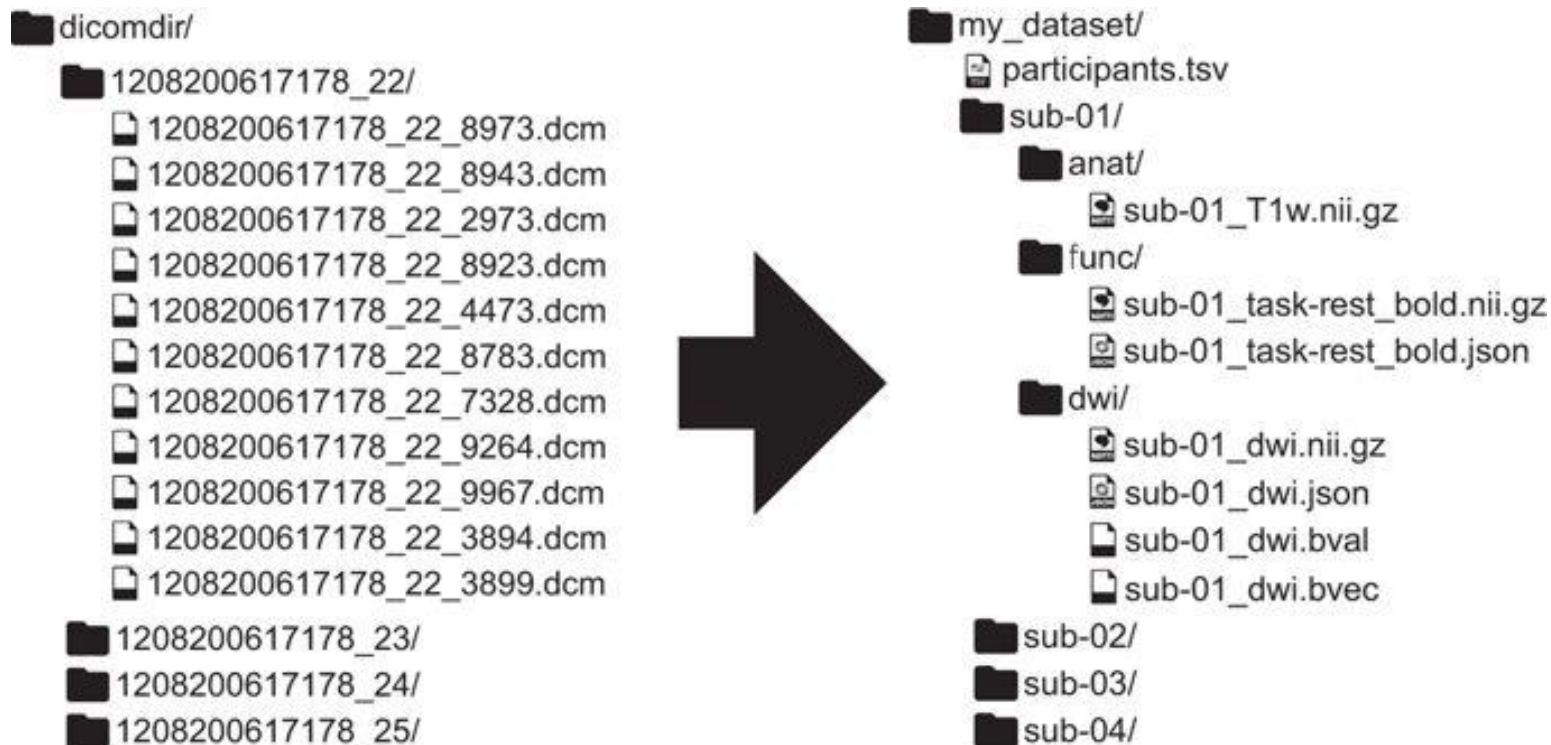
- » Data publication and archiving
- » Research data

Krzysztof J. Gorgolewski<sup>1</sup>, Tibor Auer<sup>2</sup>, Vince D. Calhoun<sup>3,4</sup>, R. Cameron Craddock<sup>5,6</sup>, Samir Das<sup>7</sup>, Eugene P. Duff<sup>8</sup>, Guillaume Flandin<sup>9</sup>, Satrajit S. Ghosh<sup>10,11</sup>, Tristan Glatard<sup>7,12</sup>, Yaroslav O. Halchenko<sup>13</sup>, Daniel A. Handwerker<sup>14</sup>, Michael Hanke<sup>15,16</sup>, David Keator<sup>17</sup>, Xiangrui Li<sup>18</sup>, Zachary Michael<sup>19</sup>, Camille Maumet<sup>20</sup>, B. Nolan Nichols<sup>21,22</sup>, Thomas E. Nichols<sup>20,23</sup>, John Pellman<sup>6</sup>, Jean-Baptiste Poline<sup>24</sup>, Ariel Rokem<sup>25</sup>, Gunnar Schaefer<sup>1,26</sup>, Vanessa Sochat<sup>27</sup>, William Triplett<sup>1</sup>, Jessica A. Turner<sup>3,28</sup>, Gaël Varoquaux<sup>29</sup> & Russell A. Poldrack<sup>1</sup>

Received: 18 December 2015

Accepted: 19 May 2016

Published: 21 June 2016



# NLTools

pypi v0.5.1 (Auto) Tests failing code quality A DOI 10.5281/zenodo.2229813 python 3.7 | 3.8

platform linux | osx | win

**NLTools** is a Python package for analyzing neuroimaging data. It is the analysis engine powering **neuro-learn**. There are tools to perform data manipulation and analyses such as univariate GLMs, predictive multivariate modeling, and representational similarity analyses. It is based loosely off of Tor Wager's **object-oriented Matlab toolbox** and leverages much code from **nilearn** and **scikit-learn**.

## nipy.org

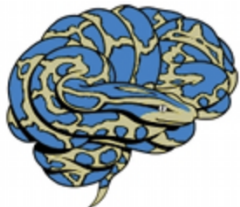
Welcome to NIPY. We are a community of practice devoted to the use of the Python programming language in the analysis of neuroimaging data. You can find us on [github](#), as well as social media [[blog](#)] [[twitter](#)]. We welcome contributions and ask that you read about our standards of conduct. You are also invited to ask for help.

## Nilearn

Doc

Github


Nilearn is a Python module for fast and easy statistical learning on neuroimaging data.



## Nipype: Neuroimaging in Python Pipelines and Interfaces



# Fast reproducible identification and large-scale databasing of individual functional cognitive networks

[Philippe Pinel](#) , [Bertrand Thirion](#), [Sébastien Meriaux](#), [Antoinette Jobert](#), [Julien Serres](#), [Denis Le Bihan](#), [Jean-Baptiste Poline](#) & [Stanislas Dehaene](#)

[BMC Neuroscience](#) **8**, Article number: 91 (2007) | [Cite this article](#)

**12k** Accesses | **13** Altmetric | [Metrics](#)

N=94 (nosotros vamos a usar solamente 10)

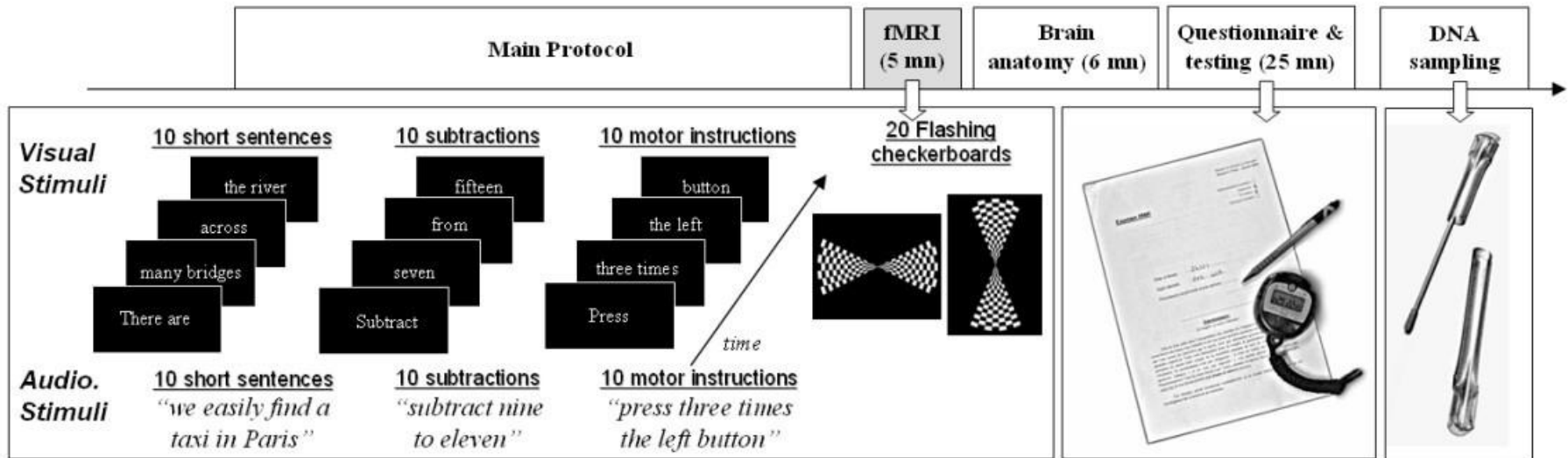
Datos de neuroimágenes (fMRI, T1), genéticos, comportamiento, demográficos

Sesión de fMRI de 5 minutos en un protocolo de localización funcional (*localizer*)

Distintas tareas asociadas a cognición, percepción y actividad motora

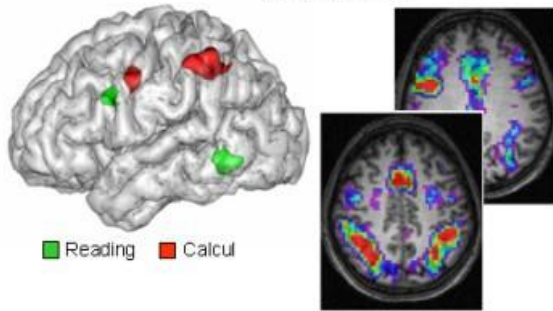
Cada tarea se presentó de forma visual y auditiva

Un registro de señal hemodinámica cada 2.4 segundos (TR) adquiridos a 3 T de campo



**hybrid databasing**

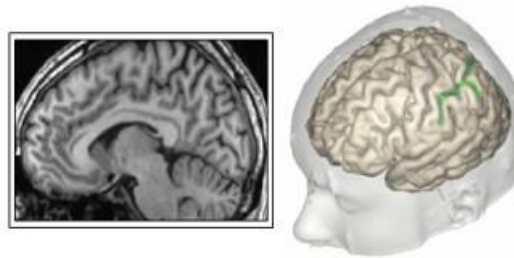
**fMRI data**



**1. Extraction of individual functional circuits (SPM2) on normalized brain :**

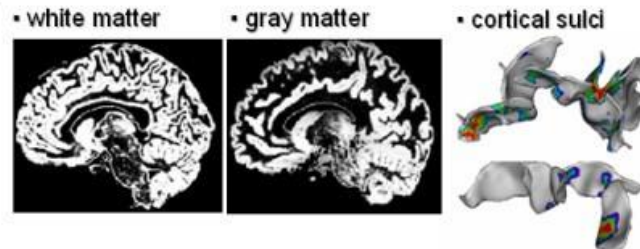
- correlates of reading
- correlates of language comprehension
- correlates of calculation
- correlates of motor responses
- basic retinotopy

**Anatomical MRI data**



**2. Morphometric analysis**

Extraction of brain volumes, sulci...



**Cognitive data**

**3. Individual cognitive profile**

- sex, age, handedness....
- education, developmental disorders
- reading difficulties
- basic numerical knowledge
- arithmetical skills
- visuo-spatial abilities
- visuo-motor abilities

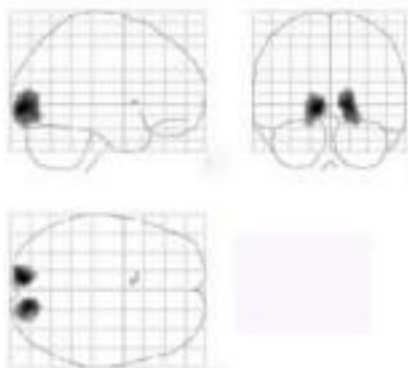
**Genetic data**

**4. Individual genotype**

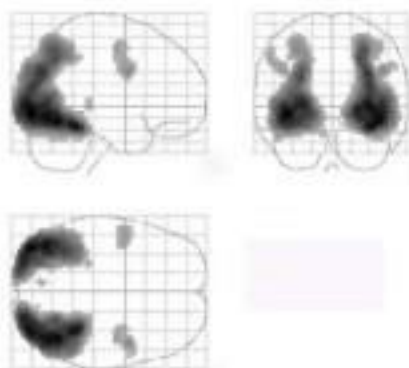
- candidate genes (COMT, BDNF...)
- normal variants of genes involved in genetic diseases
- exploration of new single nucleotide polymorphism



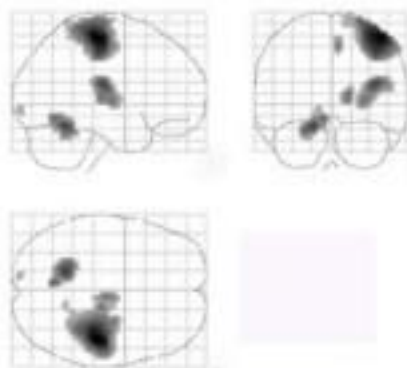
**H – V Checkerboards**



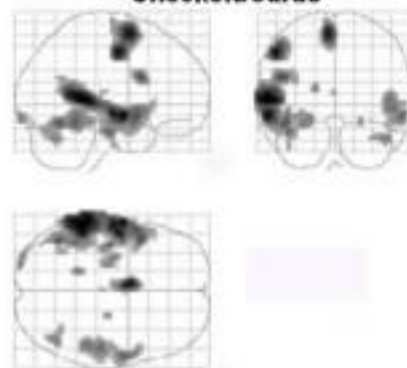
**Video – Audio trials**



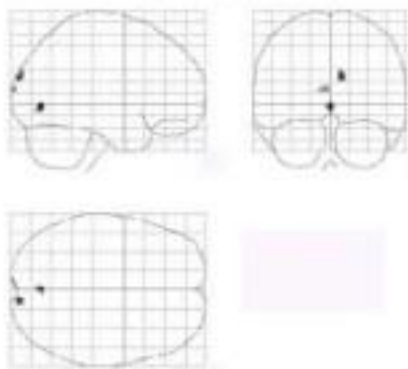
**Left – Right hand**



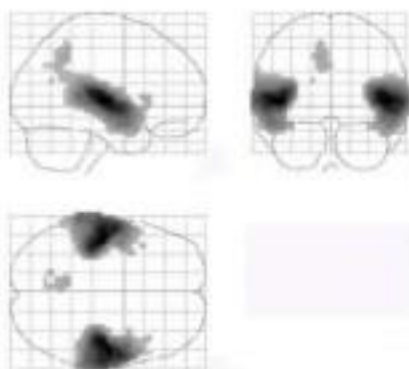
**Sentence reading – Checkerboards**



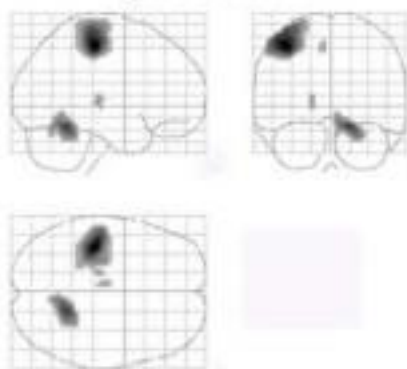
**V – H Checkerboards**



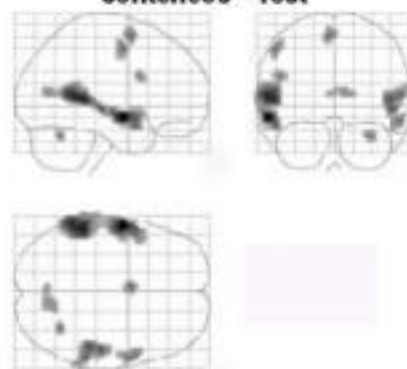
**Audio – Video trials**



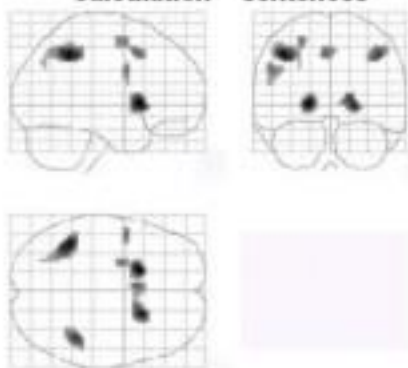
**Right – Left hand**



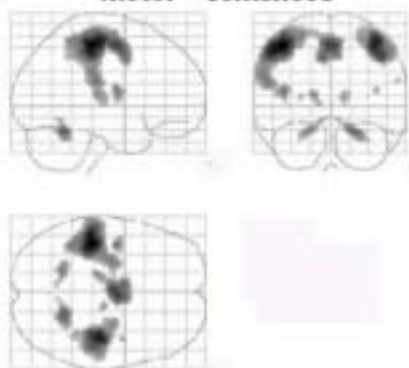
**Audio & Video sentences – rest**



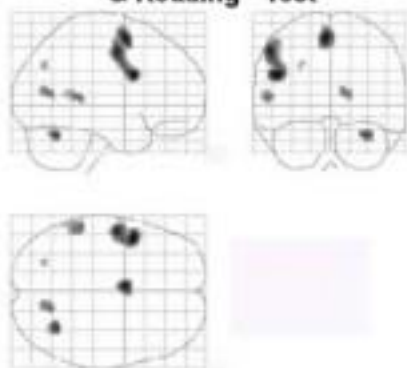
**Audio & Video calculation – sentences**



**Audio & Video motor – sentences**



**Calculation – rest & Reading – rest**



**Calculation – rest & Reading – checkerboard**

