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ALZHEIMER'S ASSOCIATION INTERNATIONAL CONFERENCE®

JULY 16-20 > AMSTERDAM, NETHERLANDS, AND ONLINE

ISTAART Neuroimaging PIA
THE BASICS OF NEUROIMAGING SEMINAR SERIES

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BASICS OF NEUROIMAGING: FUNCTIONAL MRI

Luigi Lorenzini, PhD student
Amsterdam UMC

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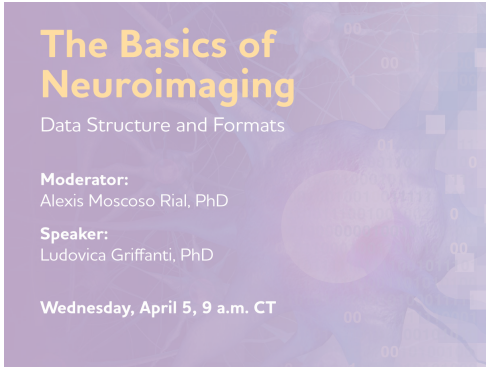
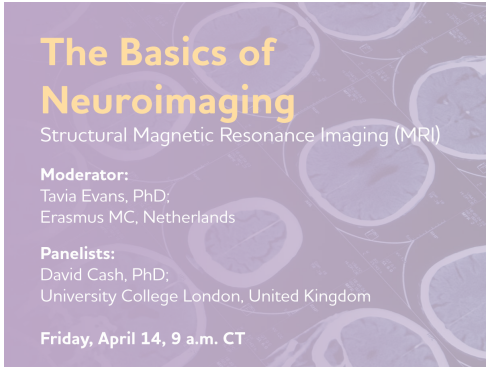
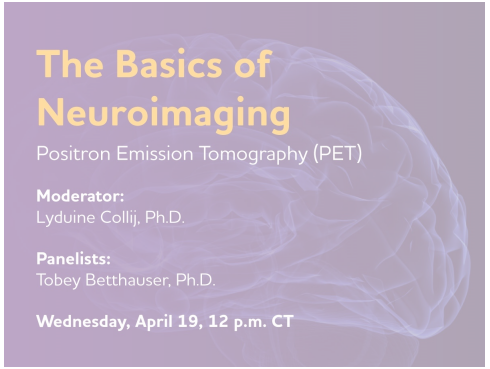
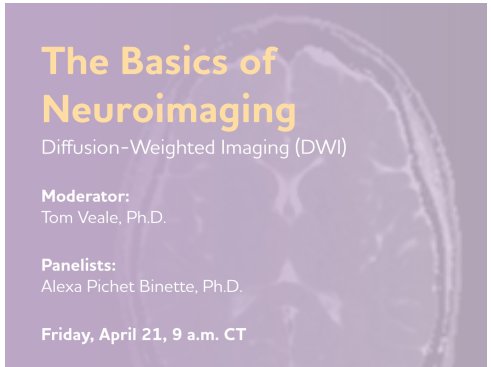
BASICS OF NEUROIMAGING

Available on demand very soon!









ADD MINE

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GOALS

By the end of this session, you should be able to:

- Understand and discuss fMRI principles and measurements
- Outline the basic preprocessing steps needed fMRI data and typical issues
- Describe the relevance and current clinical application of fMRI

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Functional MRI: What are we measuring?

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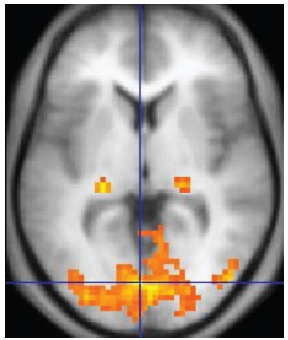
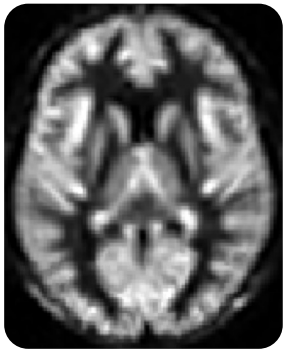
MEASURING BRAIN ACTIVITY: FMRI ET AL.

fMRI



BOLD signal

ASL



Cerebral blood flow (CBF)

EEG

Electrical Signals

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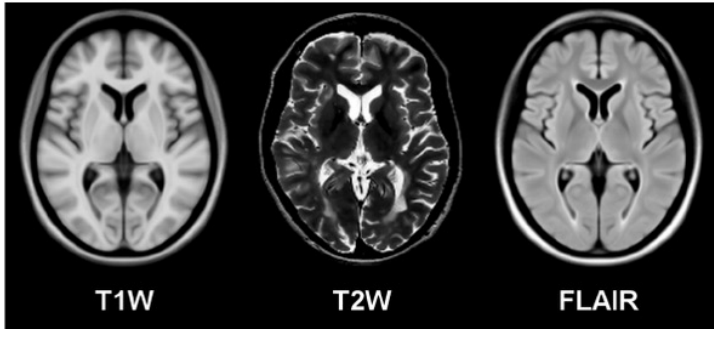
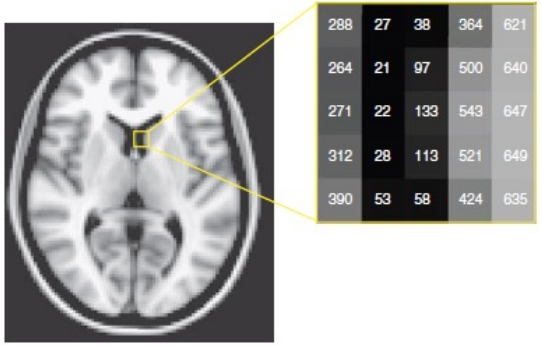
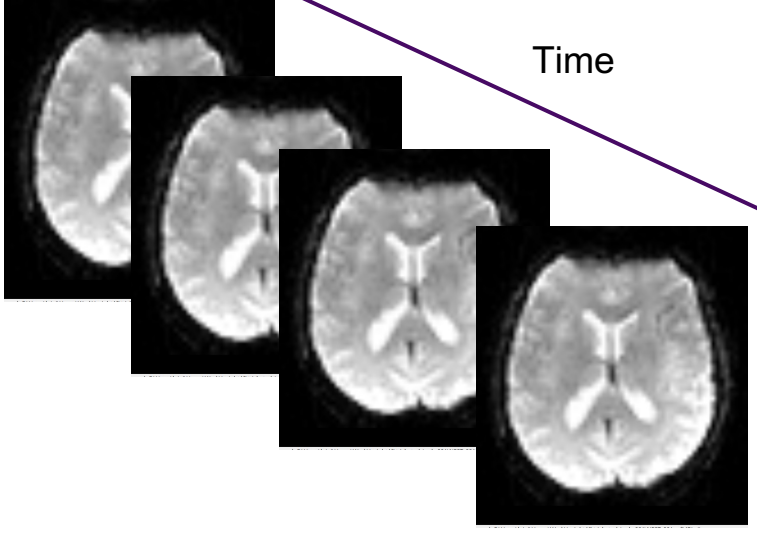
FMRI IMAGES: A MOVIE OF THE BRAIN

Structural MRI

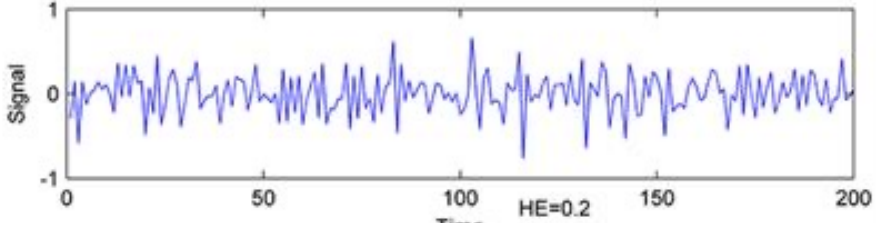




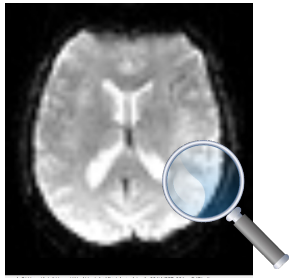
Functional MRI



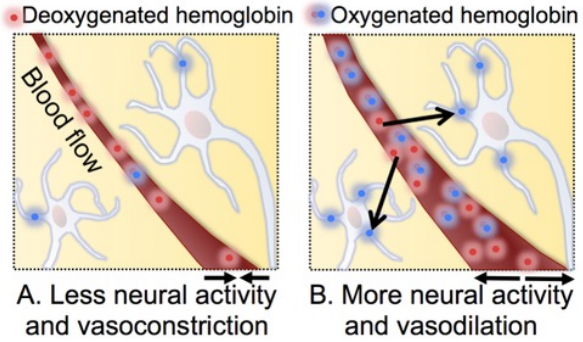
Frames = Volumes
TR = ~3 sec
T2* contrast:
sensitive to BOLD

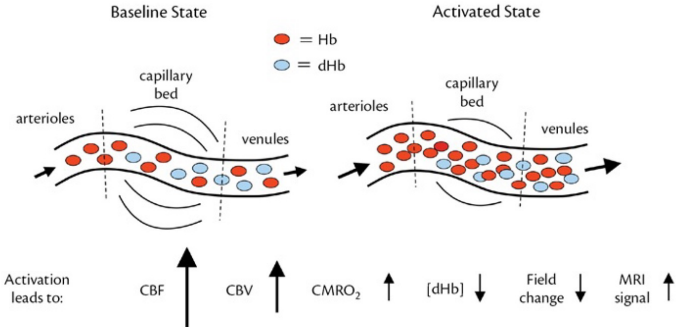


FMRI CONCEPTS: THE BOLD SIGNAL



The **BOLD** Signal



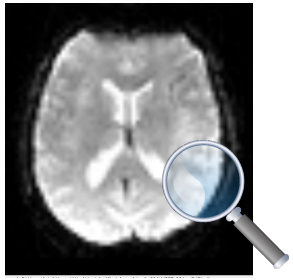


Blood oxygen level dependent (**BOLD**) signal

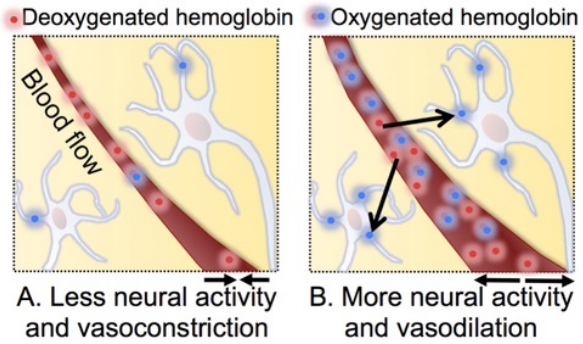
- Active neurons require oxygen! (action potentials are expensive)
- Blood levels (CBF) increase, capillaries dilate, to supply oxygen and glucose to activated neurons
- Unbalance between oxygenated and deoxygenated hemoglobin → BOLD
- The deoxygenated hemoglobin disturbs the local magnetic field
- Higher BOLD → More oxygenated hemoglobin → High activity

→ BOLD is an indirect measure of brain activation

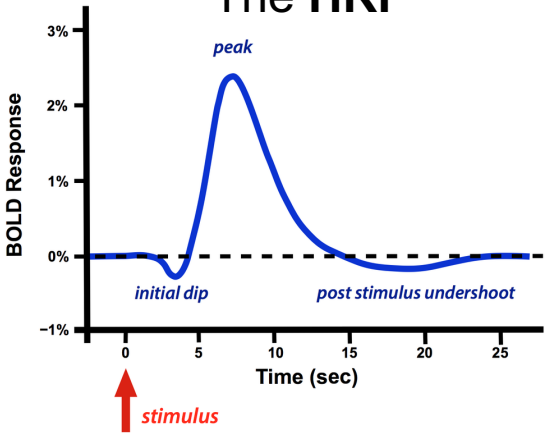
FMRI CONCEPTS: THE HEMODYNAMIC RESPONSE



The **BOLD** Signal



The **HRF**



The hemodynamic response function (HRF)

- "Ideal" BOLD response function
- Peak around 6 seconds, take ~20 to baseline
- Low temporal resolution, difficult to know the exact time of neuronal changes
- However, good for image acquisition (no need to acquire 1 image every millisecond)

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Functional MRI: Basic Pre-Processing

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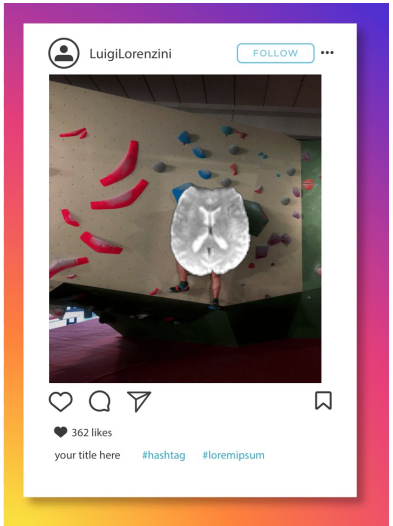
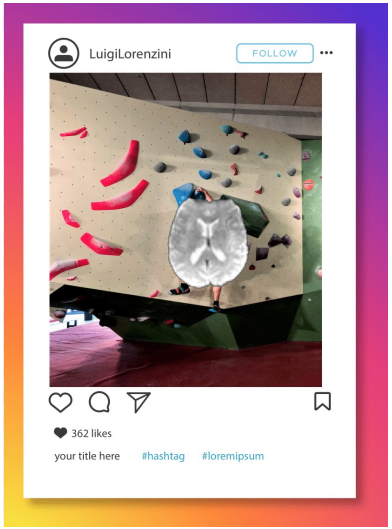
WHY PRE-PROCESSING AND QC OF FMRI

1. fMRI data are prone to a number of artifacts and sources of variability

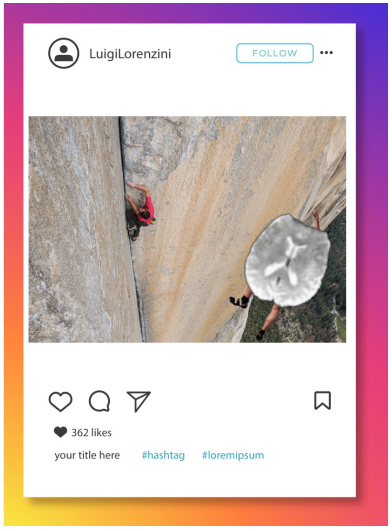
2. Raw images are not usable for direct inspection or statistical analysis



Pre-processing



Extreme Pre-processing



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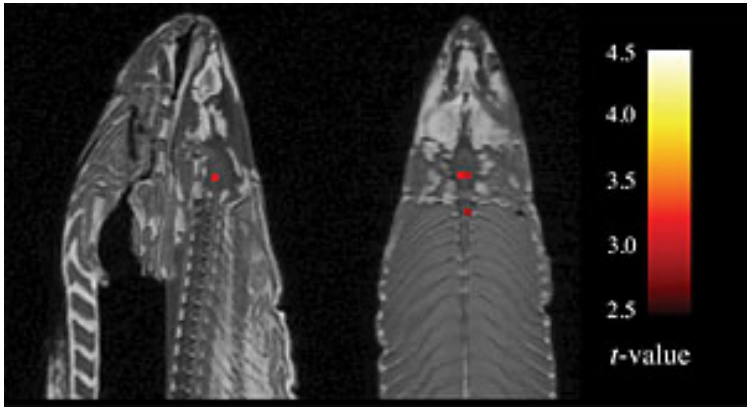
What a dead salmon tells us about fMRI pre-processing and analysis

"shown a series of photographs depicting human individuals in social situations. The salmon was asked to determine what emotion the individual in the photo must have been experiencing."



We want to clean "NOISE" and enhance our effect of interest

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PRE-PROCESSING: WHAT AND HOW ?

What

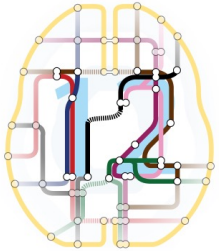
A series of steps used to

1. Remove unwanted signal fluctuations and artefacts
2. Clean desired effects
3. Standardize data

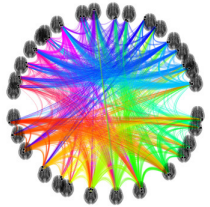
<u>Before Statistical analysis</u>

- Distortion Correction
- Motion Correction
- Standard Space Mapping
- Spatial Smoothing
- Temporal Filtering

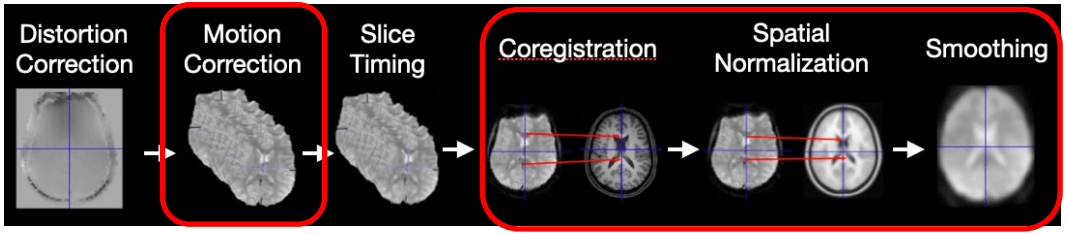
How



CONN



fMRIPrep a robust preprocessing pipeline for task-based and resting-state fMRI data



Variability in the analysis of a single neuroimaging dataset by many teams

Rotem Botvinik-Nezer, Felix Holzmeister, ... Tom Schonberg + Show authors

Nature **582**, 84–88 (2020) | Cite this article

44k Accesses | **244** Citations | **2062** Altmetric | Metrics

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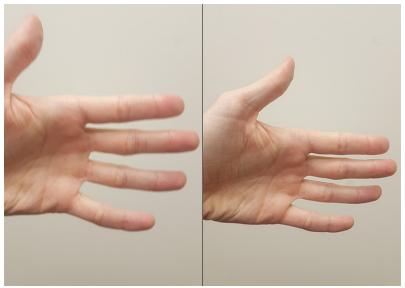
MOTION CORRECTION

Why

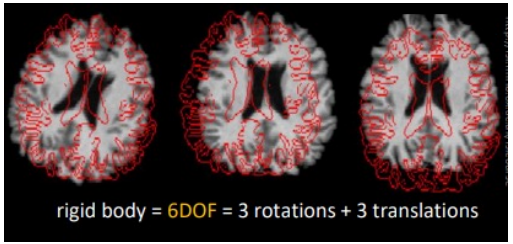
- As for real pictures, a moving target will look blurry
- We measures from moving voxels (different across the session)
- Introduce confounds (e.g. in response to a stimulus/ whole-brain correlations) that are stronger than physiological changes

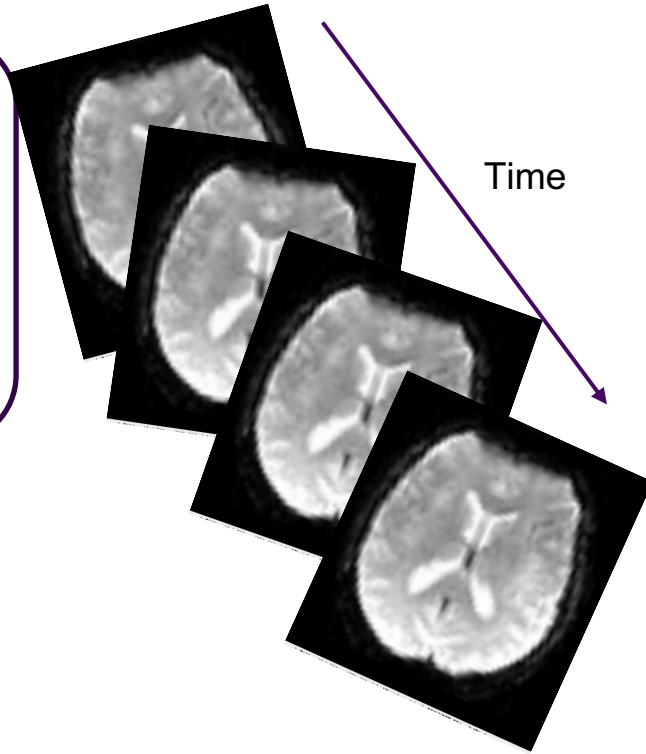


From https://andysbrainbook.readthedocs.io/

How

- Align all the volumes from a timeseries with a reference volume
- Usually, the reference volume is the first, middle or last of the TS
- Use rigid body transformation (6 DOF)
- Iterative process of finding the best alignment between 2 volumes (cost function)





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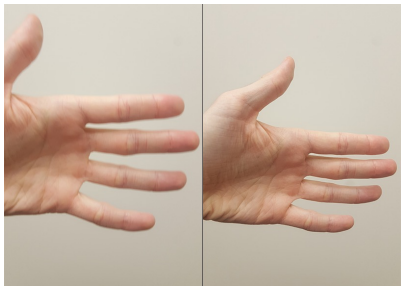

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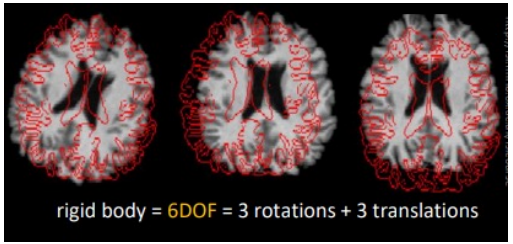

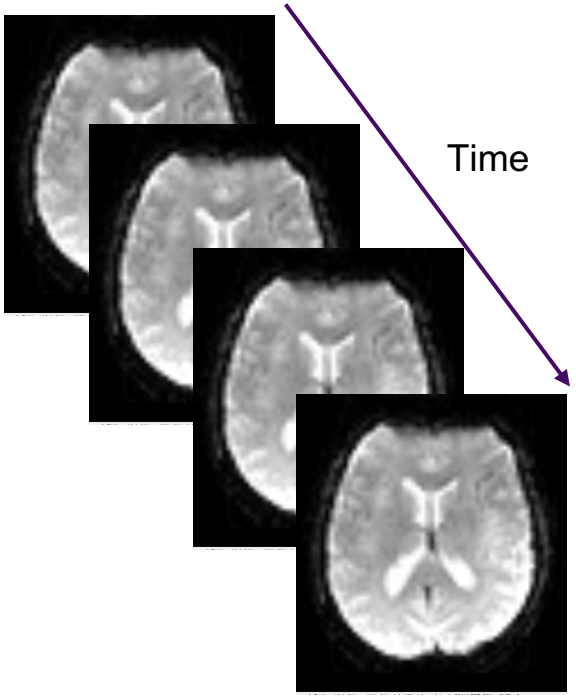

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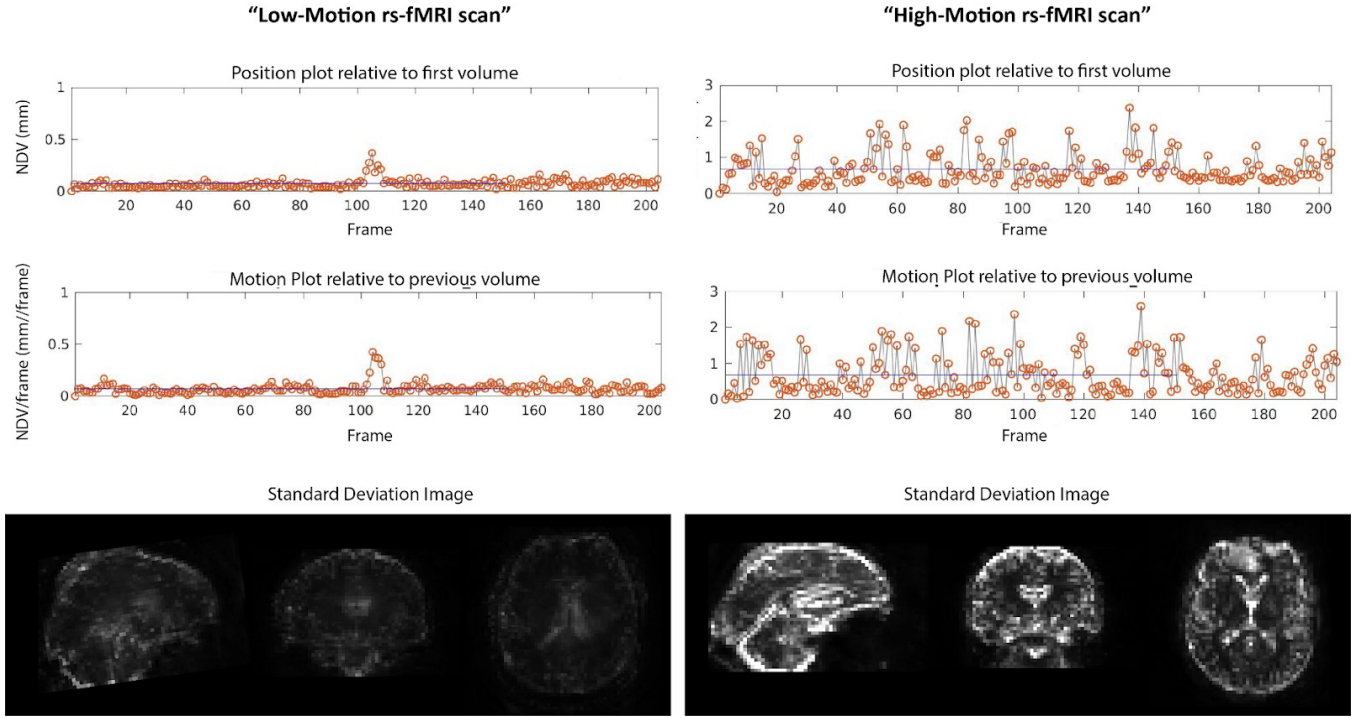
MOTION CORRECTION: MOTION PARAMETERS



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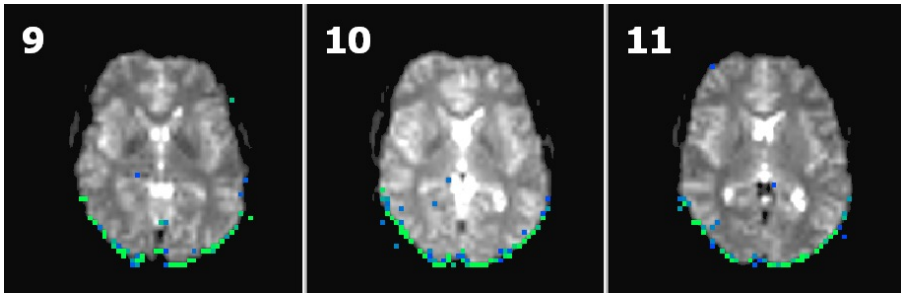
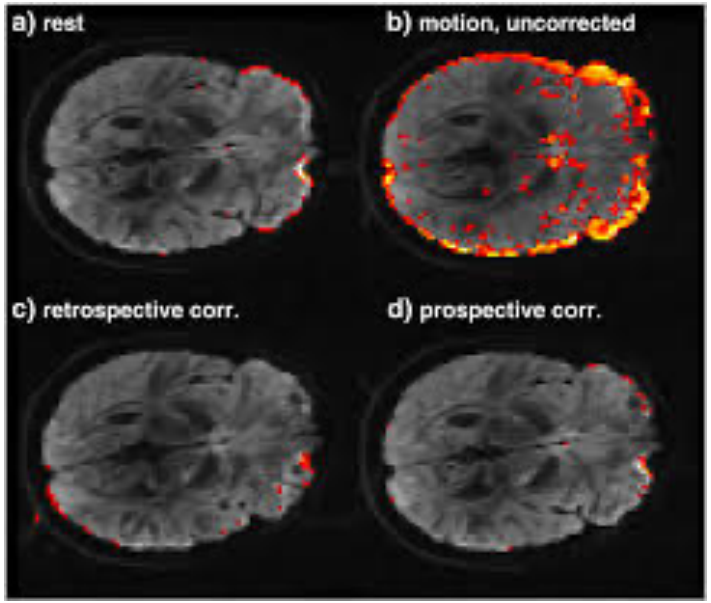
MOTION ARTIFACTS IN THE RESULTS





Kober, T., Gruetter, R., & Krueger, G. (2012). Prospective and retrospective motion correction in diffusion magnetic resonance imaging of the human brain. *Neuroimage*, *59*(1), 389-398.

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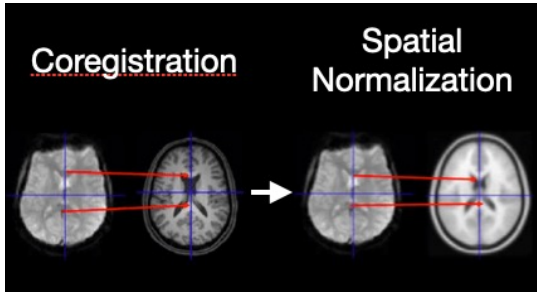
STANDARD SPACE MAPPING

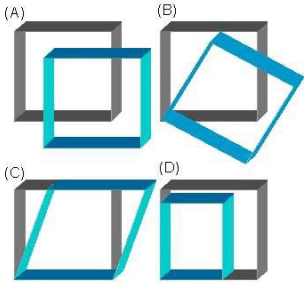
Why

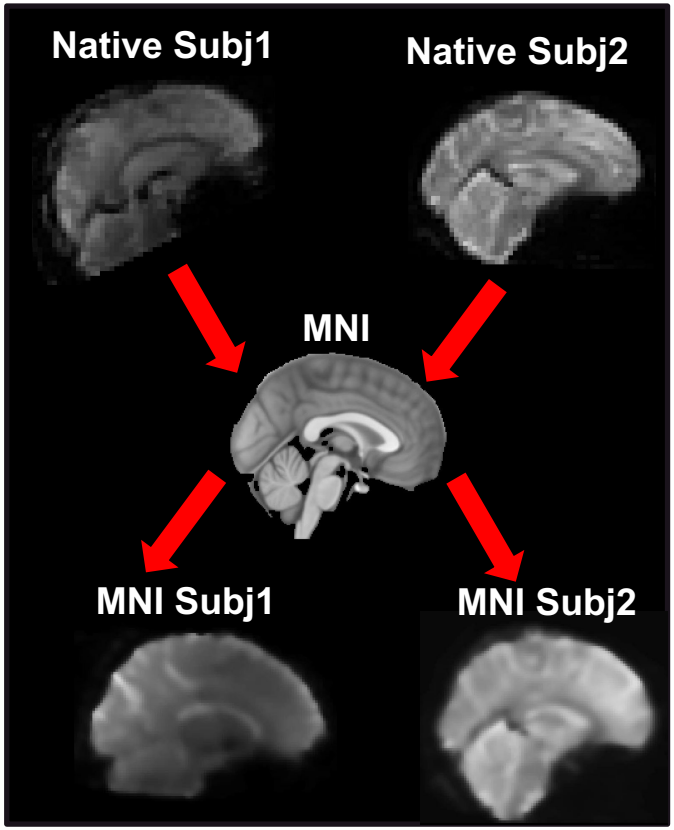
- Differences in brain size and shape exist between different individuals.
- For group analysis, we need voxels between different brains to correspond
- Registration or Normalization or Standard Space Mapping

How

- Affine Transformation, similar to rigid body but 12 DOF (allows zooms and shears)
- We register to the anatomical T1 (coregistration), previously registered to MNI space (normalization)
- Then we can apply the T1 -> MNI transformation to our fMRI







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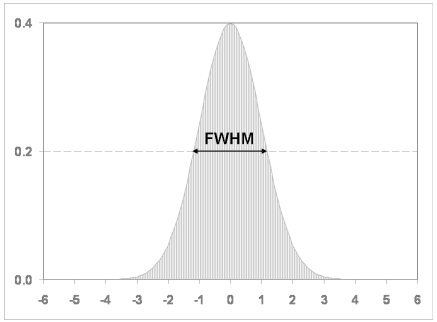
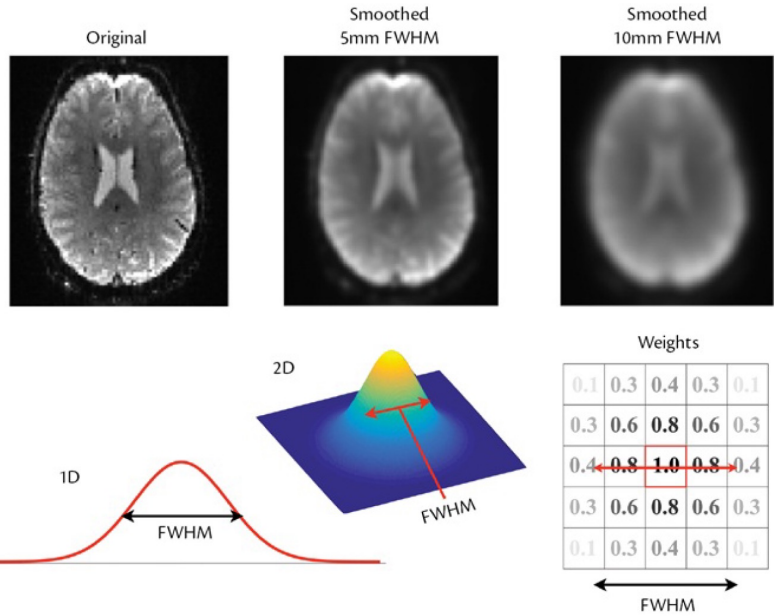
SPATIAL SMOOTHING

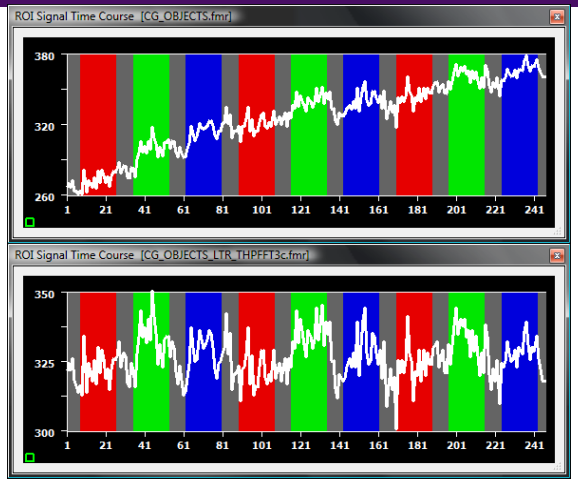
- Smooth functional data = replace the value at each voxel with a weighted average of that voxel's neighbors
- Lower resolution? Yes. But also, greater signal to noise!
- High frequencies of the signal are removed while enhancing low frequencies
- Gaussian kernel of specific width (FWHM) determines the amount of smoothing





TEMPORAL FILTERING (SMOOTHING)

- Remove noise based on its frequency
- Low-frequency drifts: due to both physiological and physical (scanner-related) noise
- Linear and non-linear drifts
- Voxel's timecourses represented as frequency domain (e.g. Fourier transform), low drifts are set to 0

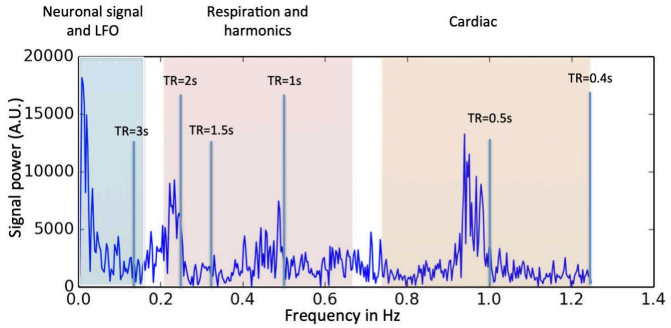


Examples of Scanner-related Noise:

- Hardware imperfections
- Heating of components

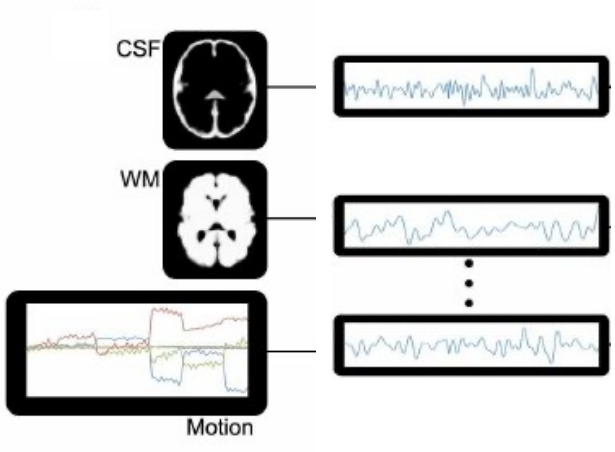
Examples of Physiological Noise:

- Cardiac pulsations
- Respiratory Cycle

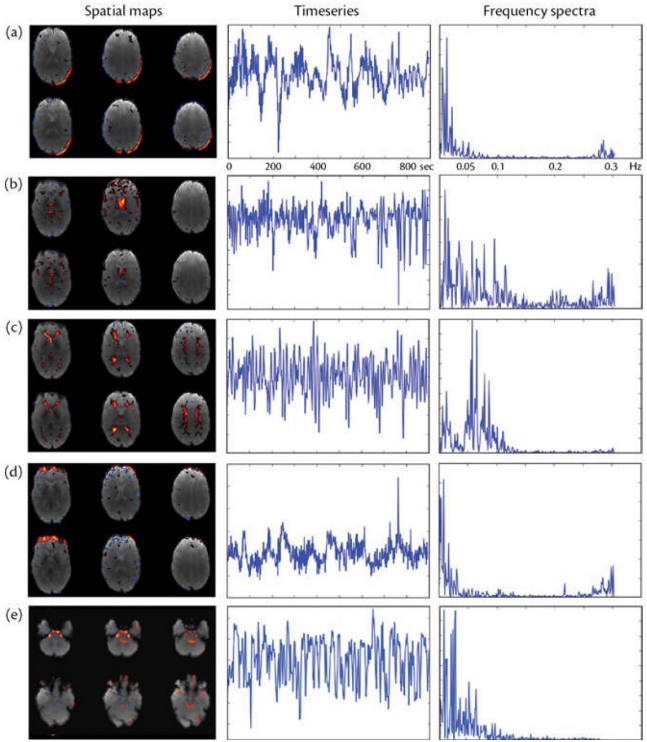


FILTERING OF PHYSIOLOGICAL NOISE: STATISTICAL APPROACHES

GLM approach



ICA approach



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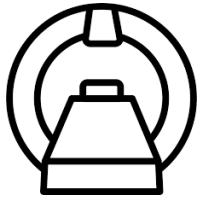
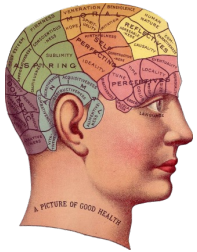
Functional MRI: Derived data and applications

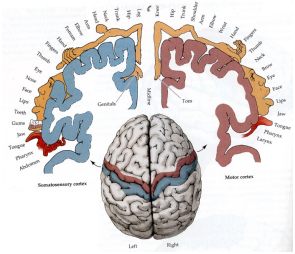
FMRI: CURRENT APPLICATIONS

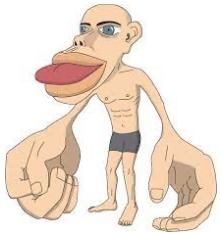
REST

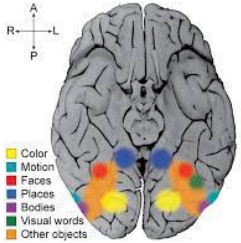


Functional Localization

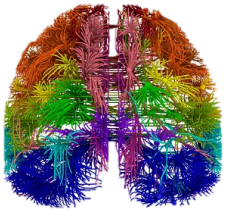


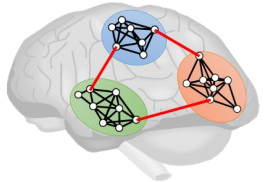


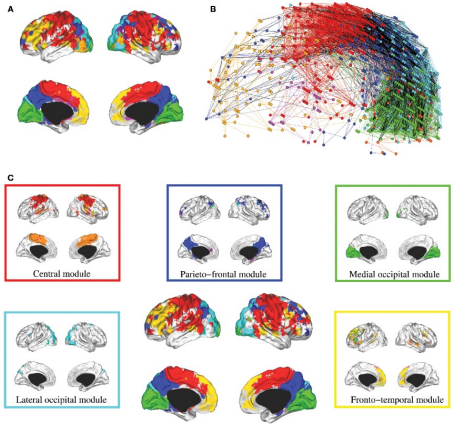




Brain Networks







Meunier, D. et al (2019)

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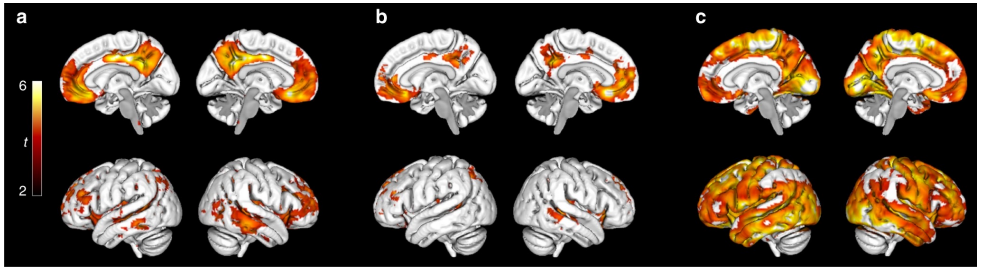
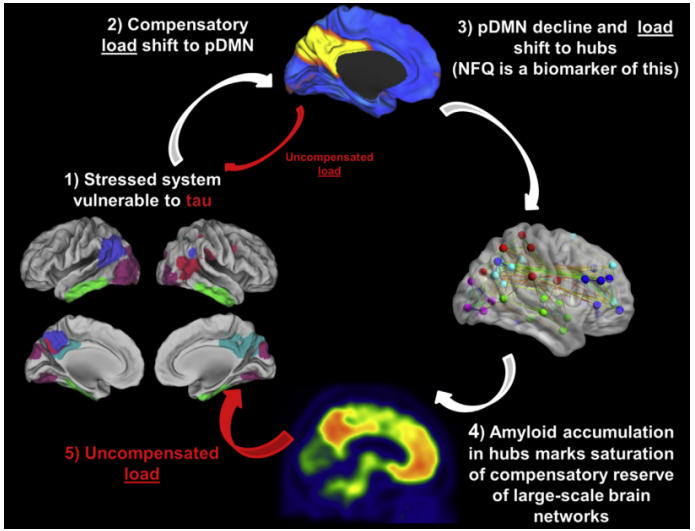
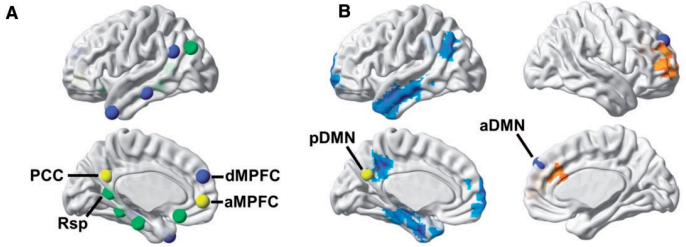
FUNCTIONAL ALTERATIONS IN AD

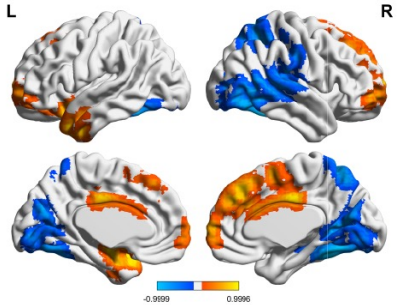


Palmqvist, et a. (2017).

Network failure cascade model







Decreased FC Increased FC

Jones, D. et al. (2016).

Lorenzini et al. (2022)

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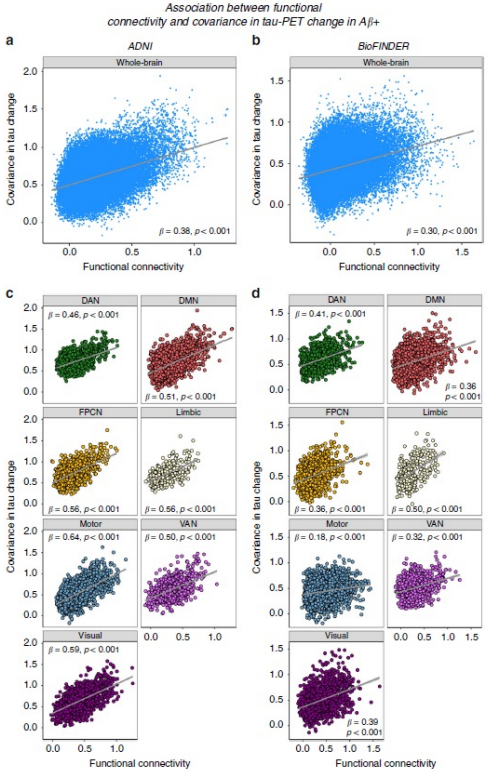
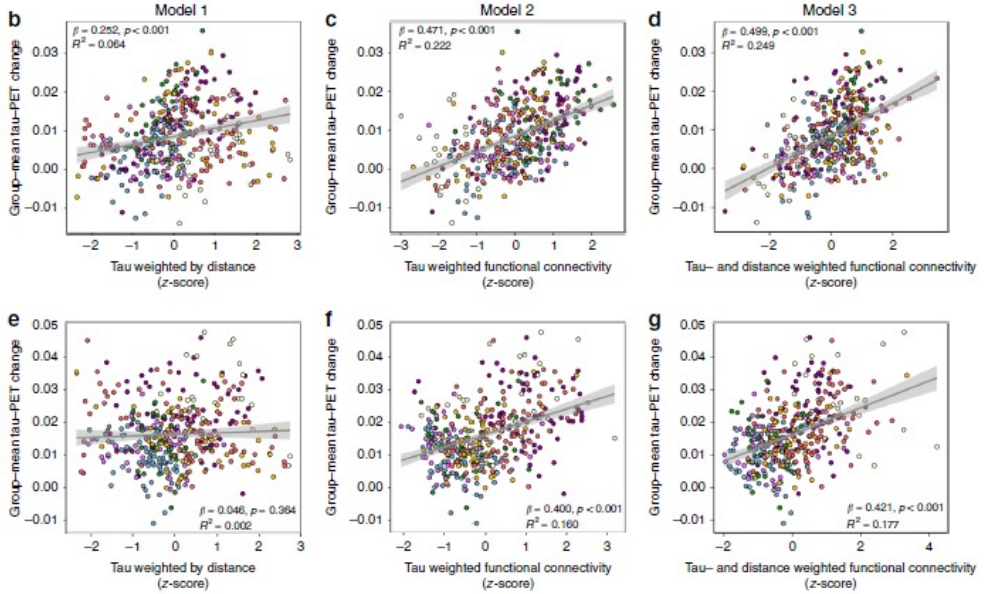
SPREADING OF PATHOLOGICAL PROTEINS ACROSS FUNCTIONAL CONNECTIONS





Franzmeier, N et al (2020).

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POP QUIZ!

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Question 1

fMRI motion correction works by:

a) Aligning volumes between two fMRI time series

b) Aligning volumes within on fMRI time series

c) Registering the fMRI scan to a structural scan

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Question 2

Spatial smoothing:

a) Decrease signal to noise ratio

b) Has no effect on signal to noise ratio

c) Increase signal to noise ratio

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Question 3

Which one of these statements is **false** about BOLD signal:

a) It's a measure of neuronal electrical activity

b) It's based on the unbalance between oxygenated and deoxygenated hemoglobin

c) Measures brain hemodynamic response

Thank You!

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