Principles of fMRI

Part II

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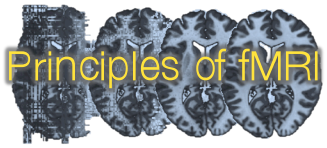
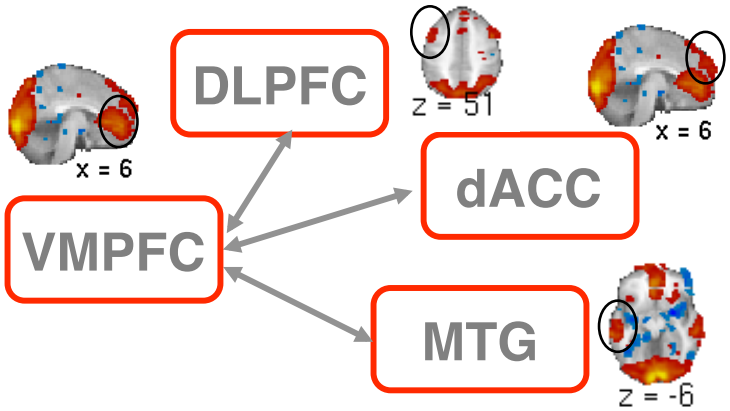
Functional Connectivity

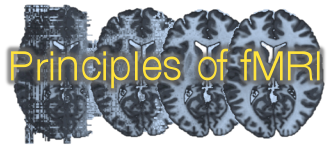
Brain Connectivity



- Functional Connectivity
  - Undirected association between two or more fMRI time series and/or performance and physiological variables.
  - Makes statements about the structure of relationships among brain regions.
  - Usually makes no assumptions about the underlying biology.

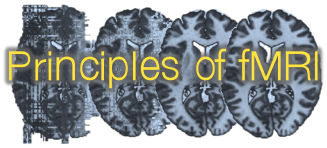


Functional Connectivity

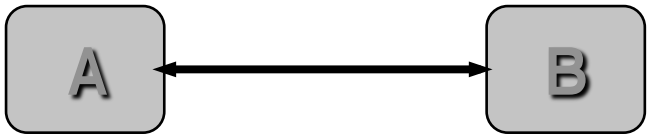


- Methods include:
  - Seed analysis
  - Inverse covariance methods
  - Multivariate decomposition methods
    - Principle Components Analysis
    - Independent Components Analysis
    - Partial Least Squares

Bivariate Connectivity

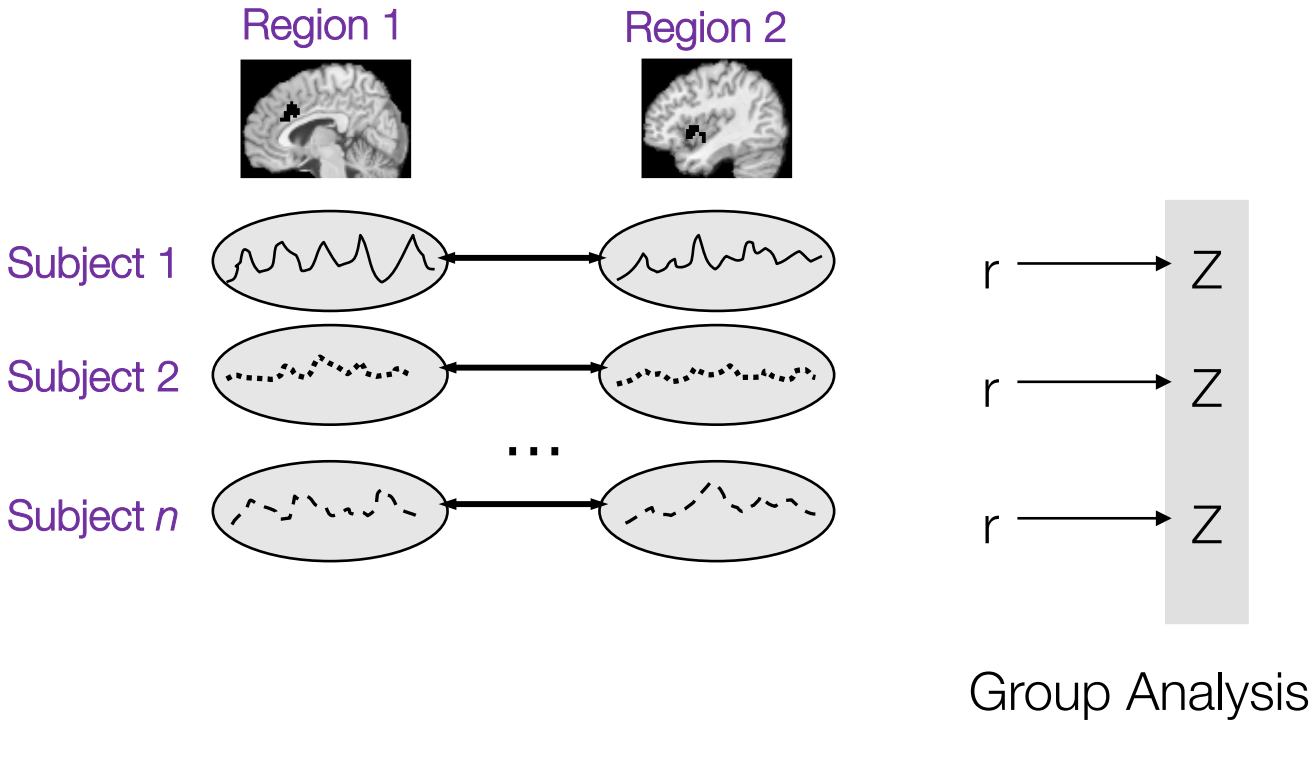


- Simple functional connectivity
  - Region A is related to Region B.
  - Provides information about relationships among regions.
  - Can be performed on time series data within a subject, or individual differences (contrast maps, one per subject).

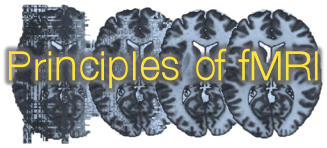


Time Series Connectivity

- Calculate the cross-correlation between time series from two separate brain regions.



Seed Analysis

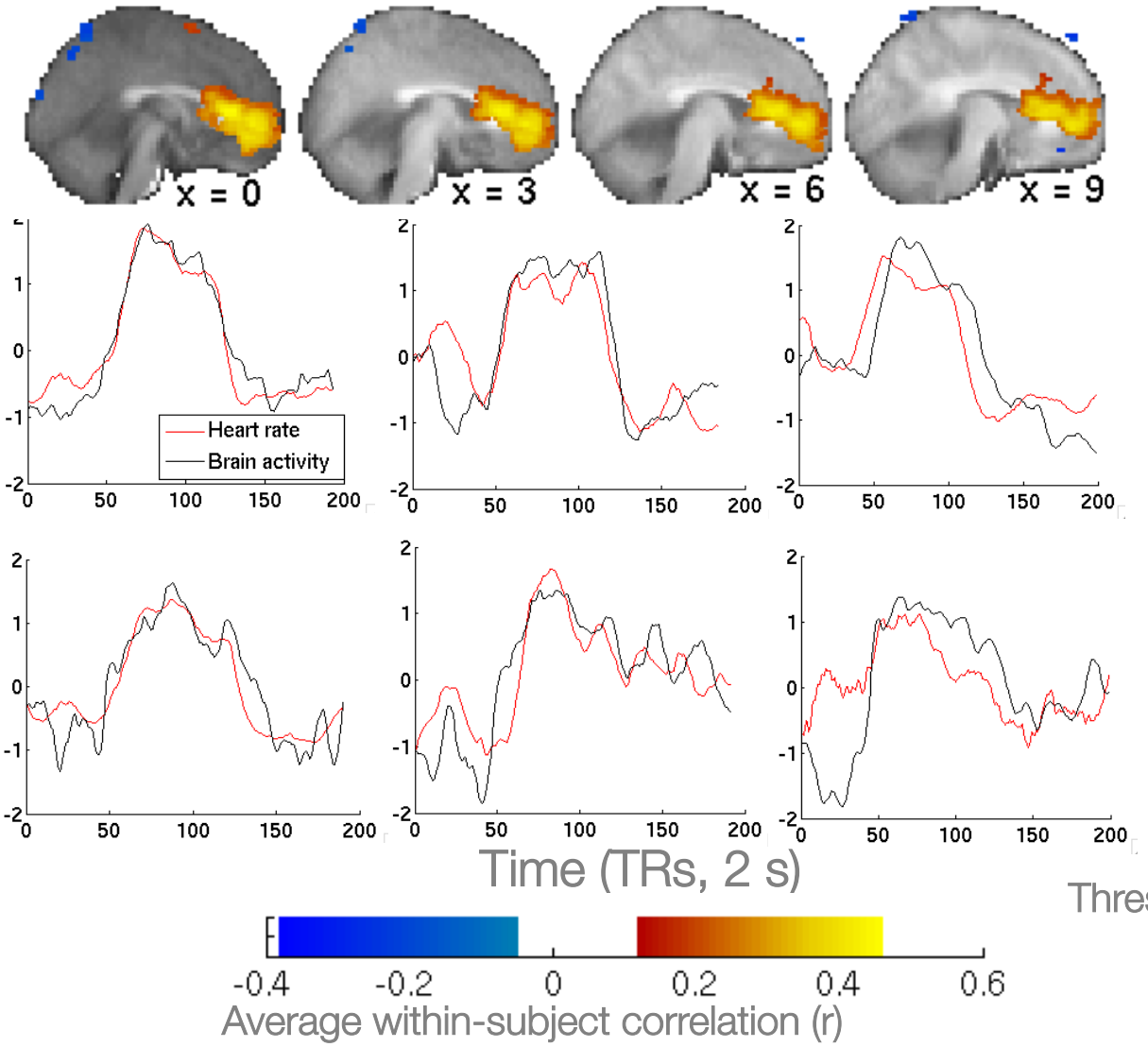


- In seed analysis the cross-correlation is computed between the time course from a predetermined region (seed region) and all other voxels.

- This allows researchers to find regions correlated with the activity in the seed region.

- The seed time course can also be a performance or physiological variable

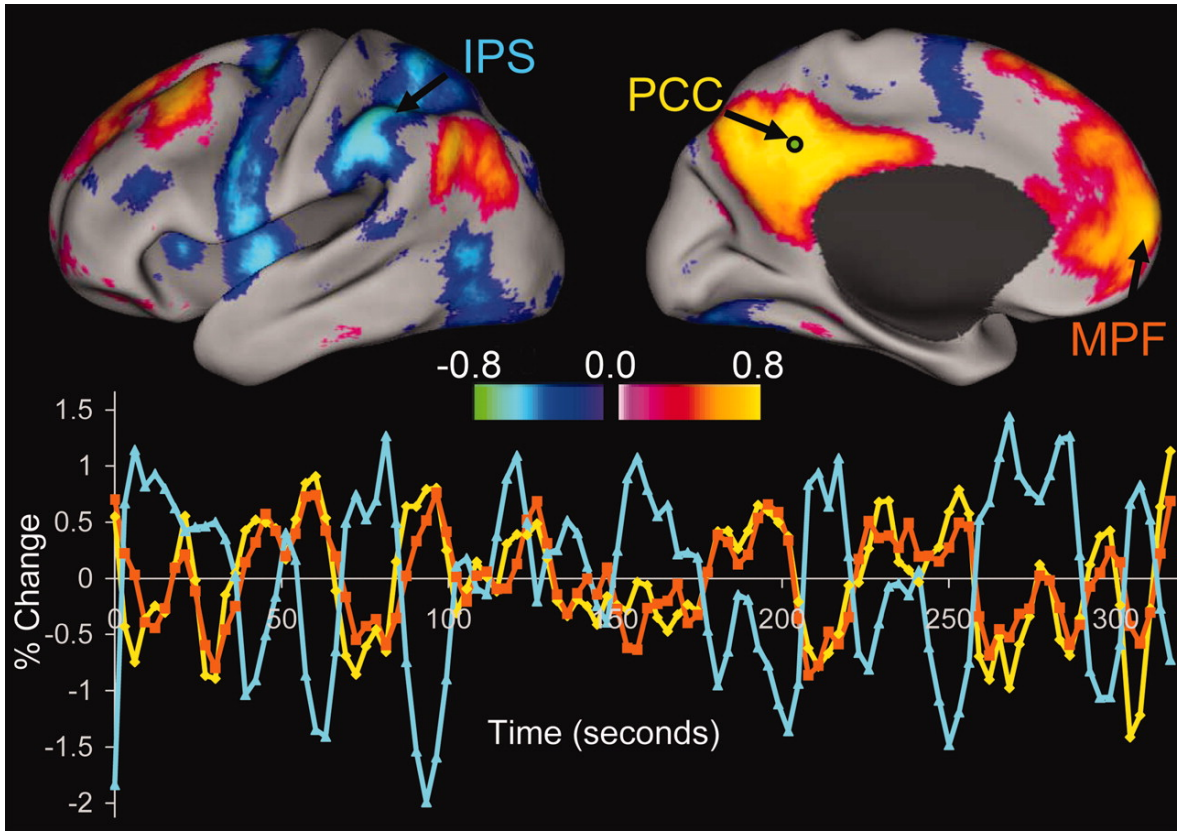
Correlations Between Brain Activity and Heart-rate



VMPFC

Threshold: p < .005

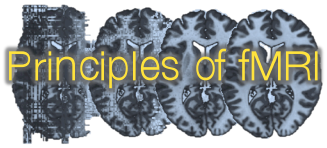
Resting State fMRI



Intrinsic correlations between a seed region in the PCC and all other voxels in the brain for a single subject during resting fixation.

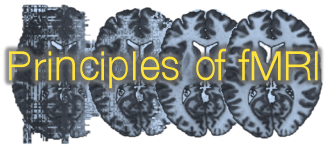
Fox et al. 2005

Issues



- One of the main problems with time series connectivity is the fact that there may be different hemodynamic lags in different regions:
  - Time series from different regions may not match up, even if neural activity patterns match up.
  - If lags are estimated from data, temporal order may be caused by vascular (uninteresting) or neural (interesting) response.

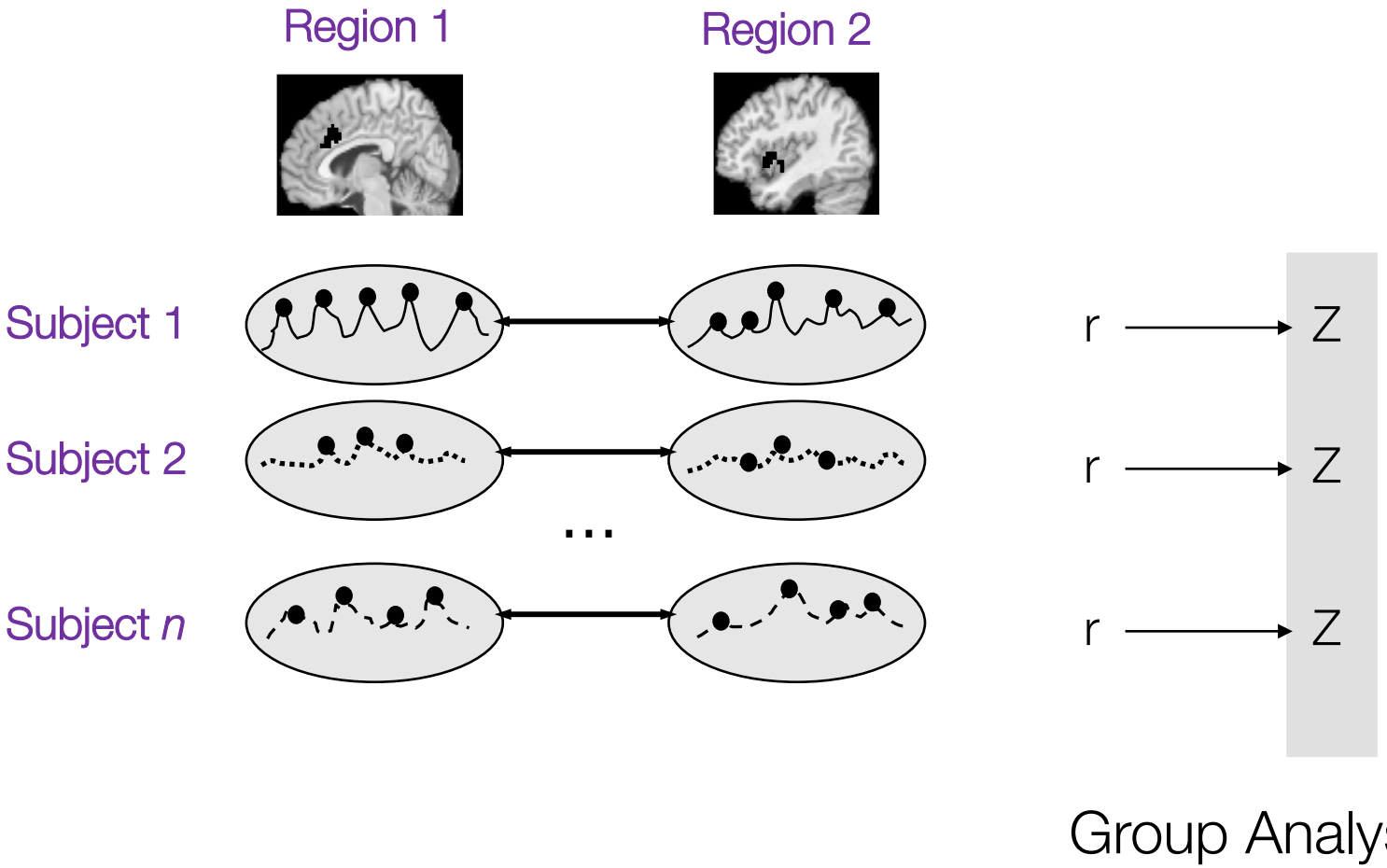
Beta Series



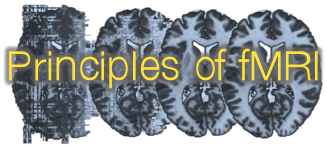
- The beta series approach can be used to minimize issues of inter-region neurovascular coupling.

- Procedure:
  - Fit a GLM to obtain separate parameter estimates for each individual trial.
  - Compute the correlation between these estimates across voxels.

Beta Series


Region 1
Region 2
Subject 1
Subject 2
...
Subject *n*
r
Z
r
Z
r
Z
Group Analysis

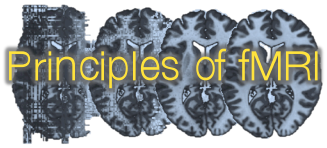
Individual Differences



- One way of studying differences between groups of subjects is to use some trait as a covariate in between-subject analysis.

- These types of analysis of individual differences allow researchers to study relationships between brain and behavior.

Individual Differences



Subject

Contrast Image

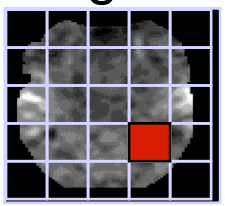
Seed Value

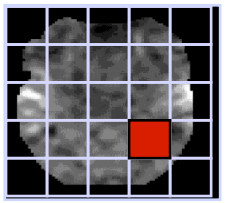
Group Results

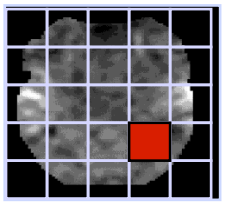
1

2

N



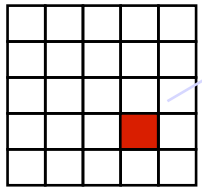


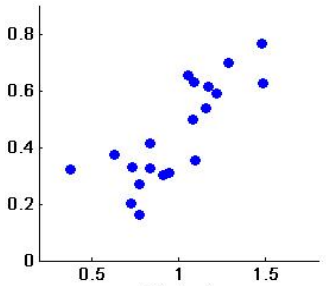


x_1

x_2

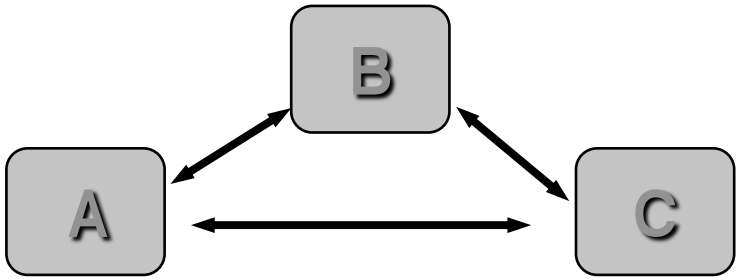
x_N



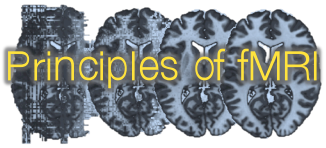


Partial Correlation

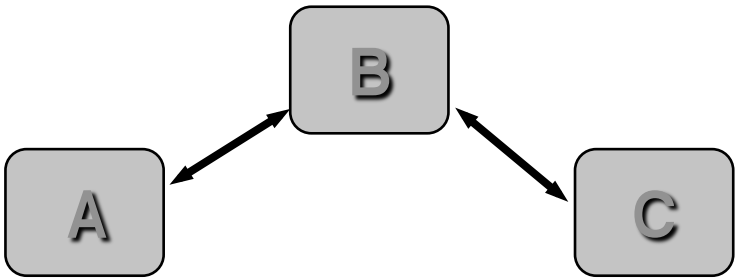
- Partial Correlation
  - Correlation between two regions, after the effect of all other regions have been removed.
  - Helps protect against ‘illusory’ correlations between regions (e.g., A and C uncorrelated after controlling for B).



Inverse Covariance Methods



- For multivariate normal data there exists a duality between the inverse covariance (precision) matrix and the graph representing relationships between regions.
  - Conditional independence between variables (regions) corresponds to zero entries in the precision matrix.
  - Graphical lasso (GLASSO) can be used to estimate sparse precision matrices and graphs.



$$\Sigma^{-1} = \begin{bmatrix} & & 0 \\ & & \\ 0 & & \end{bmatrix}$$

End of Module

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