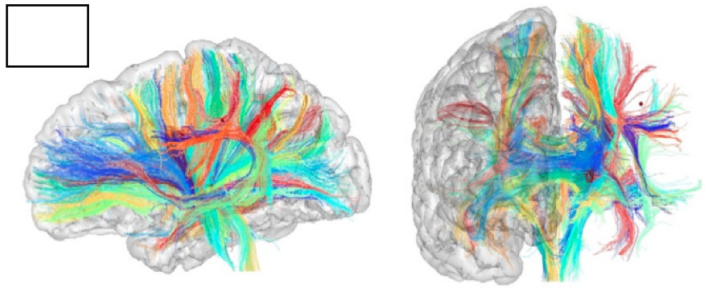
Connectivity Intro

Scott Peltier
University of Michigan

University of Michigan Functional MRI Course 2022

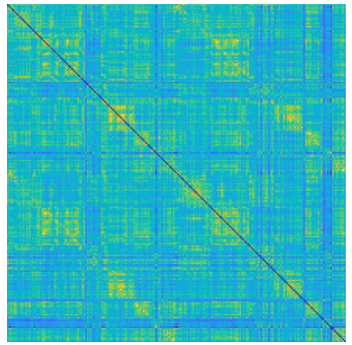
Connectivity definitions



Anatomical/structural connectivity: presence of axonal connections

- example: **tracing techniques, DTI**

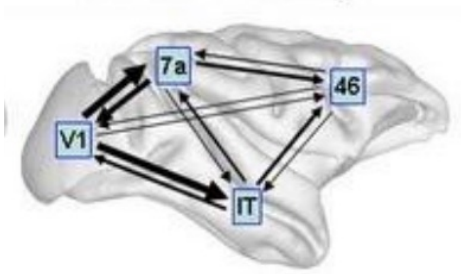
Functional connectivity: statistical dependencies between regional time series



- **Simple temporal correlation between activation of remote neural areas**
- Descriptive in nature; establishing whether correlation between areas is significant
- example: **seed voxel, eigen-decomposition (PCA, SVD), independent component analysis (ICA)**

Effective connectivity: causal/directed influences between neurons or populations

- **The influence that one neuronal system exerts over another** (Friston et al., 1997)
- Model-based; analysed through model comparison or optimisation
- examples: **SEM** - Structural Equation Modelling
  DCM - Dynamic Causal Modelling



Sporns 2007

Adapted from UCL Intro to Connectivity

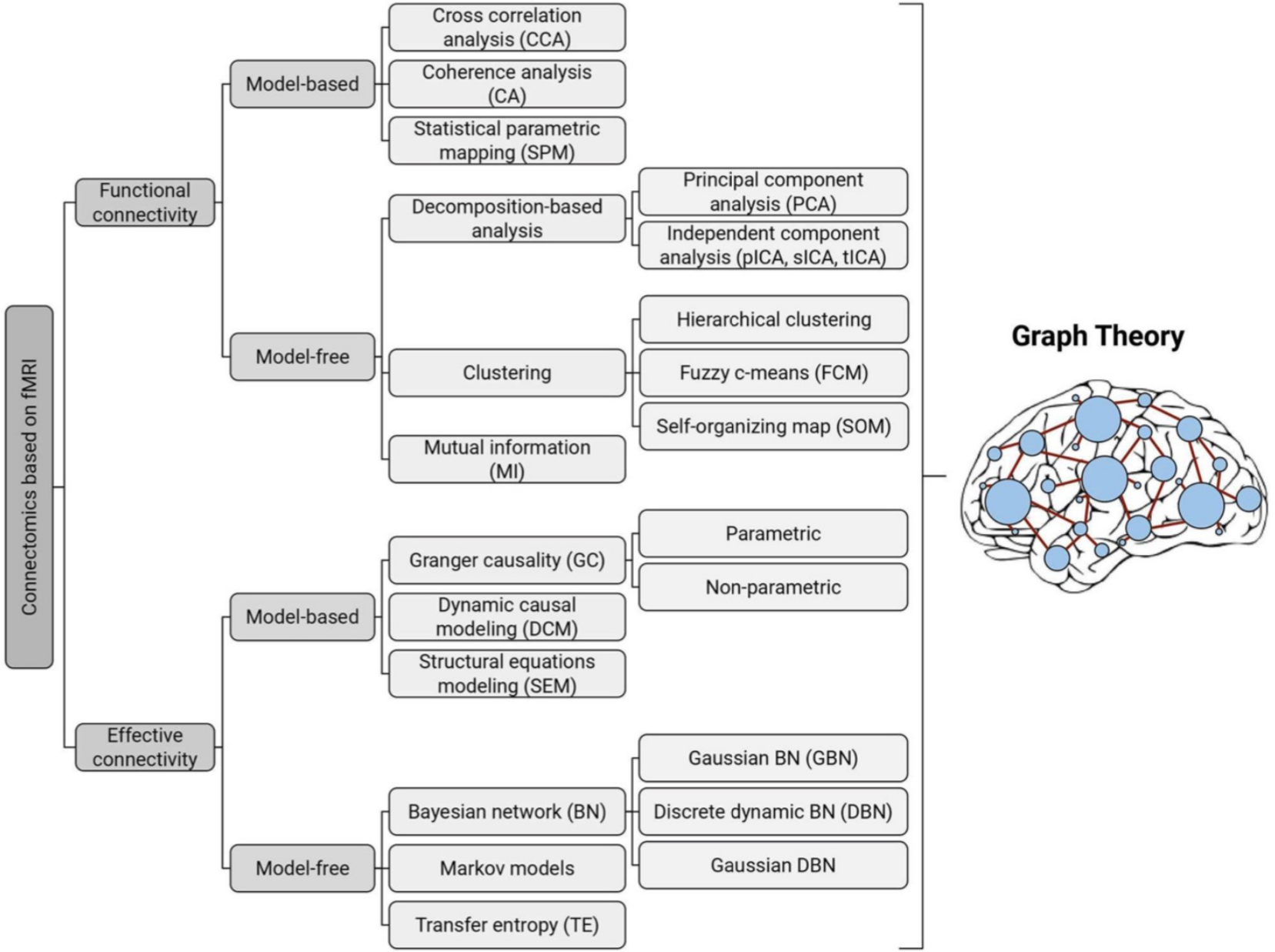


FIGURE 1 | Taxonomy of existing methods for modeling functional and effective connectivity patterns using fMRI. Each of the identified methods can be represented in terms of a graph, where the nodes correspond to cortical or subcortical regions and the edges represent (directed or undirected) connections (Bullmore and Sporns, 2012); thereby all of them can be further examined with graph-theoretic measures.

Farahani et al.
Front Neuroscience
13:585 (2019)

Seed region construction

- Seed-based
  - Calculate connectivity between one region and all voxels
- ROI-based
  - Multiple regions, calculate ROI-ROI connectivity
- Parcellation
  - Regularly defined ROI definition
- These can both *a priori*, anatomical, or functional based

Functional connectivity

Seed based example (Hart et al., J Neurosurg 126:1941, 2017)

Pearson correlation

$$r(x) = \frac{\int S(x,t)R(t)dt}{\left(\int R^2(t)dt \int S^2(x,t)dt\right)^{1/2}}$$

$$Z(x) = tanh^{-1}(r(x))$$

Fisher z transformation

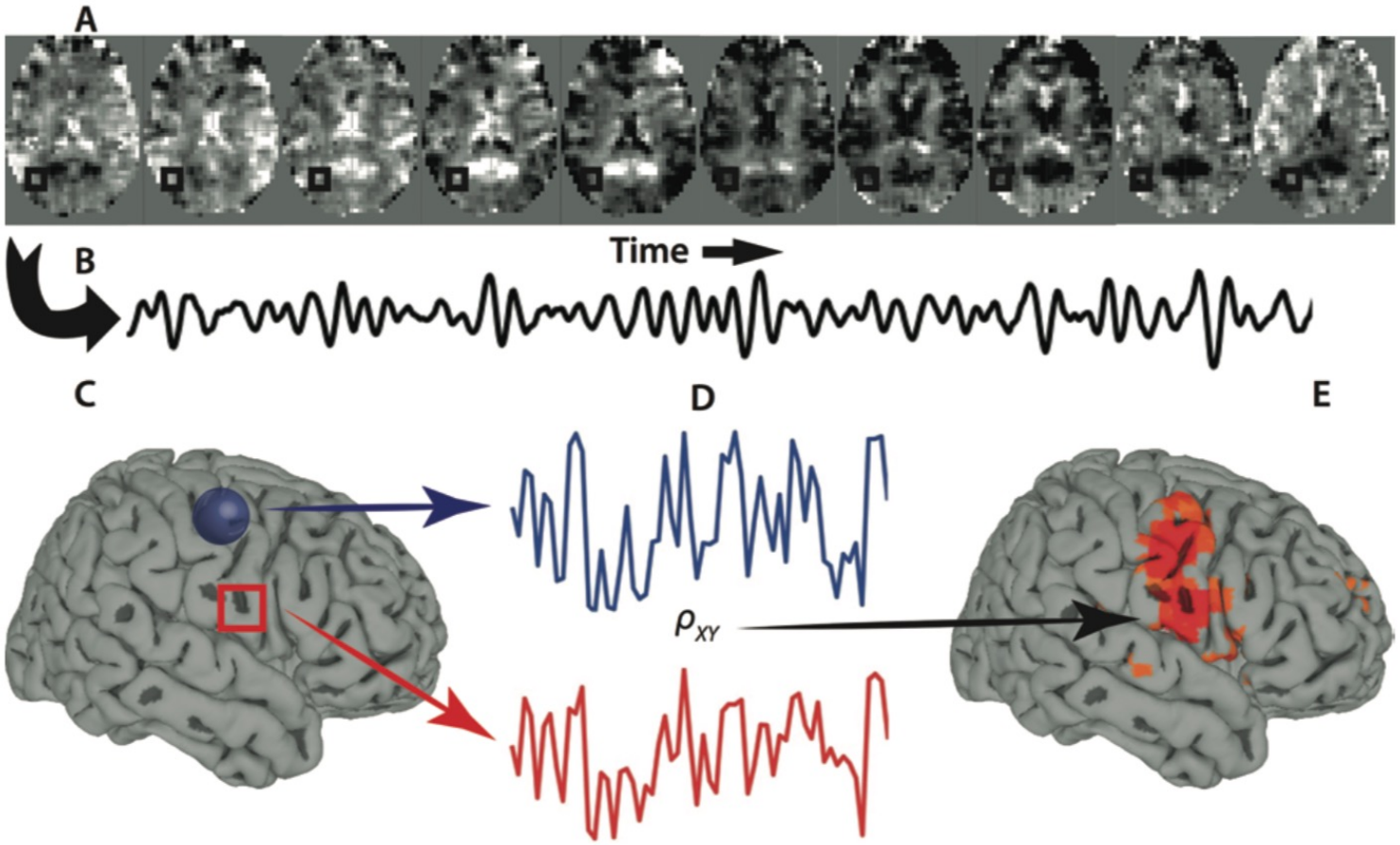
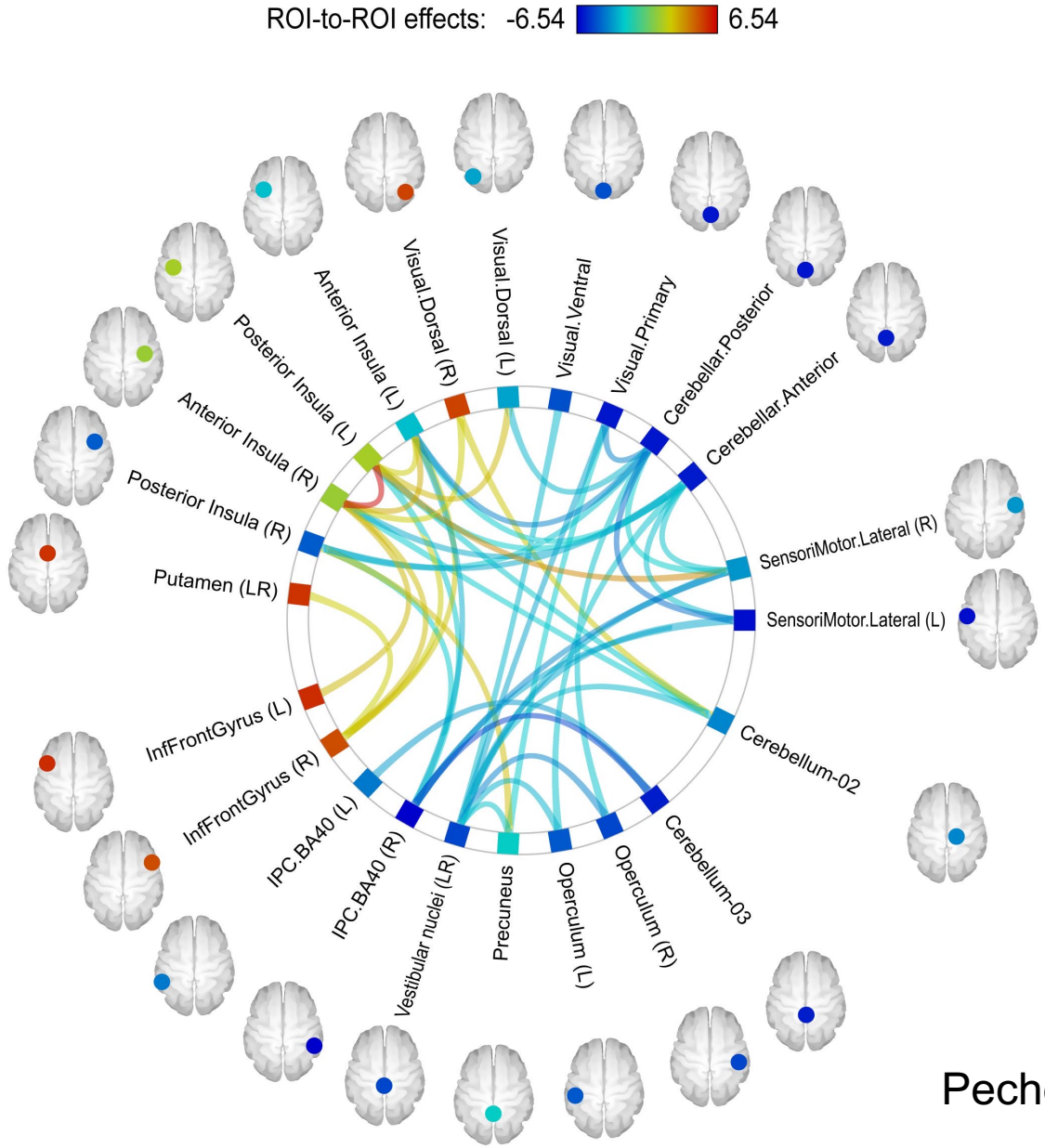


FIG. 1. The SCA method. **A:** An rsfMRI sequence (in the present study, a multiecho echo-planar imaging series) acquired 269 whole-brain 3D volumes over the scanning period (1 volume was acquired in 2.42 sec [the TR], yielding a total acquisition time of 10 min and 51 sec). The *black box* in the left lower brain region illustrates how the BOLD contrast changed over time. **B:** Each voxel therefore has a signal contrast change over time or the time series, which is shown here, with the time series of the region highlighted by the black box. **C:** A seed (in *blue*) is chosen depending on, for example, previous literature findings, a scientific hypothesis, or task-based activation. We selected a seed in the middle precentral gyrus and used a *red box* to highlight a region in the inferior precentral gyrus. The cortical reconstruction here was performed with the AFNI surface mapper SUMA (http://afni.nimh.nih.gov/afni/suma). **D:** The time series of this seed (in *blue*) is then compared with the time series of all other voxels, involving a measure of statistical correlation, most commonly Pearson correlation. Here, we used the area in the *red box* to show how the time series were compared. For SCA, however, all voxels were compared in a mass-univariate comparison independent of the seed time series. **E:** The voxel-wise correlation coefficients are rendered on the same cortical surface and thresholded to display those with a specified correlation (e.g., R > 0.5) Note, important preprocessing steps for both the rsfMRI scans and structural images need to be carried out before SCA. Figure is available in color online only.



ROI-to-ROI example

Pechenkova, et. al., Front. Physiol. 10:761 (2019)

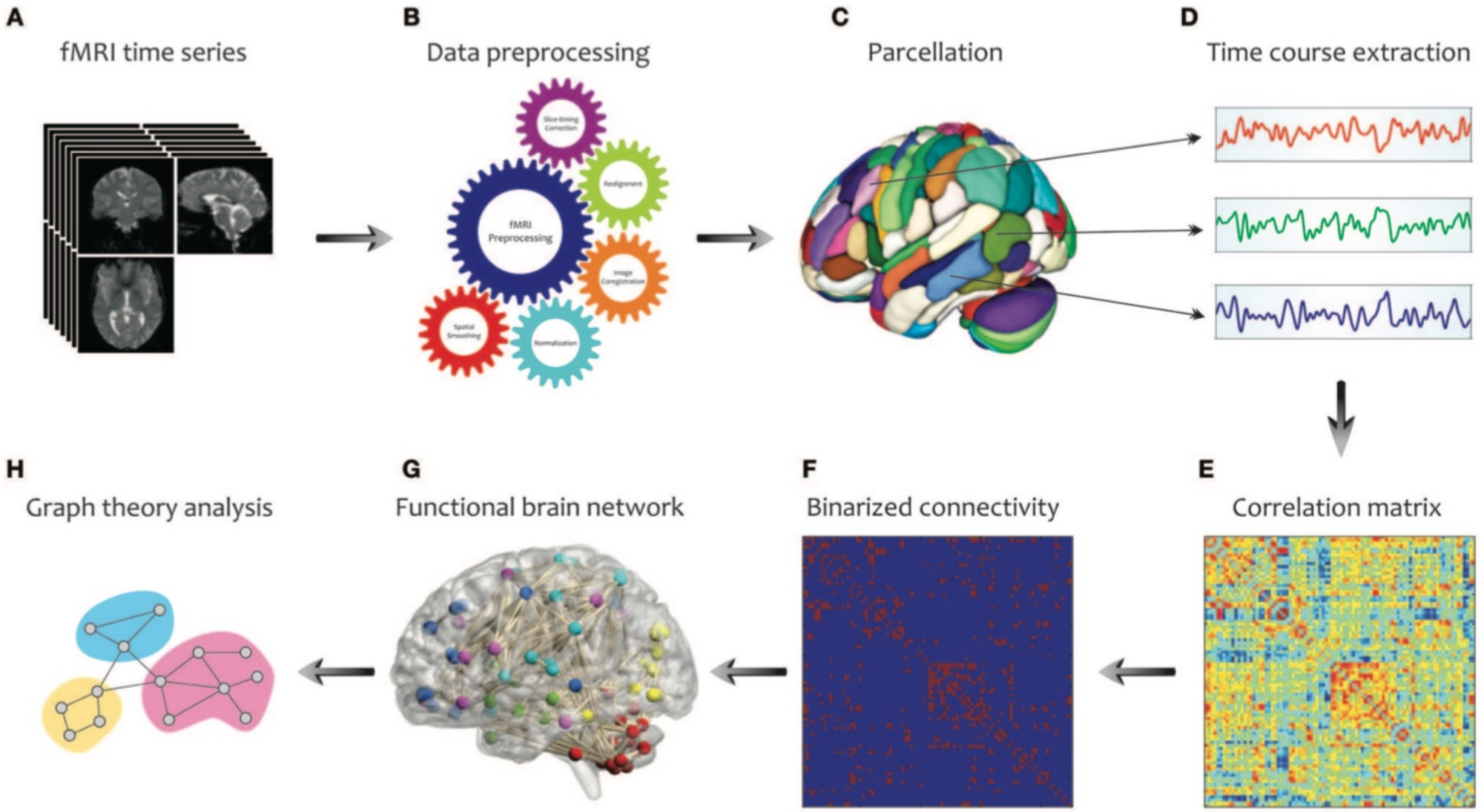


FIGURE 3 | Schematic representation of brain network construction and graph theoretical analysis using fMRI data. After processing **(B)** the raw fMRI data **(A)** and division of the brain into different parcels **(C)**, several time courses are extracted from each region **(D)** so that they can create the correlation matrix **(E)**. To reduce the complexity and enhance the visual understanding, the binary correlation matrix **(F)**, and the corresponding functional brain network **(G)** are constructed, respectively. Eventually, by quantifying a set of topological measures, graph analysis is performed on the brain's connectivity network **(H)**.

Farahani et al., Front Neuroscience13:585 (2019)

Dynamic connectivity

- Can calculate connectivity in time windows during fMRI time series
- Examine dominant brain states, dwell time in each state