电子科技大学
University of Electronic Science and Technology of China

# Functional connectome fingerprinting:

## identifying individuals using patterns of brain connectivity

**Emily S Finn, et al. [Nature 2015]**

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# Outline



- Introduction
- Fingerprint: brain connectivity
- Cognitive behavior prediction
- Discussion
- Conclusion

# Part 1 Introduction

# Introduction



- Human brain is known as the most sophisticated system in the world
  - $10^{11}$ neurons(神经元)
  - $10^{15}$ synaptic linkages(突触连接)
  - Complex structure connection and functional connection

# Introduction

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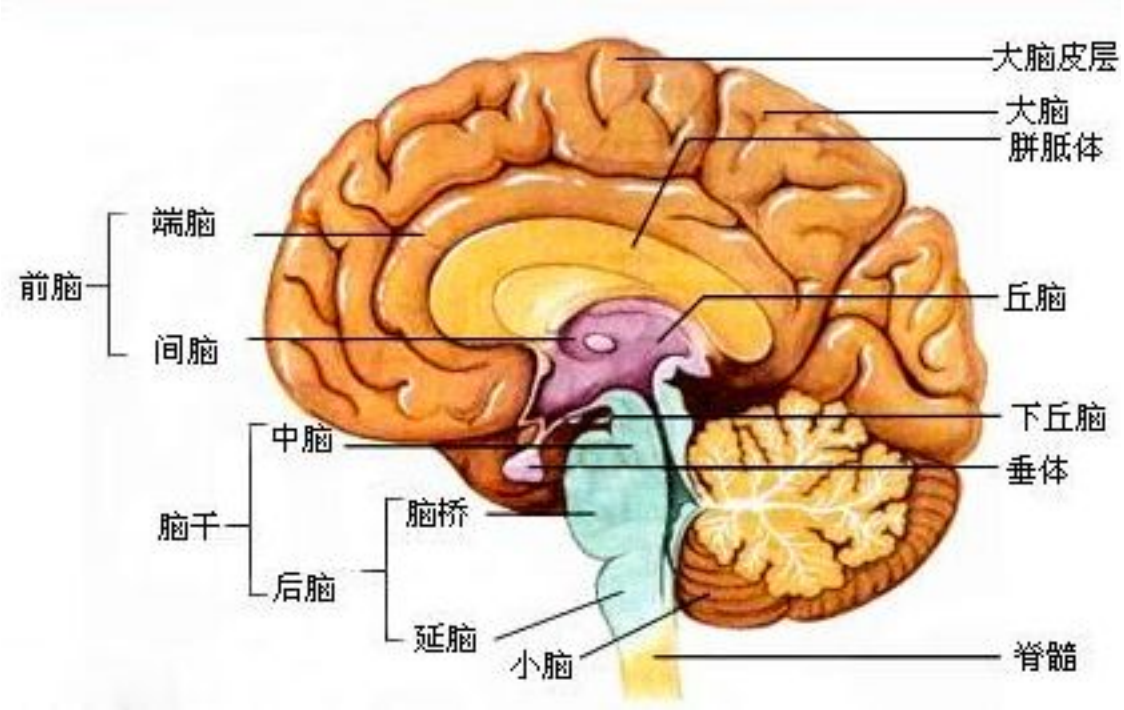
- Brain anatomical structure



# Introduction



- Neuroimaging lead the way to study the human brain, it includes various techniques:
  - **Magnetic resonance imaging(MRI, fMRI, DTI)**
  - Computed axial tomography(CT)
  - Electroencephalogram(EEG)
  - …

# Introduction

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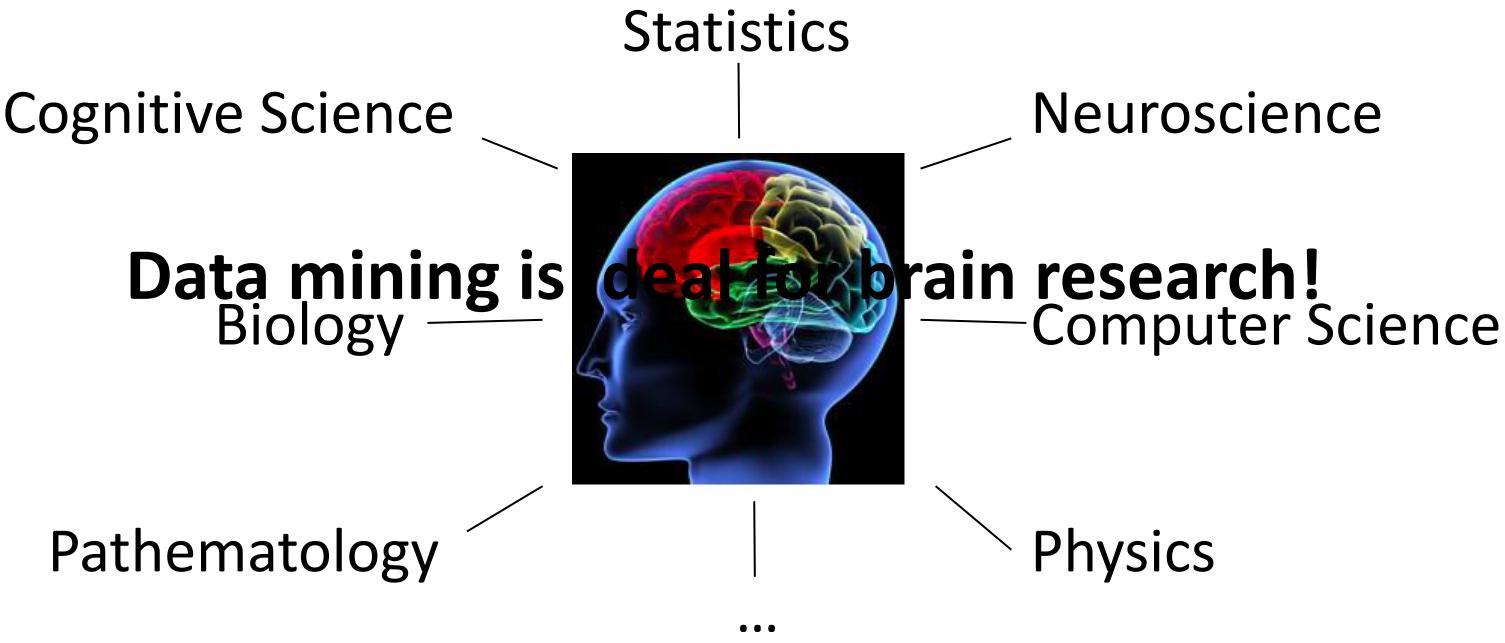
- Neuroimaging towards multidisciplinary sciences



# Introduction



- What is MRI?

**Magnetic resonance imaging** (MRI) is a medical imaging technique which provides us a Noninvasive (非侵入) and intuitive way to investigate the anatomy (解剖) and physiology of the body

# Introduction

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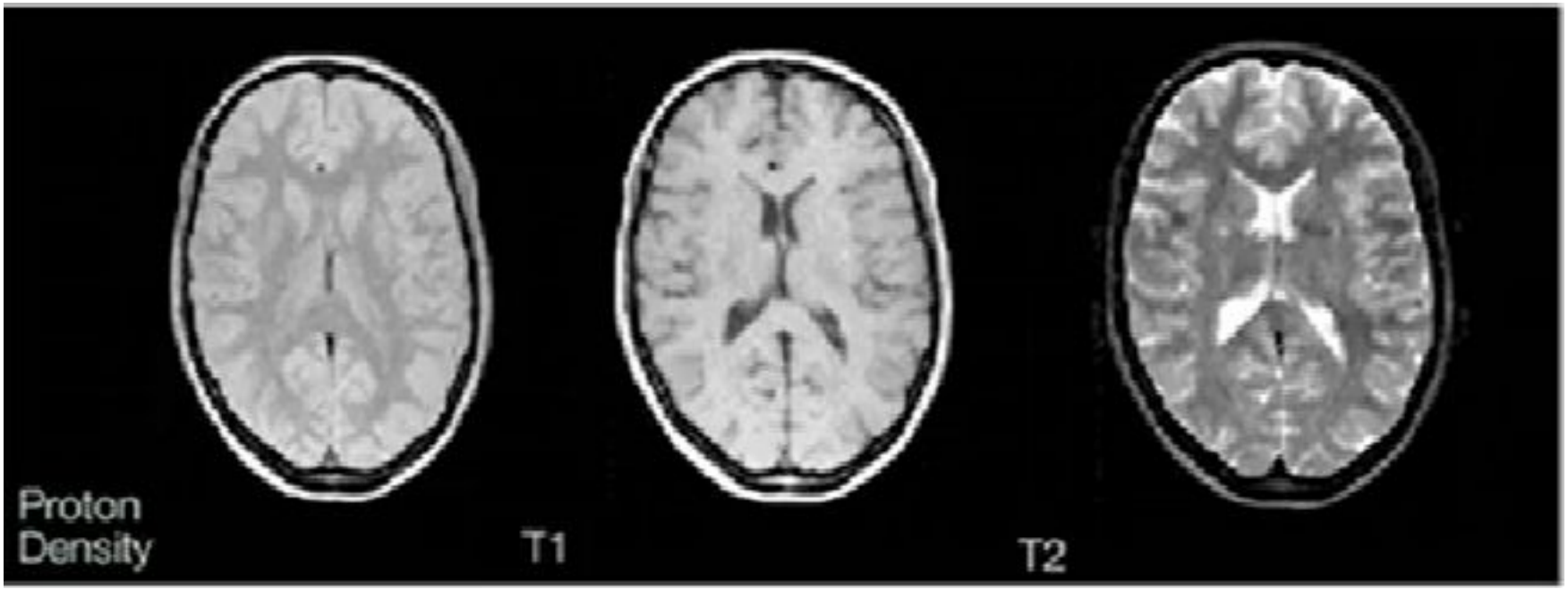
- MRI images look like this



# Introduction

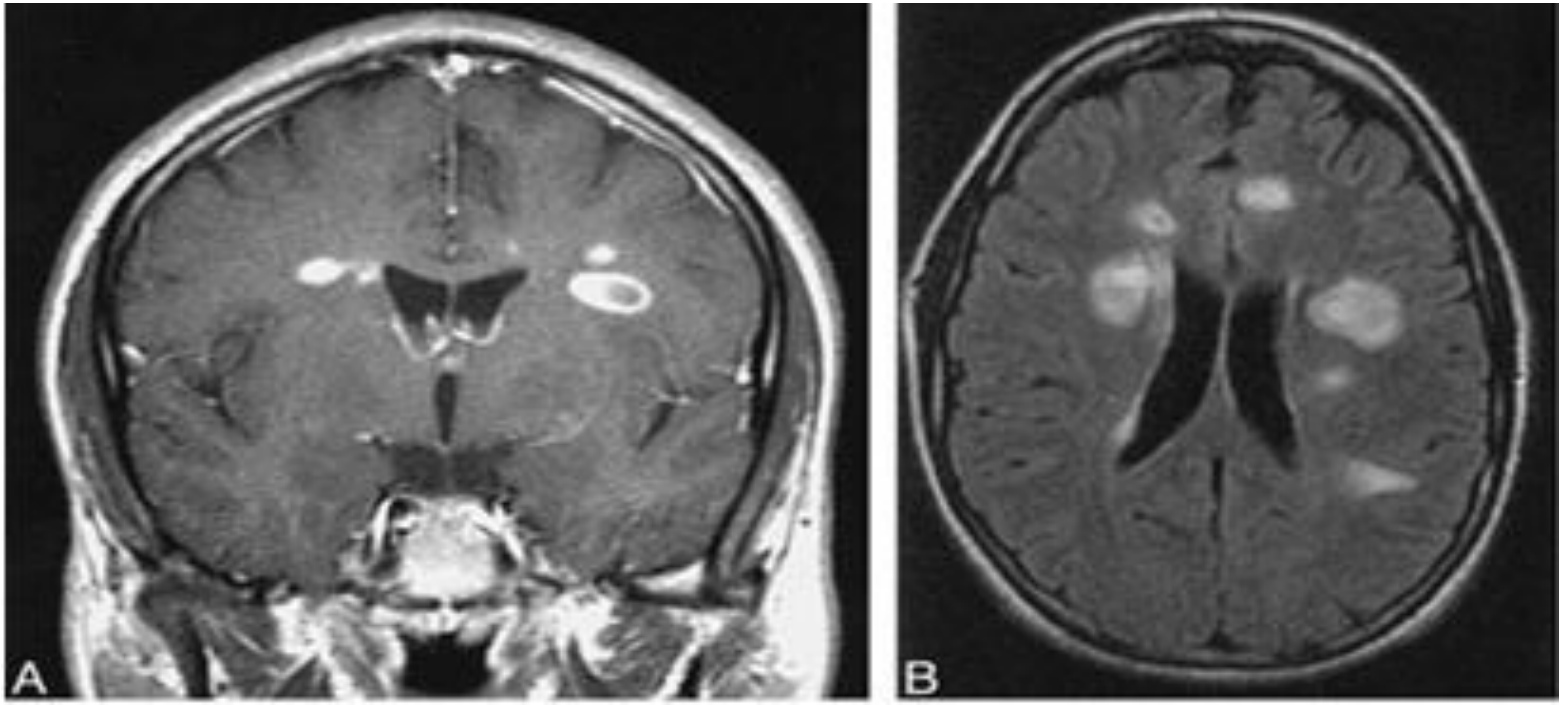


- Advantages of MRI
  - Nonintrusive (非侵入的)
  - No ionising radiation (电离辐射) damage
  - Voxel (三维像素) level analysis
  - Multiple approachs to construct image (T1, T2, proton density…)

# Introduction



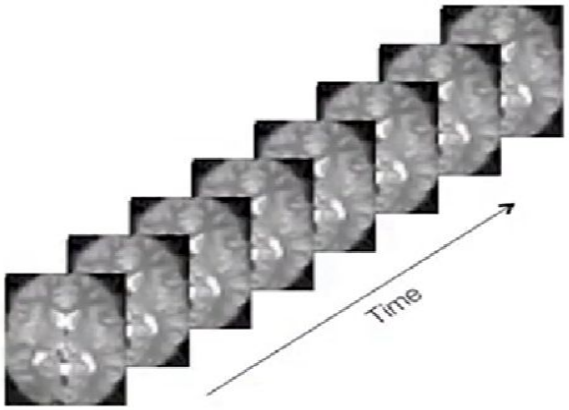
- What can we do about MRI?



# Introduction



- fMRI is a category of special MRI which allows to study brain's functional connection
- Detecting changes over time to construct functional connection pattern



# Introduction

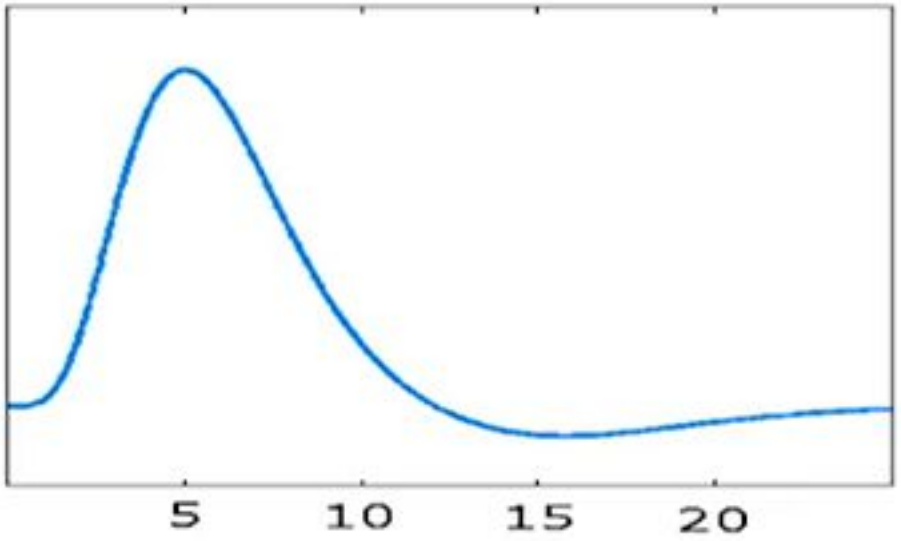


- BOLD fMRI(Blood Oxygenation Level Dependent)
  - Blood Oxygenation level changes relating to neuronal activities
  - Oxygenated and deoxygenated hemoglobin (血红蛋白) has different effect on imaging

# Introduction



- BOLD fMRI(Blood Oxygenation Level Dependent)




hemodyamic response function

# Part 2 Fingerprint: brain connectivity

# Fingerprint: brain connectivity

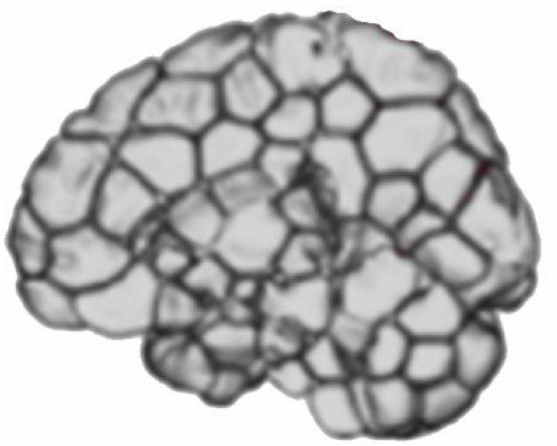


- Biological characteristics
  - Fingerprint
  - Human face
  - Iris (虹膜)
  - Retina
  - …

# Fingerprint: brain connectivity



- To quantify brain structure, a brain atlas (defined on Yale data set) consisting of 268 nodes is used in this study



Brain network with 268 nodes

# Fingerprint: brain connectivity

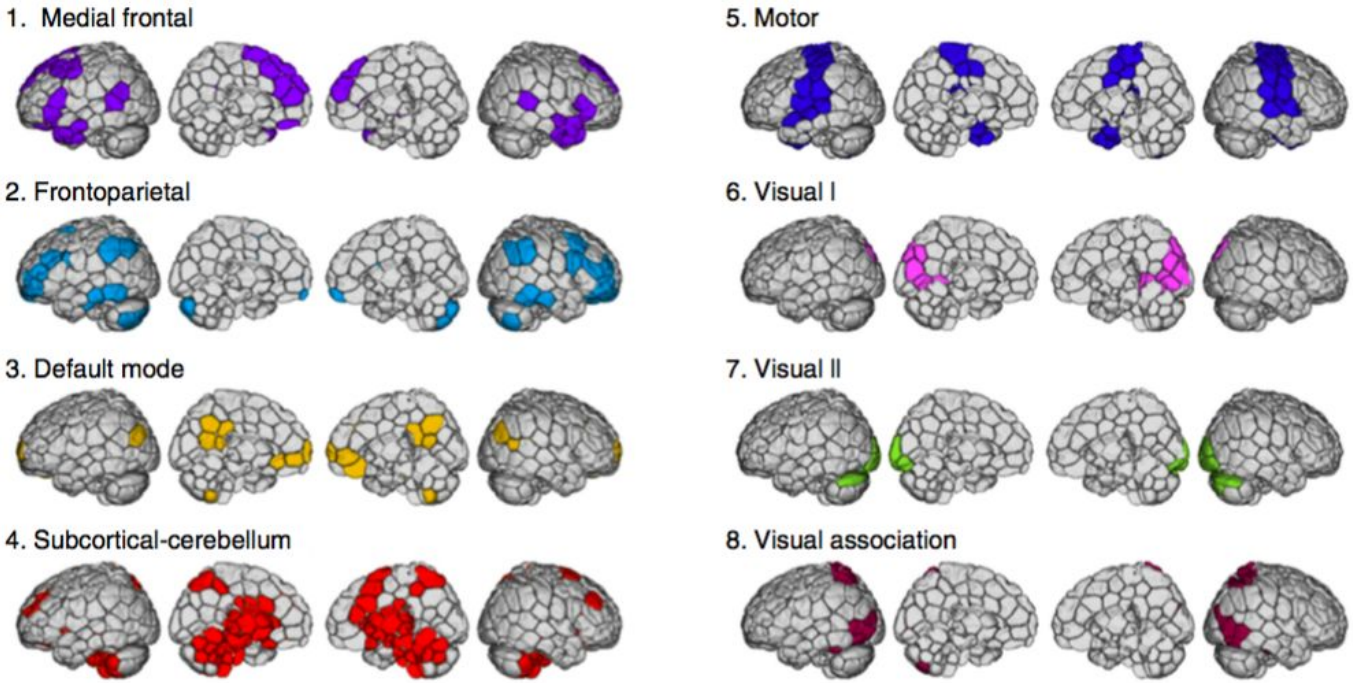


- **Connectivity matrices**: 268 x 268 matrices, calculated by Pearson correlation coefficient
- **Similarity measurement**: Pearson correlation coefficient between vectors of edge values taken from the target matrix and database matrices

# Fingerprint: brain connectivity



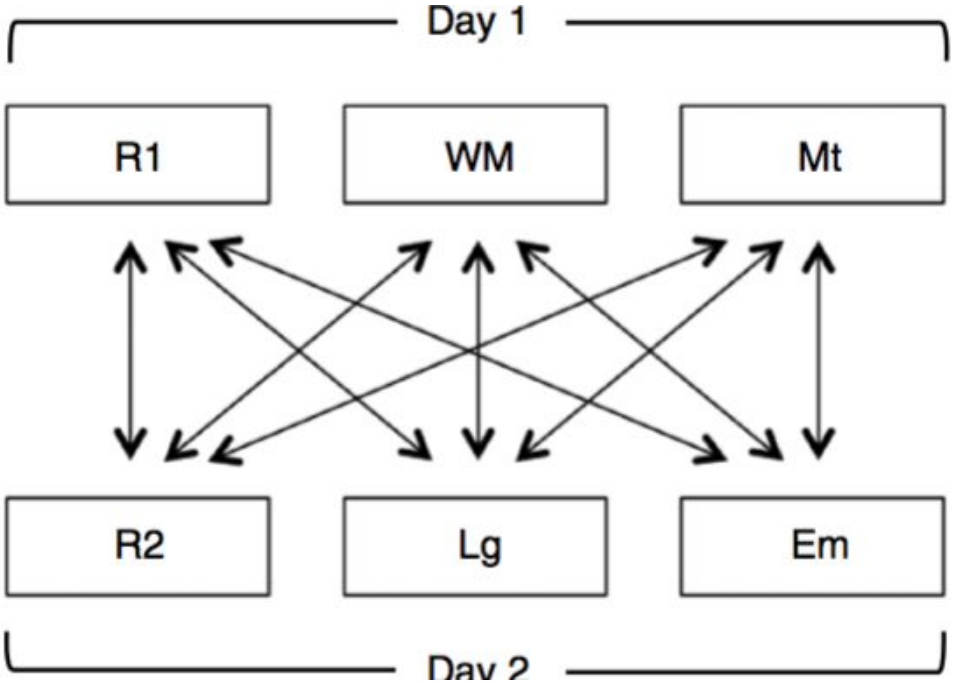
- 268 nodes are further grouped into eight networks



# Fingerprint: brain connectivity



- Data for this study was collected in six fMRI sessions in two different days for each subject




R1: resting-state

WM: working-memory task

Mt: motor task

R2: resting-state

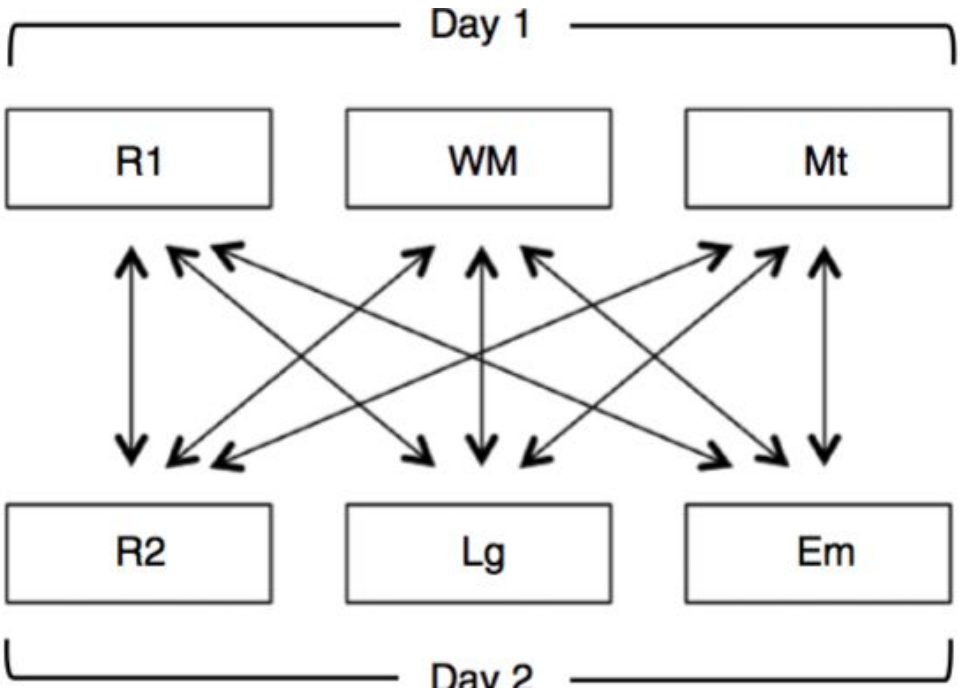
Lg: language task

Em: emotion task

# Fingerprint: brain connectivity



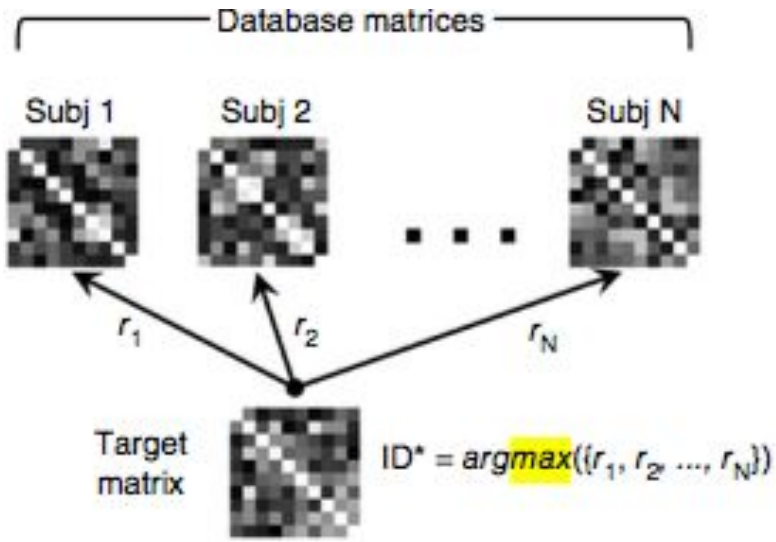
- Identification performed across pairs of scans taken from different days



# Fingerprint: brain connectivity



- Identification process is to find the maximally similar matrix in database compared against target



# Fingerprint: brain connectivity

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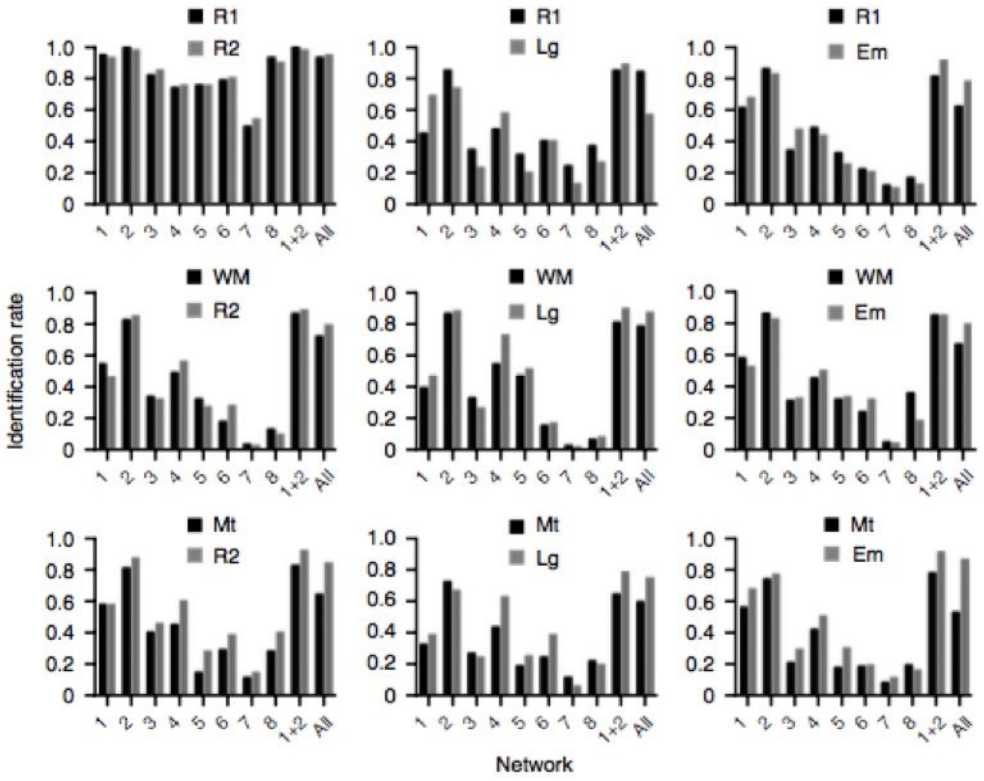
- Experiment result




Black bar: database session

Gray bar: target session

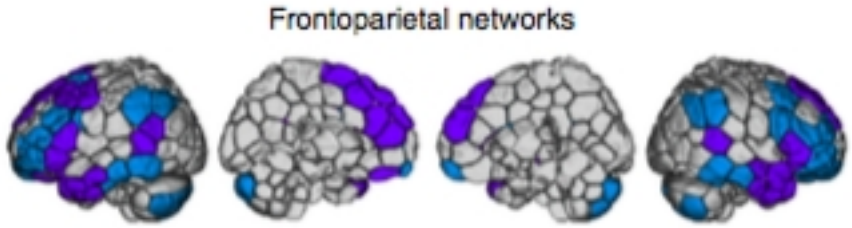
1 + 2: combination of network 1 and 2

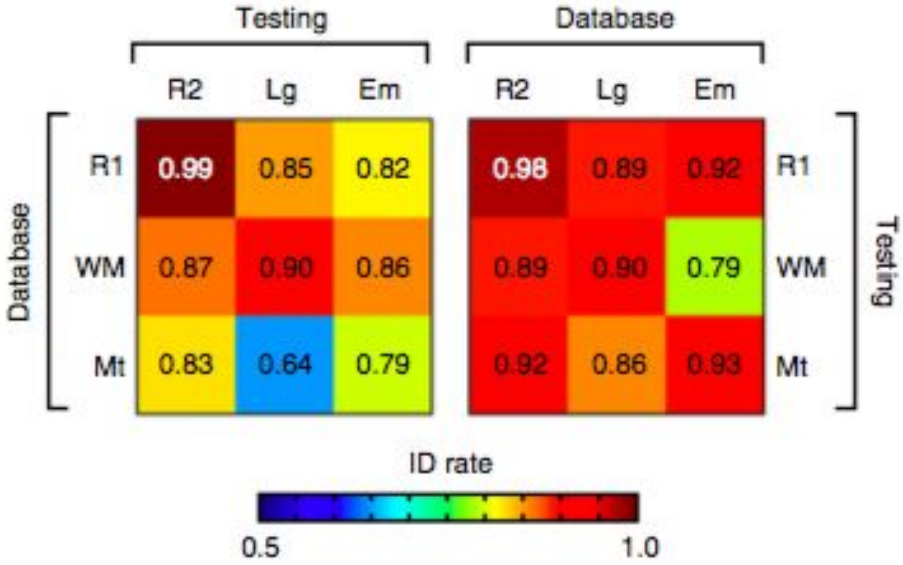
All: whole-brain identification

# Fingerprint: brain connectivity



- Experiment result
  - Combination of network 1 and 2 shows high performance



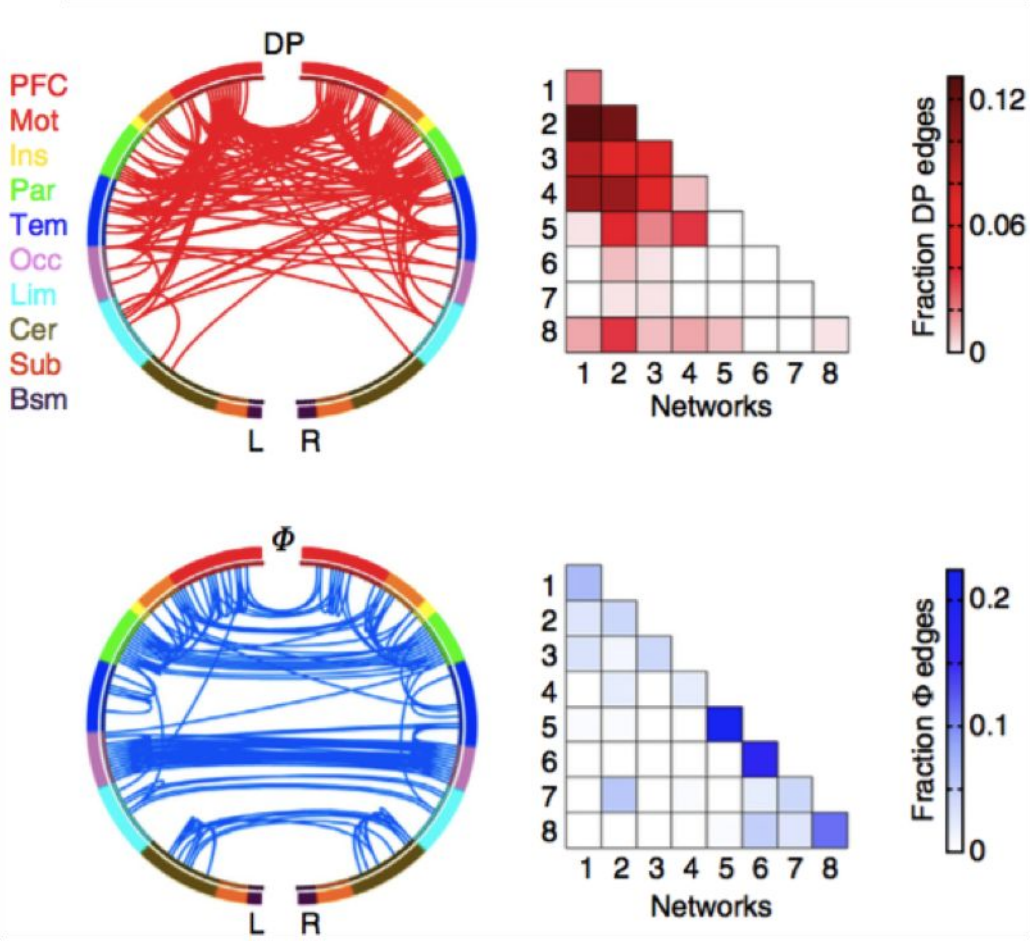



# Fingerprint: brain connectivity



- To find out edge's contribution to identification, used two parameter:
  - **DP**: ability to distinguish subjects
  - $\phi$: quantifies the consistency of a connection

# Fingerprint: brain connectivity



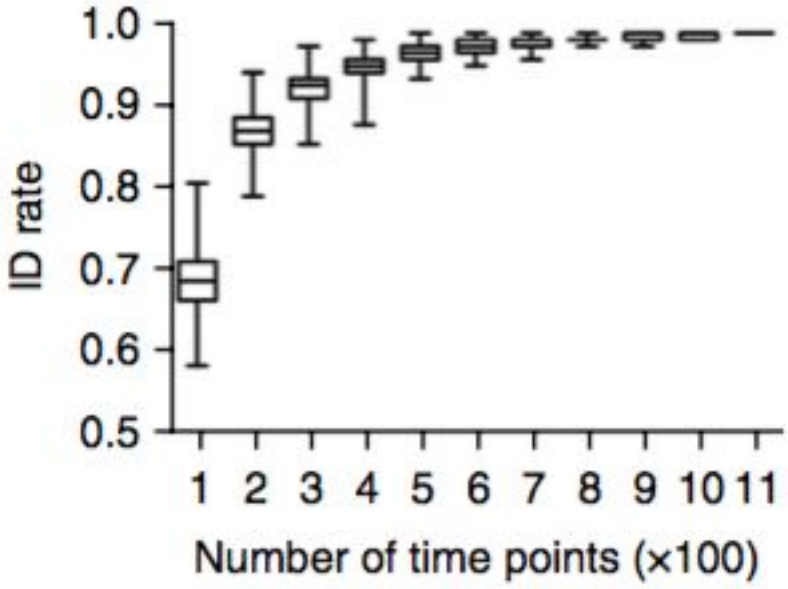

Highly unique(DP, top, red) and highly consistent(φ, bottom, blue)

L, left hemisphere; R, right hemisphere

# Fingerprint: brain connectivity



- Longer time courses better preserved individual characteristics in connectivity profiles



# Cognitive behavior prediction



- **Fluid intelligence (gF)**: the capacity for on-the-spot reasoning to discern patterns and solve problems independently of acquired knowledge
- Regression and leave-one-out-cross-validation (LOOCV) was used for the prediction analysis

# Cognitive behavior prediction



- Feature selection
  - Pearson correlation was performed between each edge and gF score across subjects in the training set
  - Edges were separated into two group: positively and negatively correlated with gF

# Cognitive behavior prediction



- Model building
  - **network strength**:

$$[\text{Positive feature network strength}]_s = \sum_{i,j} c_{ij} m_{ij}^{(+)}$$

$$[\text{Negative feature network strength}]_s = \sum_{i,j} c_{ij} m_{ij}^{(-)}$$

c: individual *s*'s connectivity matrix

$m^{(+)}$: positive correlation matrices between edges and gF $m^{(+)}$: negative correlation matrices between edges and gF

# Cognitive behavior prediction



- Linear regression
  - Network strength as the explanatory variable and, gF as the dependent variable

$$[\text{Predicted gF score}]^{pos} = a^{*}(\text{Network strength})^{pos} + b$$

$$[\text{Predicted gF score}]^{neg} = a^{*}(\text{Network strength})^{neg} + b$$

# Cognitive behavior prediction

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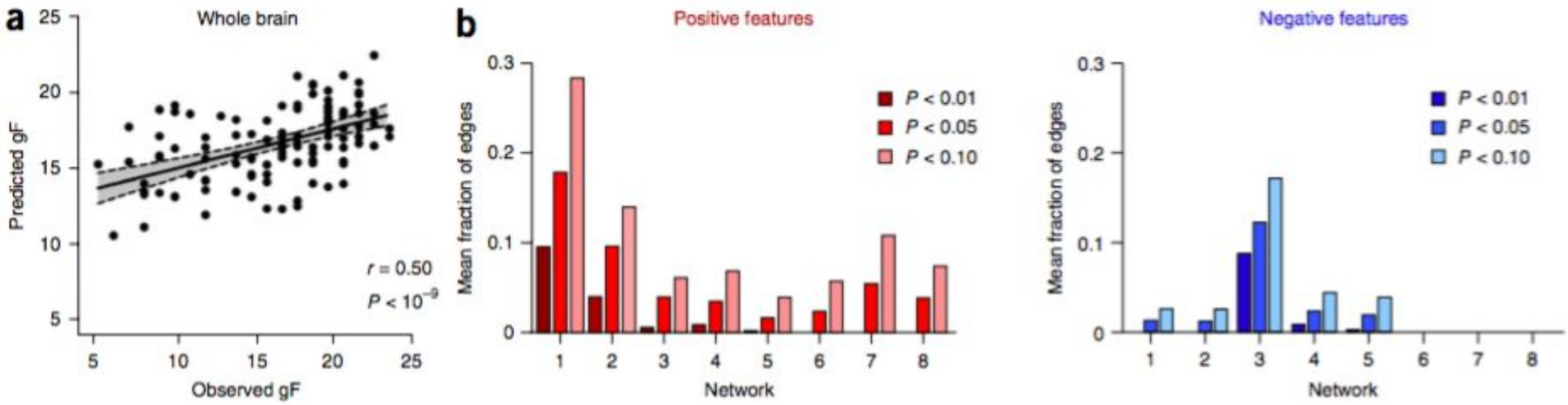
- Experiment result




a: analysis comparing predicted and observed gF with whole brain
b: distribution of positive and negative feature in different network

# Cognitive behavior prediction

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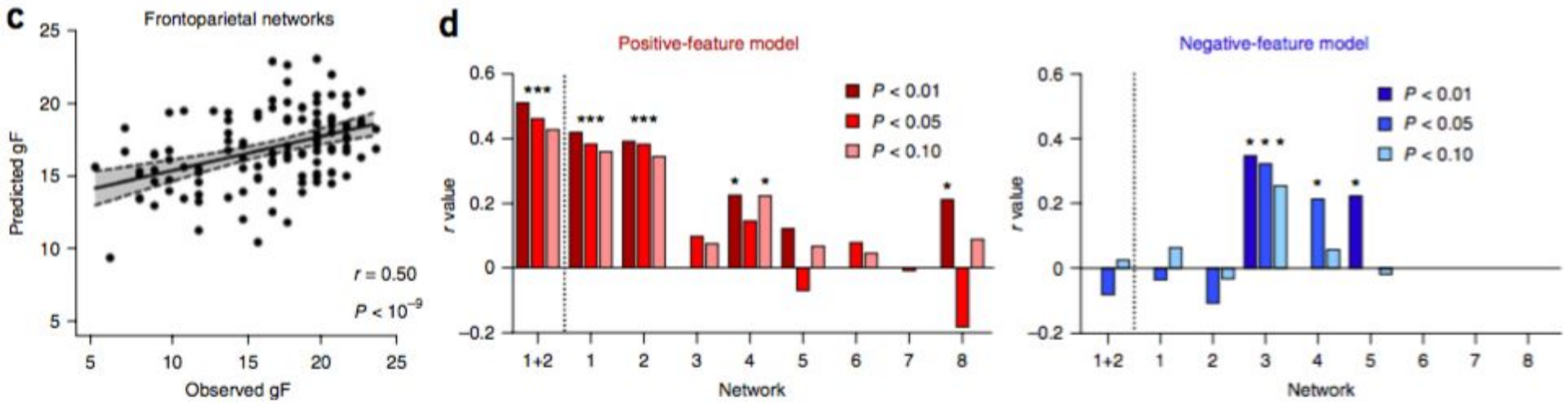
- Experiment result




c: analysis comparing predicted and observed gF with Frontoparietal networks

b: r value of each model in LOOCV analysis

# Discussion



- Brain altas parcellation scheme have effect on identification accuracy
- Longer time series improve identification accuracy
- Task to task, task to rest session identifications are more challenging, additional information improves identification accuracy

# Conclusion



- Individual's functional brain connectivity profile is both unique and reliable, similarly to a fingerprint
- Connectivity profiles can be used to predict the fundamental cognitive trait of fluid intelligence