# تکنیک های چندمدالیته نقشه برداری مغز: مزایا و محدودیت ها

# Multimodality Brain Mapping: Advantages and Pitfalss

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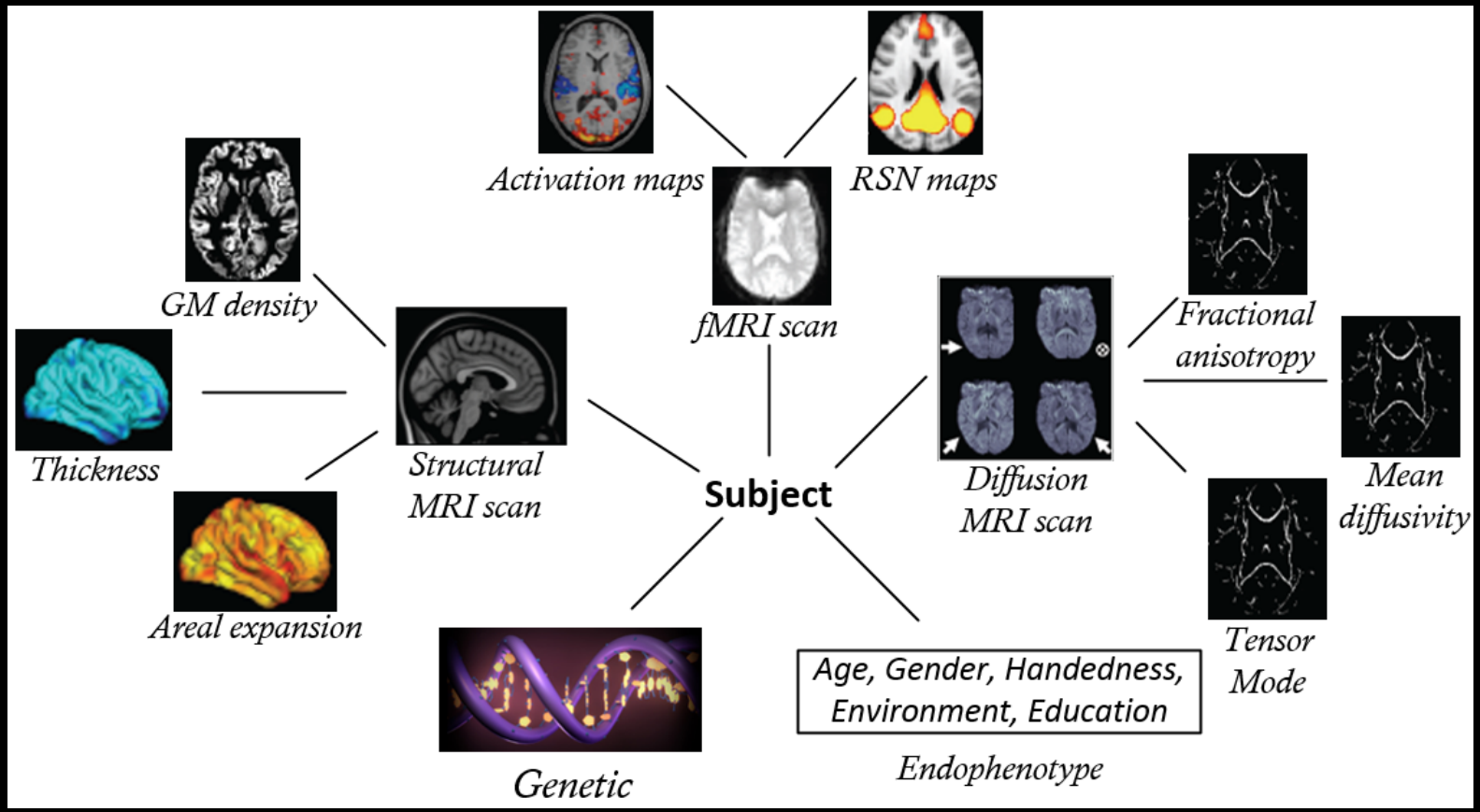
**Iran**

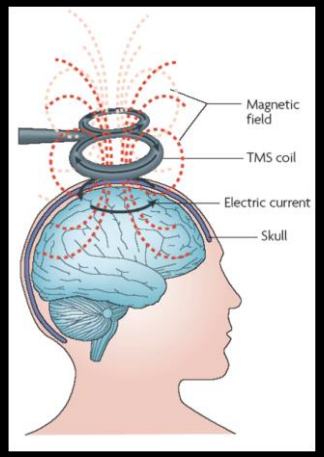
# Outline

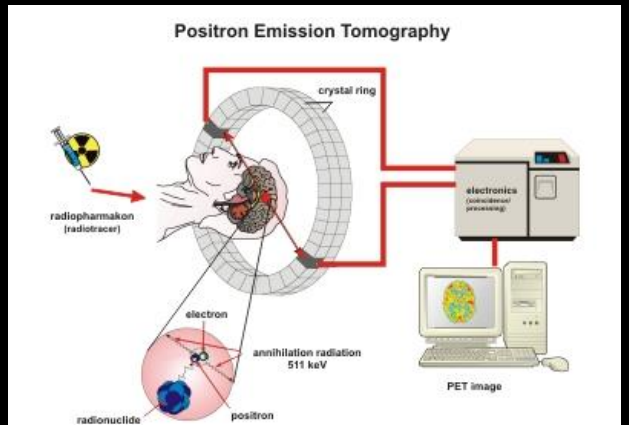
- The Ensemble of Brain Mapping Modalities
- Reasons and Challenges of Combining
- Multimodal Data Acquisition/Stimulation Techniques for Brain Mapping
- Data Analysis Approaches in Multimodal Brain Mapping
- Multimodal Presurgical Planning
- Conclusion

# Brain Mapping Approaches



# Brain Mapping Approaches



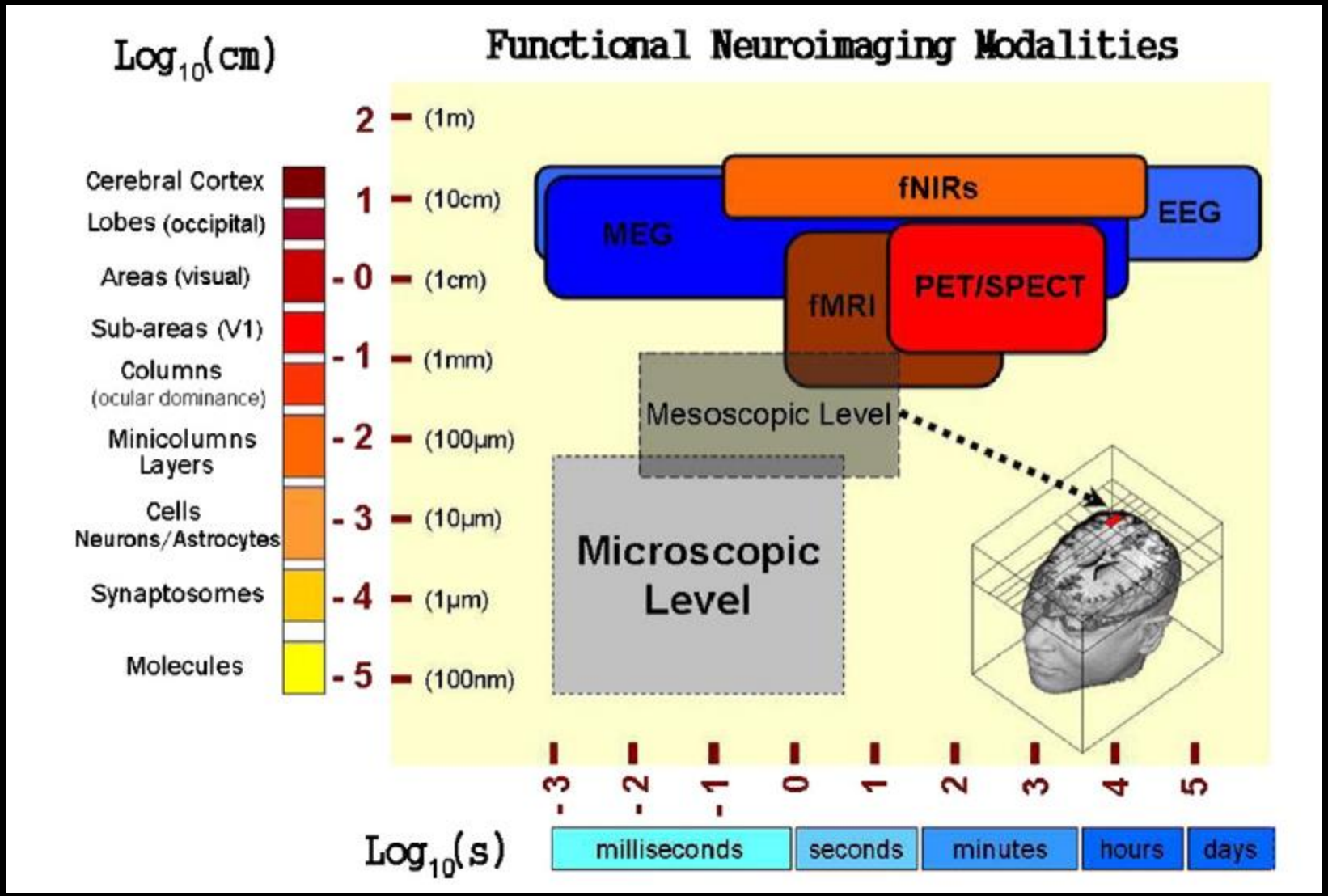

# The Ensemble of Common Brain Mapping Modalities

- MEG: Magnetoencephalography
- EEG: Electroencephalography

- fNIRS: functional Near infrared Spectroscopy
- sMRI: structural MRI
- fMRI: functional MRI
- Diffusion MRI
- PET: Positron emission tomography

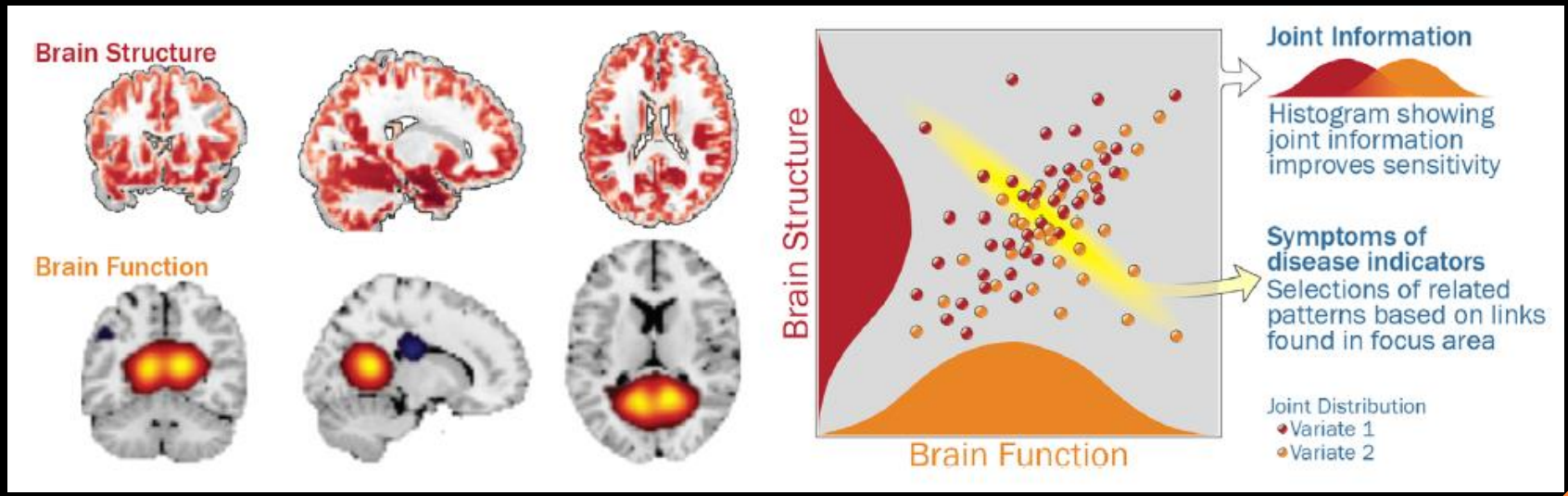
- TMS: Transcranial Magnetic Stimulation
- TES: Transcranial Electric Stimulation (TCS)

# Spatial and Temporal Resolution of Brain Mapping Modalities



# Reasons for Combining

- Complementary Resolution
- Complementary Information (Different views)
- Study a Complex system in different levels (chemical/electrical/structural/hemodynamic




[Calhoun, Biological psychiatry, 2016]

# Challenges in Multimodal Brain Mapping

- Different sampling rates in time/space
- Co-registration (Voxels/Channels/etc)
- Each signal comes from a different phenomena (Physical Model)
- Simultaneous or separate acquisitions?
- Challenges of concurrent acquisition
- Data Analysis (Data Fusion)

# Separate or Simultaneous?

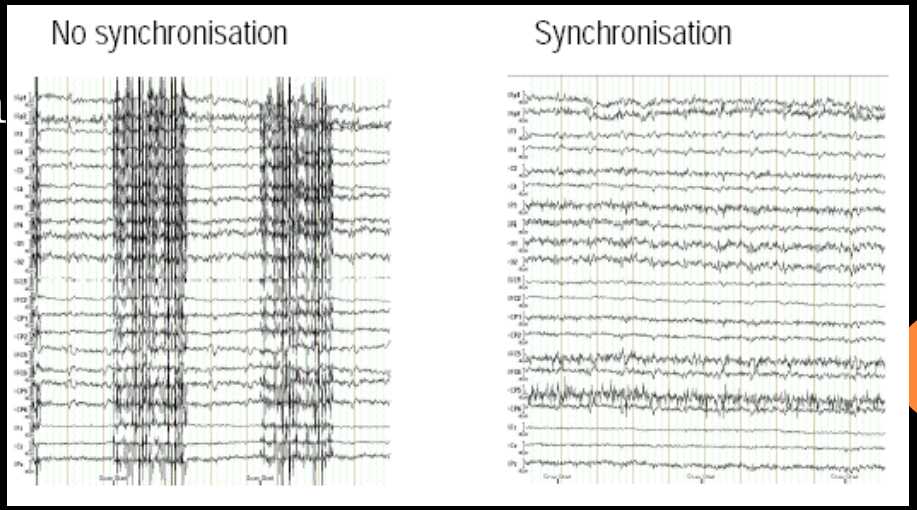
- اندازه گیری جداگانه:
  - تکرار پذیری مناطق فعال در جلسات مختلف
  - انجام پارادایم با استفاده از روش های مختلف امکان پذیر باشد
- اندازه گیری همزمان:
  - Task روی تجربه و حالت شخص تاثیر گذار باشد.
    - مطالعه روی حافظه
    - یادگیری

# Possible Simultaneous Data Acquisition

- EEG-fMRI

- EEG Artifacts
- fMRI degrading

- Epilepsy research
- Spatial origin of brain rhythms



# Possible Simultaneous Data Acquisition

- fNIRS-fMRI
- Increased spatial resolution for **NIRS**
- better filtering of physiological fluctuations within **fMRI** by using the higher temporal resolution **NIRS**
- And the additional measures of Hbo

# Simultaneous Data Acquisition and Brain Stimulation: Toward a Specific Causality studies

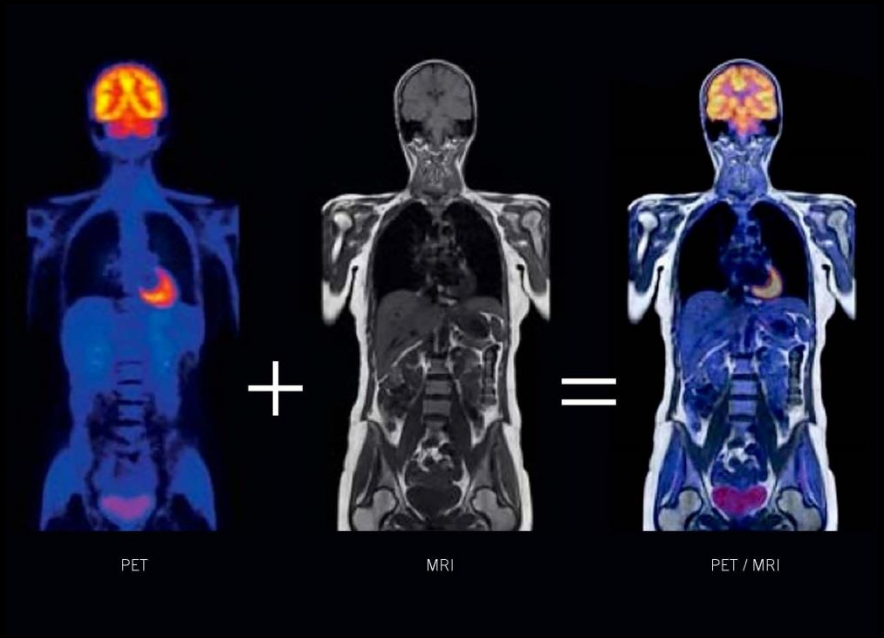
- TCS-fMRI

- TMS-fMRI

# Possible Simultaneous Data Acquisition

- PET-fMRI

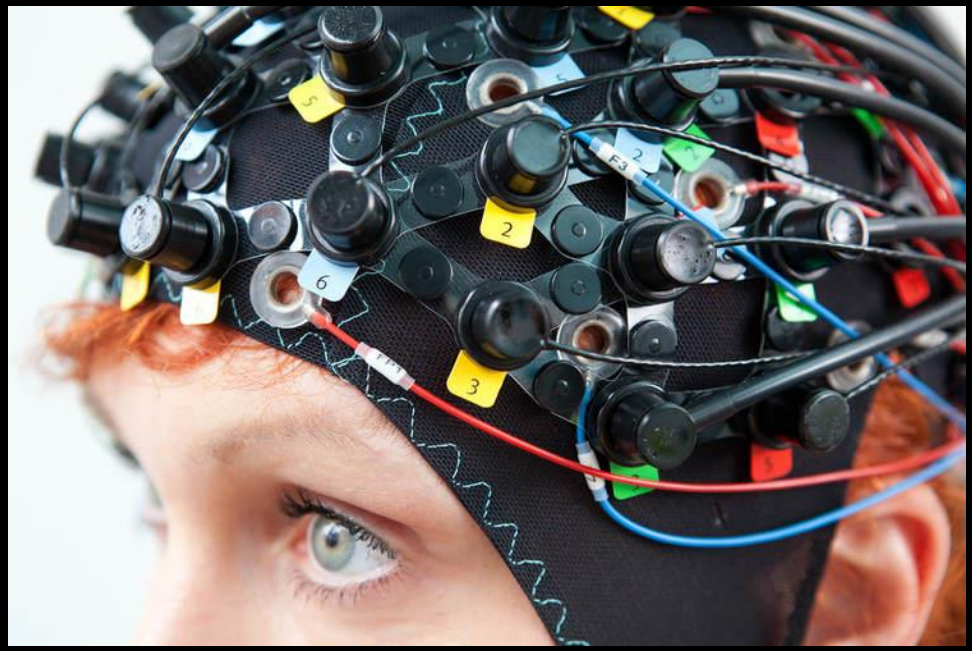
- More accurate resection of tumors due to high sensitivity of PET and resolution of MRI




# Possible Simultaneous Data Acquisition

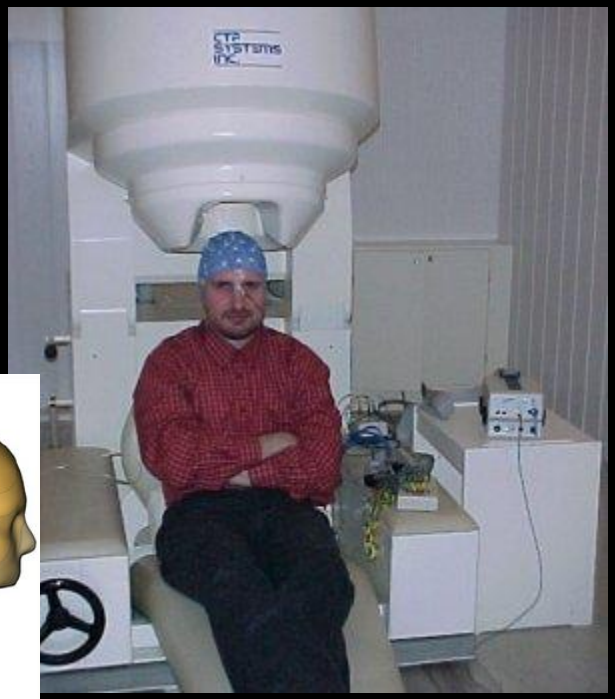
- fNIRS-EEG

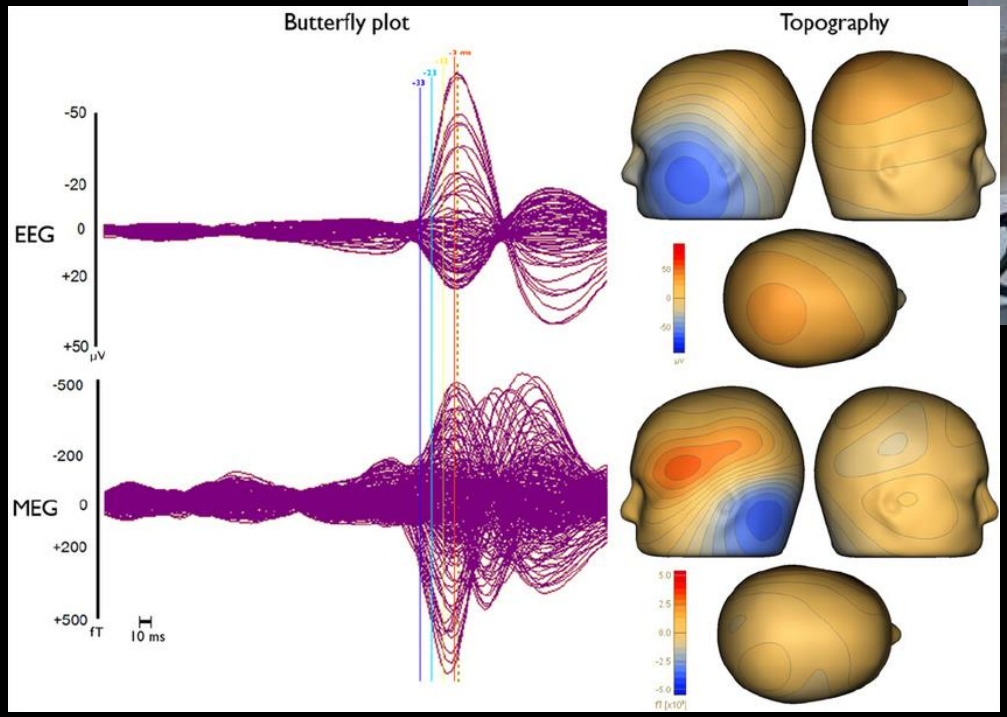
- Concurrent hemodynamic and electromagnetic brain mapping
- More comfort for patients than fMRI_EEG



# Possible Simultaneous Data Acquisition

- MEG-EEG
- Complete set of electromagnetic measurements





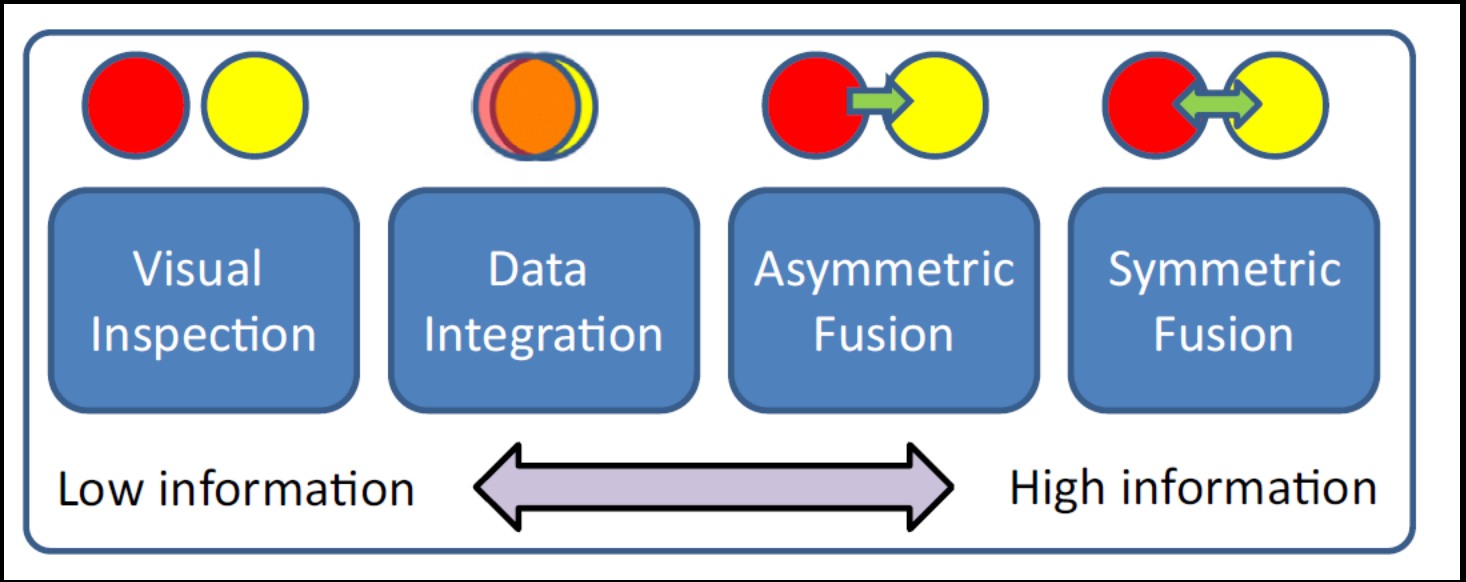

Source reconstruction in Epilepsy presurgical diagnosis, Plos One 2015

# Possible Simultaneous Data Acquisition and Stimulation

- TMS-EEG
- non-invasively studying cortical excitability and connectivity
- Functional and effective connectivity
- Challenge

- TCS-EEG

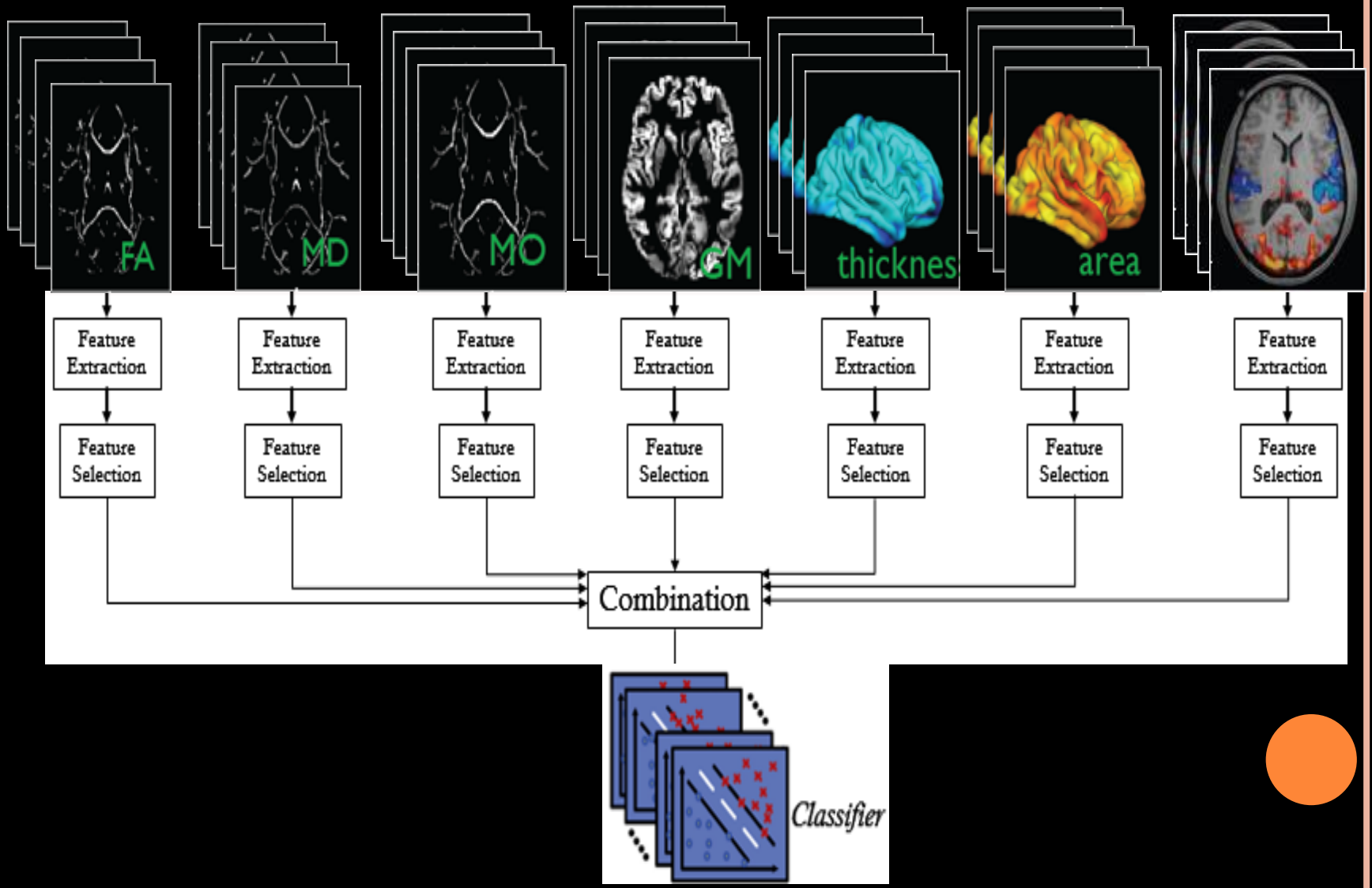
# Data Analysis Approaches in Multimodal Brain Mapping



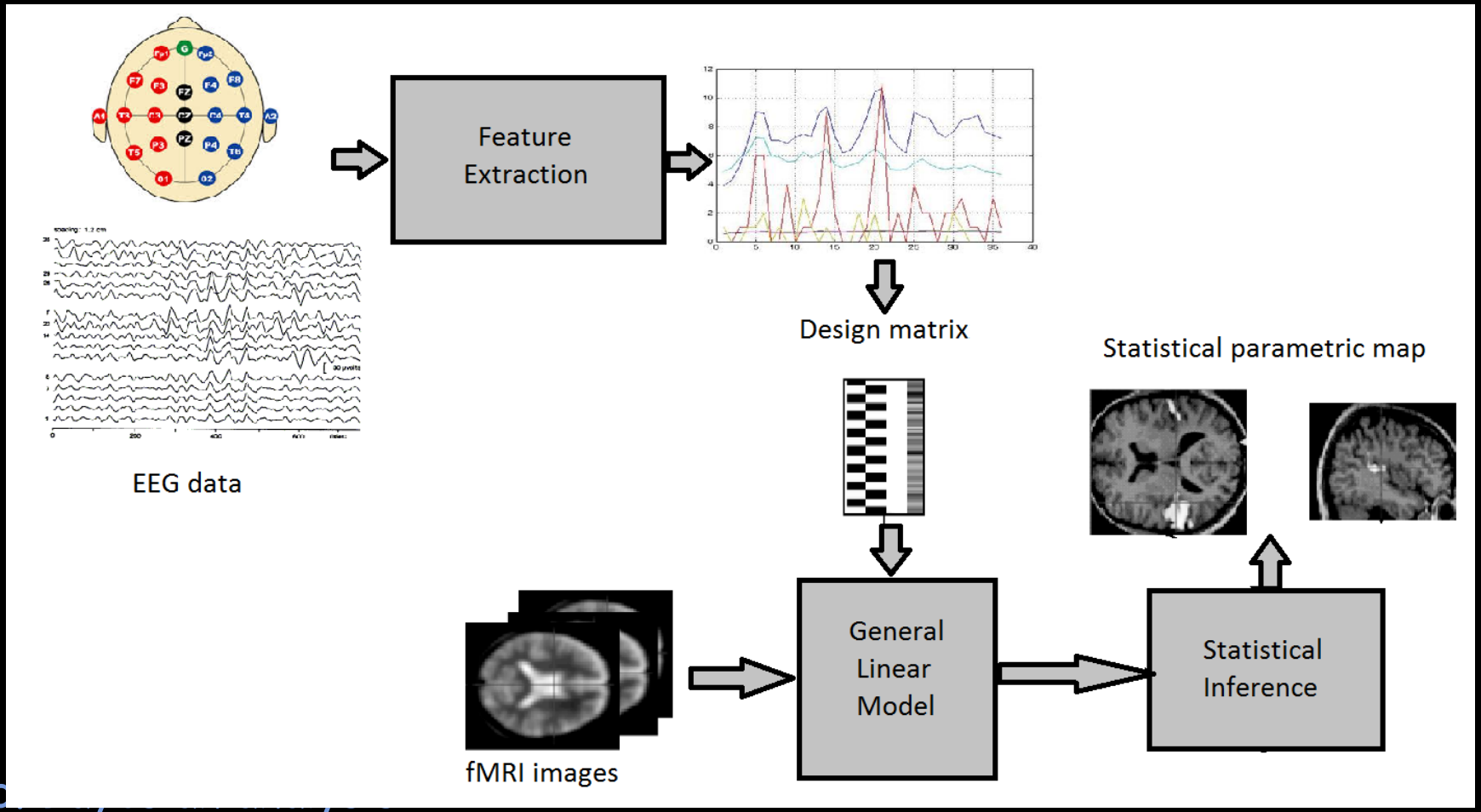

[Calhoun, Biological psychiatry, 2016]

- Data Integration
- Assymetric Fusion: Informed Analysis (EEG-Informed fMRI Analysis, fMRI-Informed EEG Analysis, etc)
- Symmetric Data Fusion

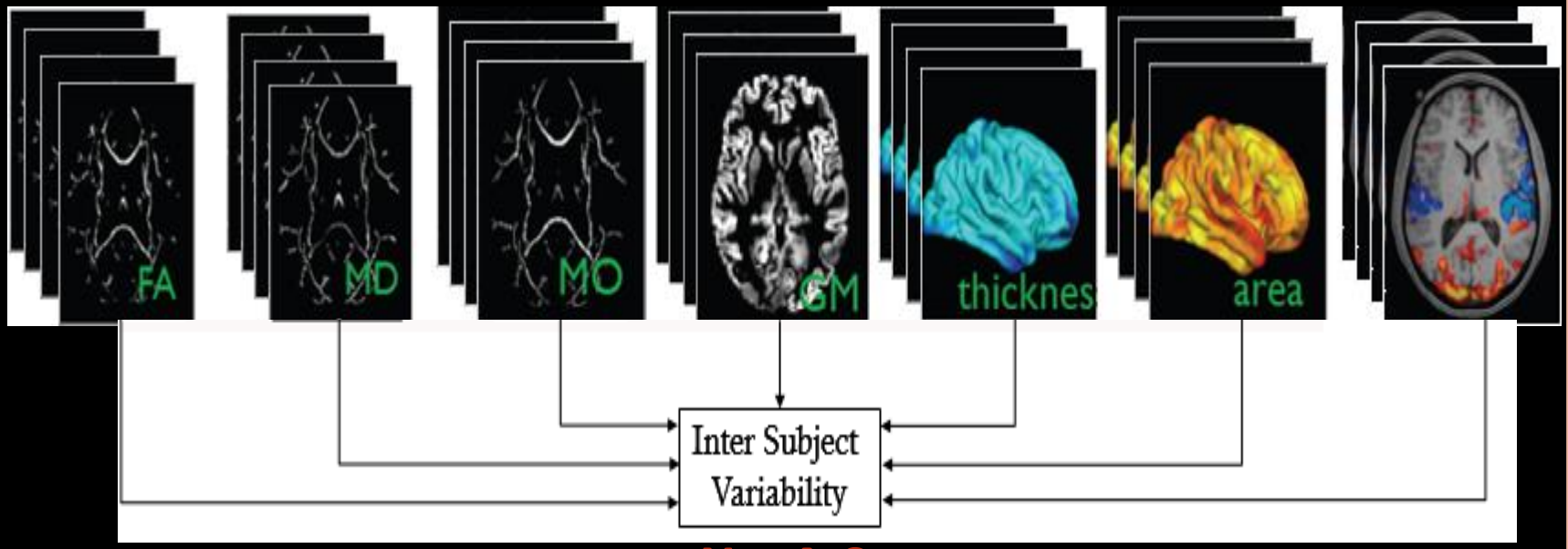
# Data Integration



# Asymmetric Analysis
# EEG-informed fMRI Analysis

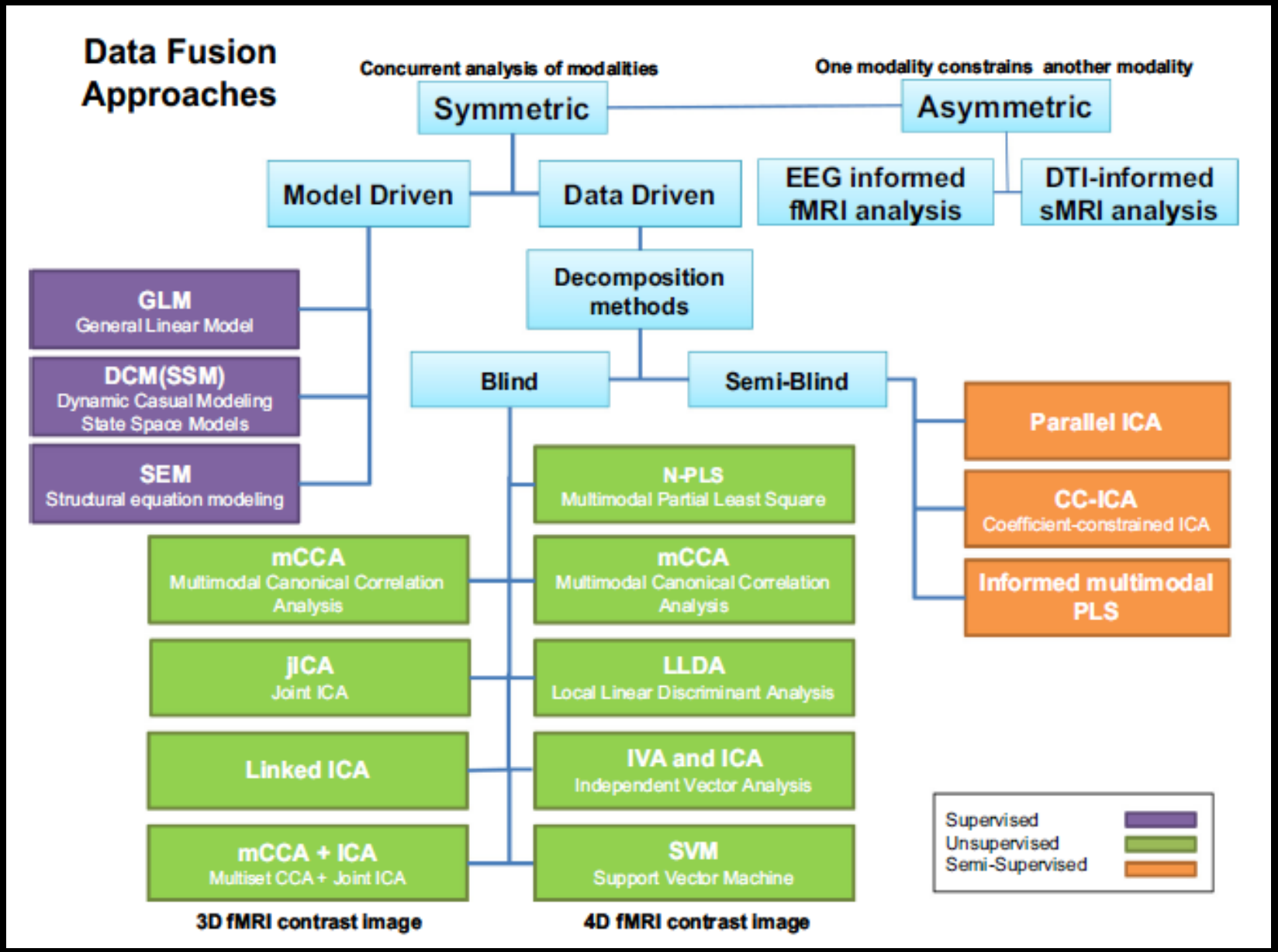


# Data Fusion



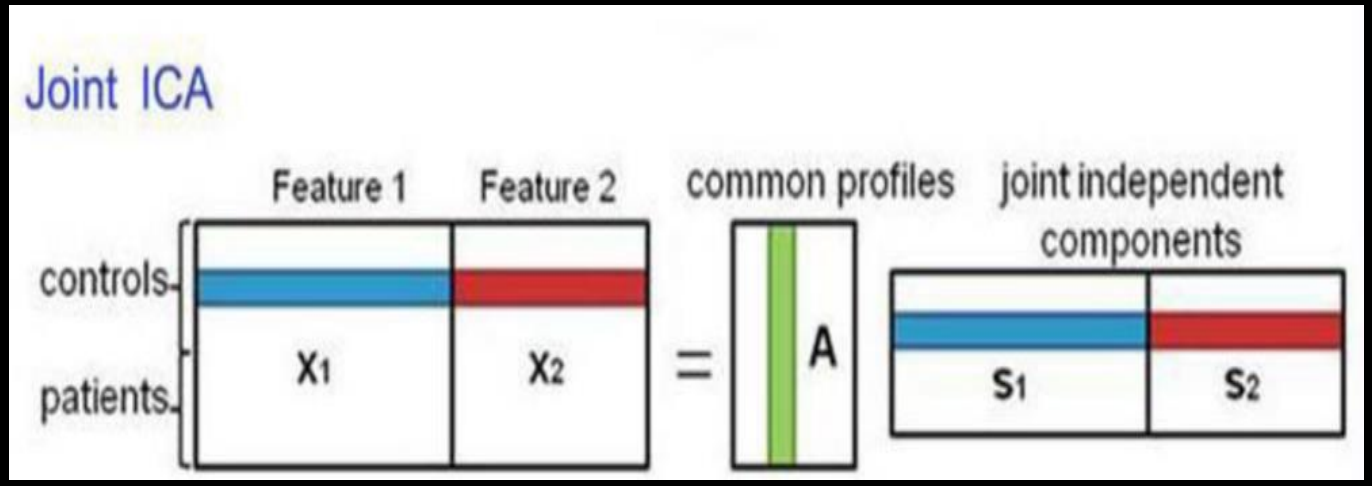

**X = A.S**

*ICA* *CCA*

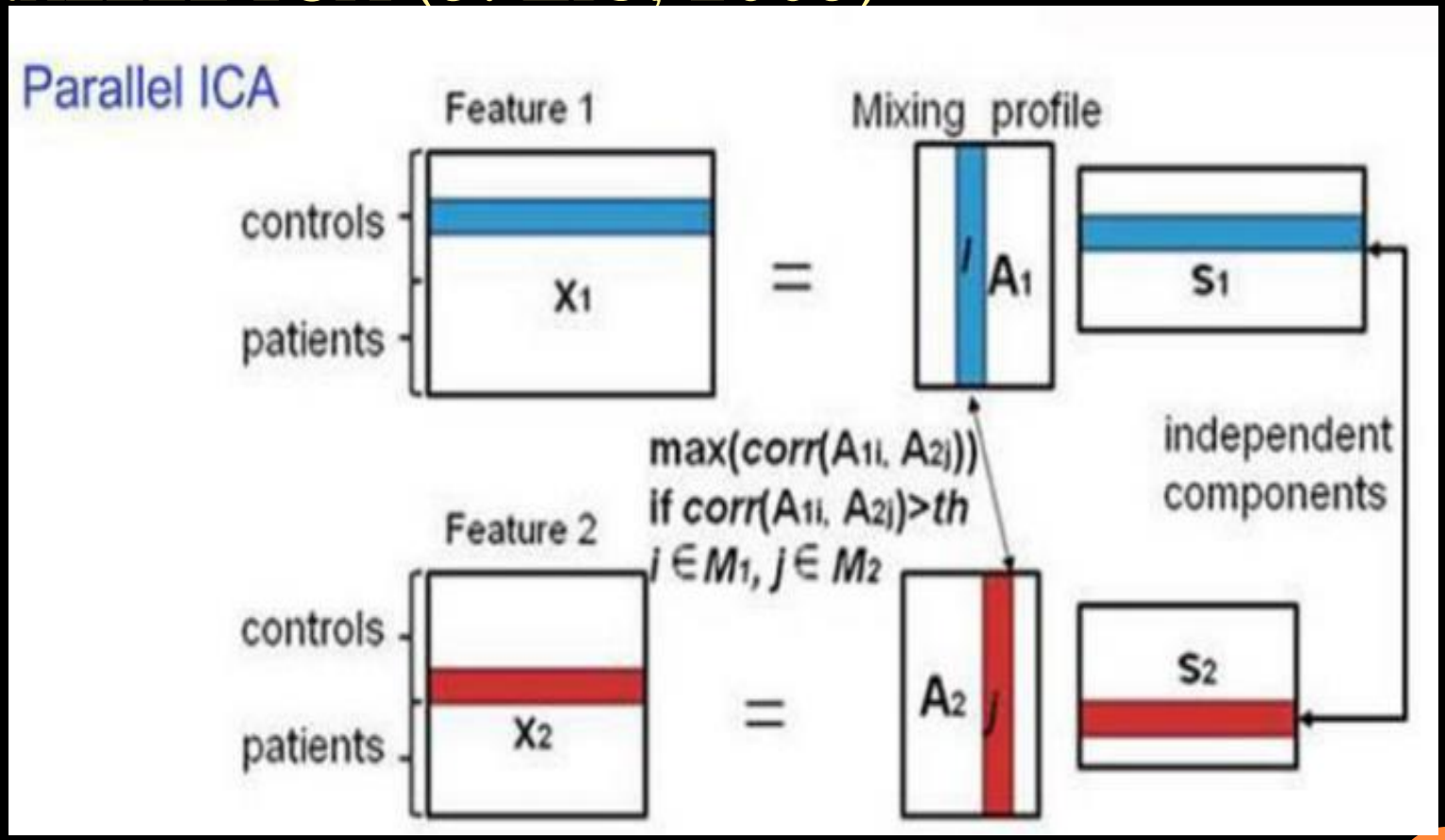



[Calhoun, Biological psychiatry, 2016]

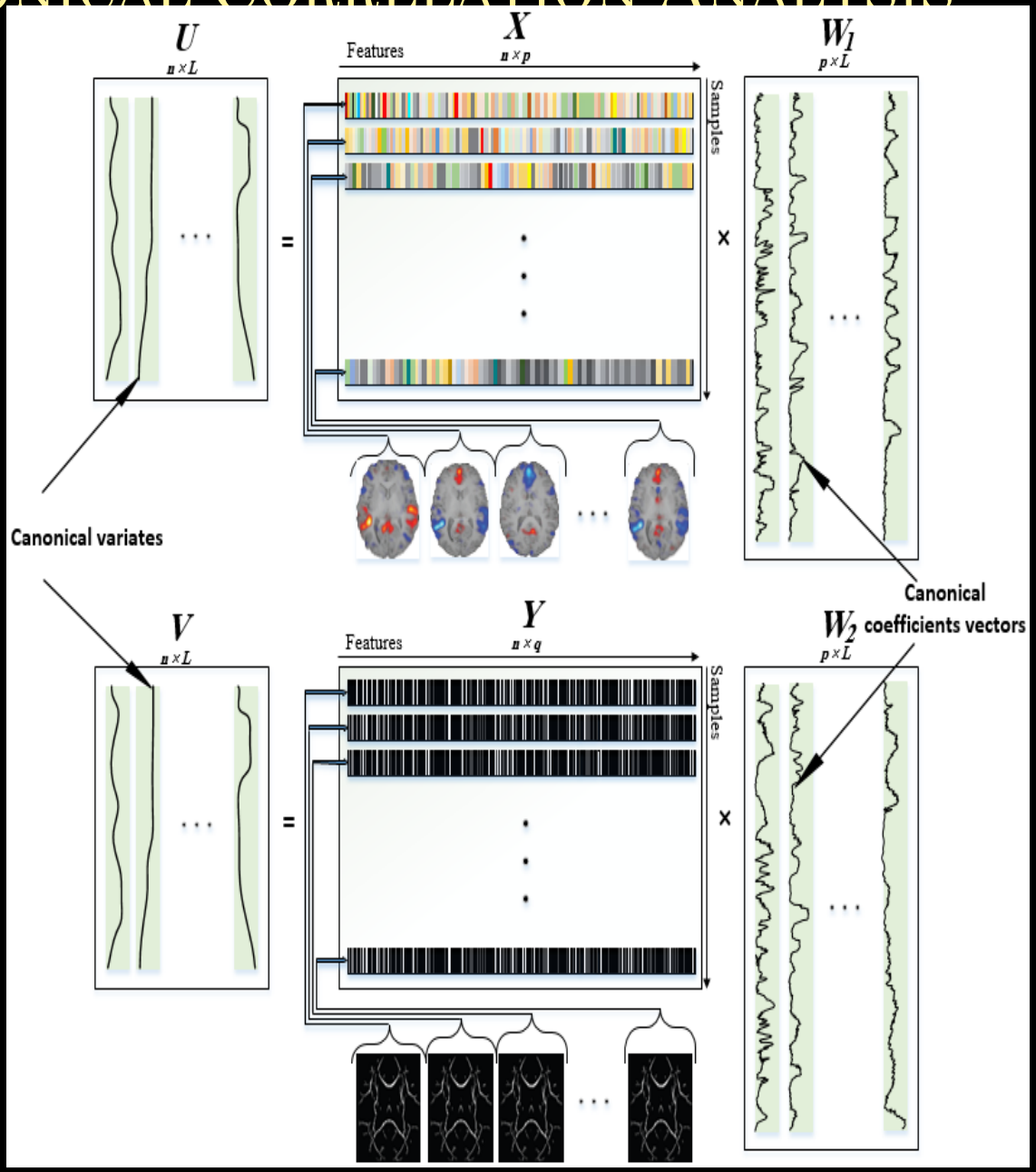
# Joint ICA (V.D. Calhoun 2002,2009)

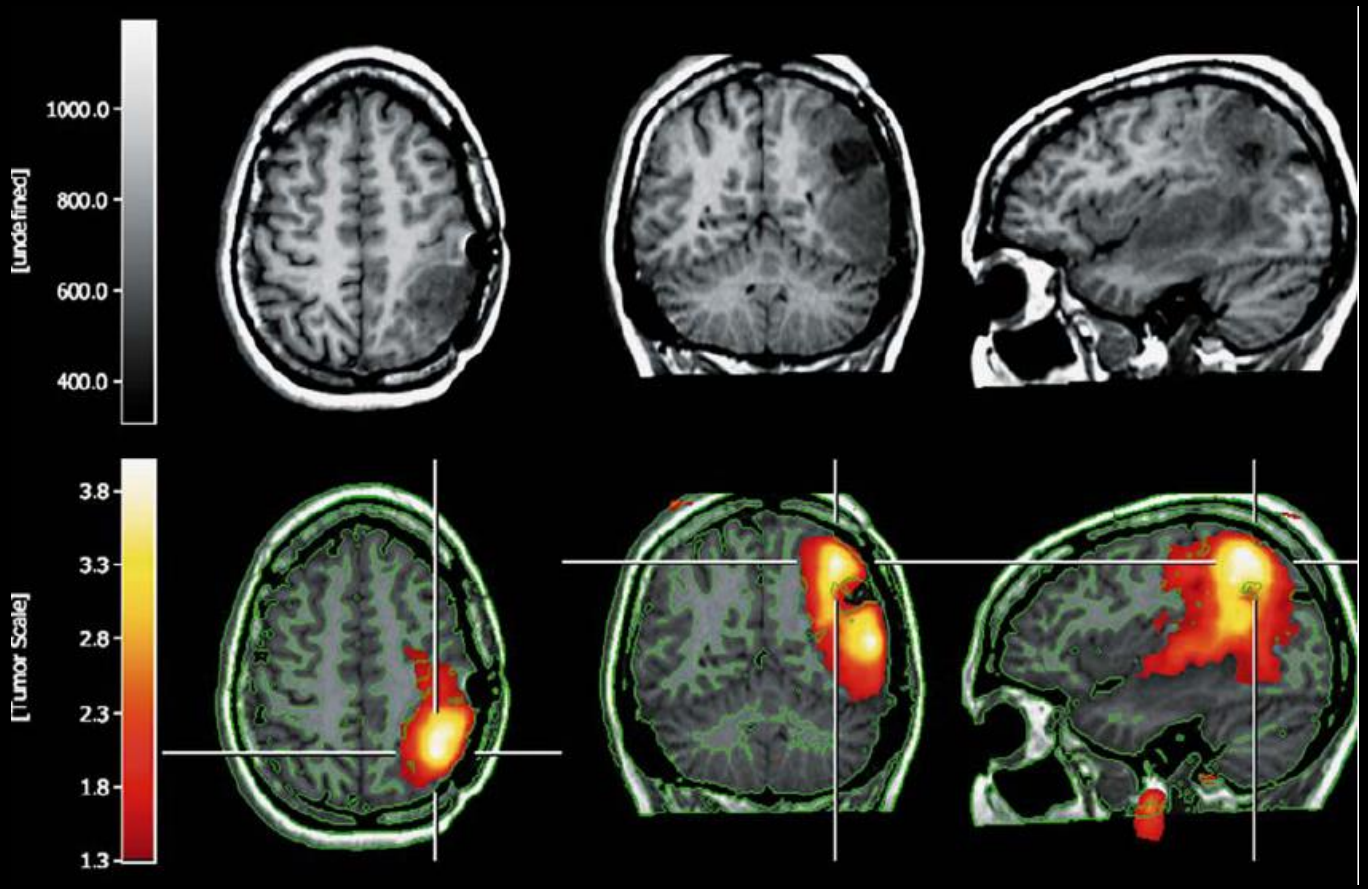


# Parallel ICA (J. Liu, 2009)



# Cannonical Correlation Analysis






# Application: Multimodal Presurgical Planning

Dr. S. Vollmar and Prof. Dr. K. Herholz, Max-Planck-Institut

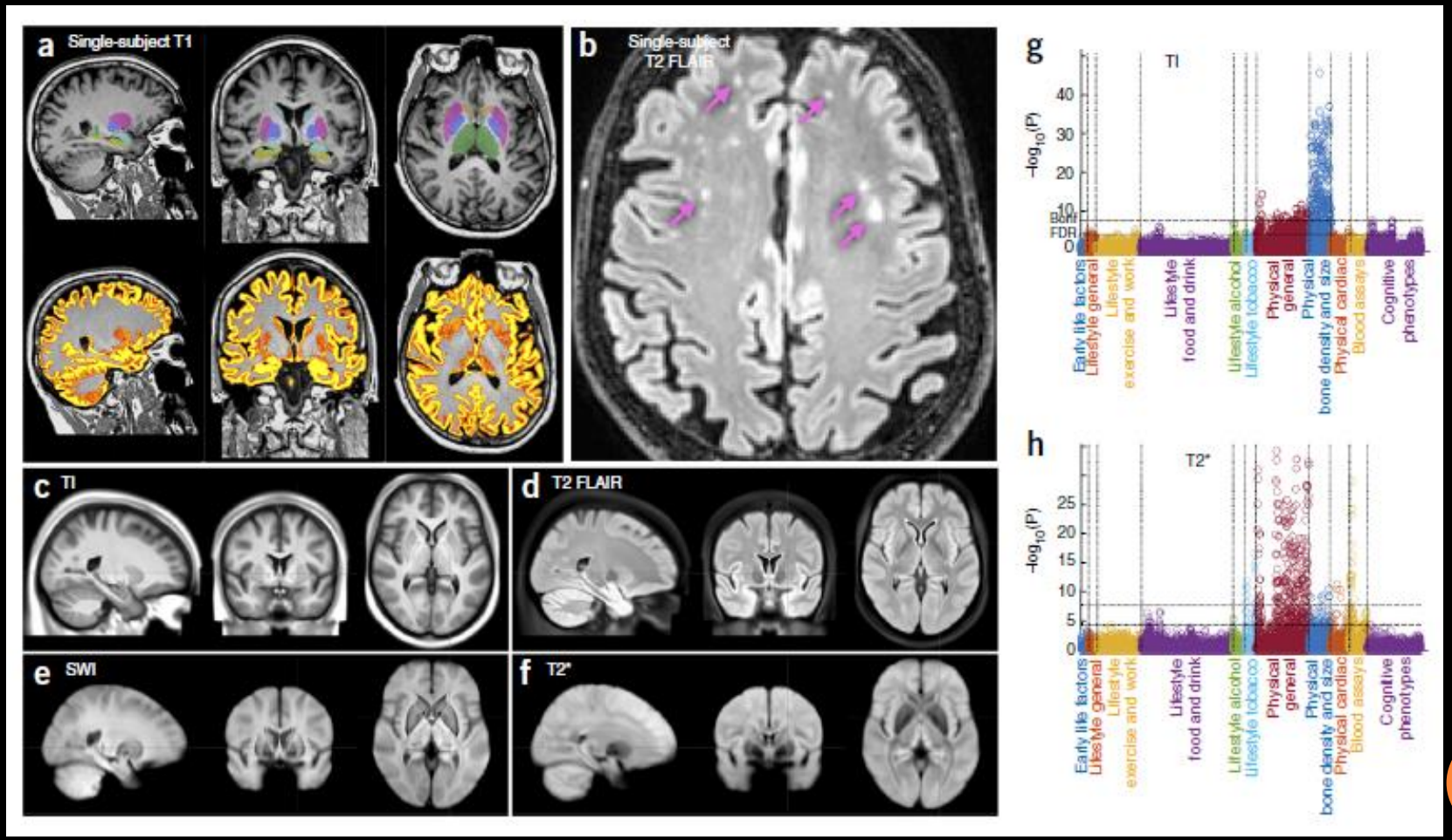
# Application to Public Health

RESOURCE

nature neuroscience

## Multimodal population brain imaging in the UK Biobank prospective epidemiological study

Karla L Miller[1], Fidel Alfaro-Almagro[1], Neal K Bangerter[2], David L Thomas[3], Essa Yacoub[4], Junqian Xu[5], Andreas J Bartsch[6], Saad Jbabdi[1], Stamatios N Sotiropoulos[1], Jesper L R Andersson[1], Ludovica Griffanti[1], Gwenaëlle Douaud[1], Thomas W Okell[1], Peter Weale[7], Iulius Dragonu[7], Steve Garratt[8], Sarah Hudson[8], Rory Collins[8,9], Mark Jenkinson[1], Paul M Matthews[10] & Stephen M Smith[1]


a Single-subject T1
b Single-subject T2 FLAIR
c T1
d T2 FLAIR
e SWI
f T2*
g T1
h T2*
-log10(P)
BAM
FDR
Early life factors
Lifestyle general
Lifestyle exercise and work
Lifestyle food and drink
Lifestyle alcohol
Lifestyle tobacco
Physical general
Physical bone density and size
Physical cardiac
Blood assays
Cognitive phenotypes

# Neuroimaging Data Fusion in Schizophernia

Subject recruitment:

- Schizophrenia (DSM-IV)

Demographic information of the participants involved in this study

| | HC | SZ |
|---|---|---|
| No. of subjects | 18 | 18 |
| Age (mean ± SD) | 30.40 ± 5.45 | 35.72 ± 9.97 |
| Gender (M/F) | 10 / 8 | 13 / 5 |
| Age range | 22 ~ 41 | 19 ~ 55 |
| Handedness (R/L) | 15 / 3 | 13 / 5 |

# Preprocessing of Structural MRI

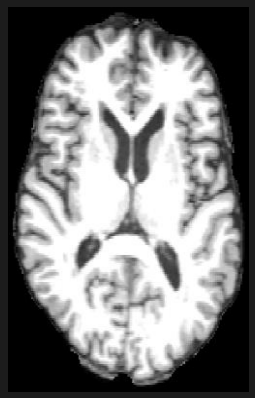
T1-weighted scans

bias correction

Non-parametric and non-uniform Normalization (N3)

skull stripping

hybrid watershed algorithm

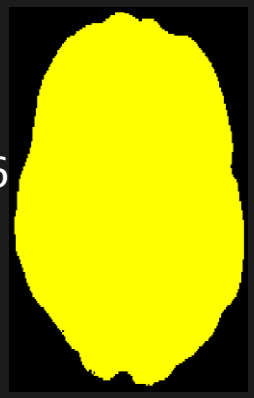


BET

fine brain extraction

affine registration

global brain mask

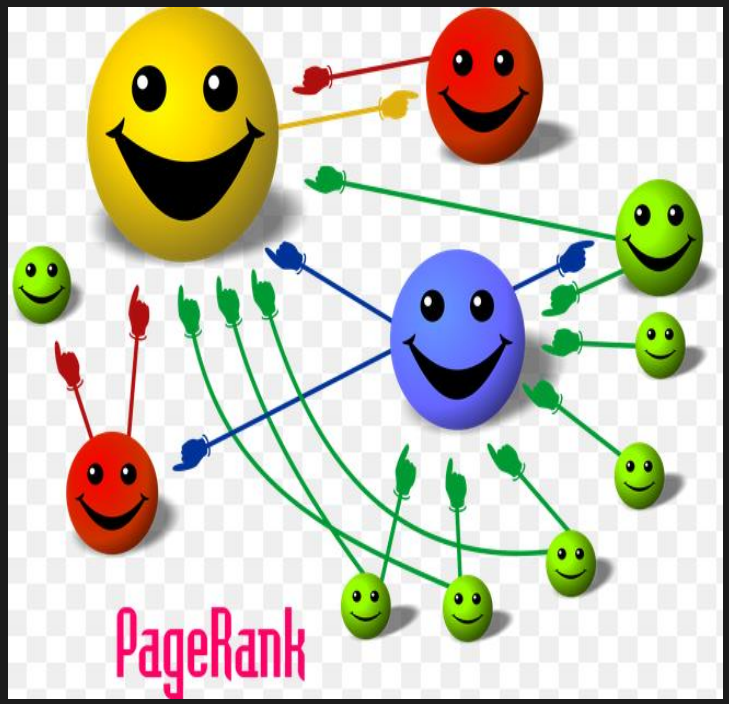


72 × 92 × 86

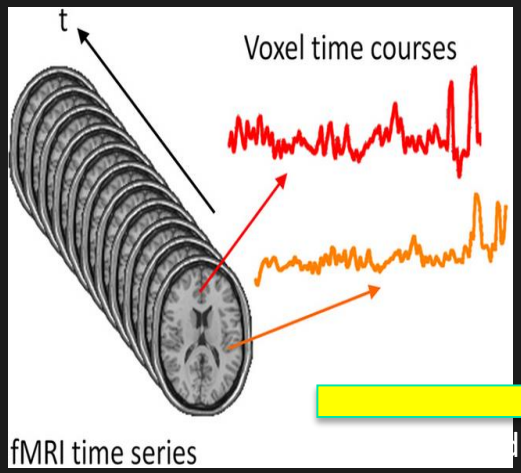
266507 voxels

# Eigenvector centrality mapping (ECM)

- Common techniques to study functional connectivity:
- seed-based correlations (focus on specific predefined ROIs)
- independent component analysis (brain sub-networks)

# ECM Calculation




Preprocessed data in MNI space

correlation analysis

264 GB RAM


Correlation Matrix

$\widetilde{\mathbf{R}} = \mathbf{R} + 1$

Re-scaling

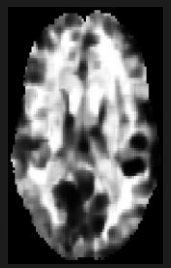
$\widetilde{\mathbf{R}} \geqslant 0$

137 MB RAM

*Power method*

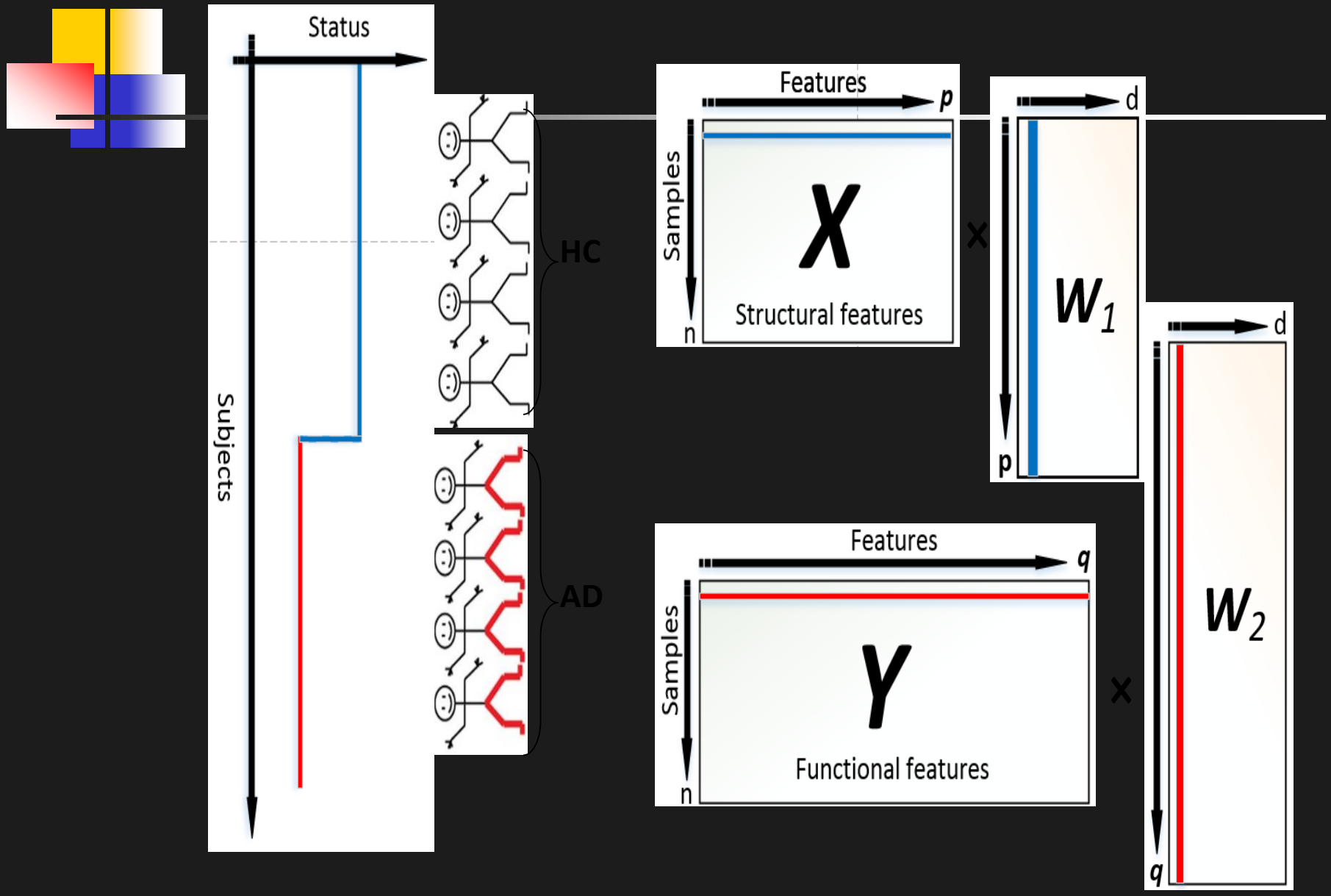
$\widetilde{\mathbf{R}}\mathbf{v} = \lambda\mathbf{v}$

dominant eigenvector

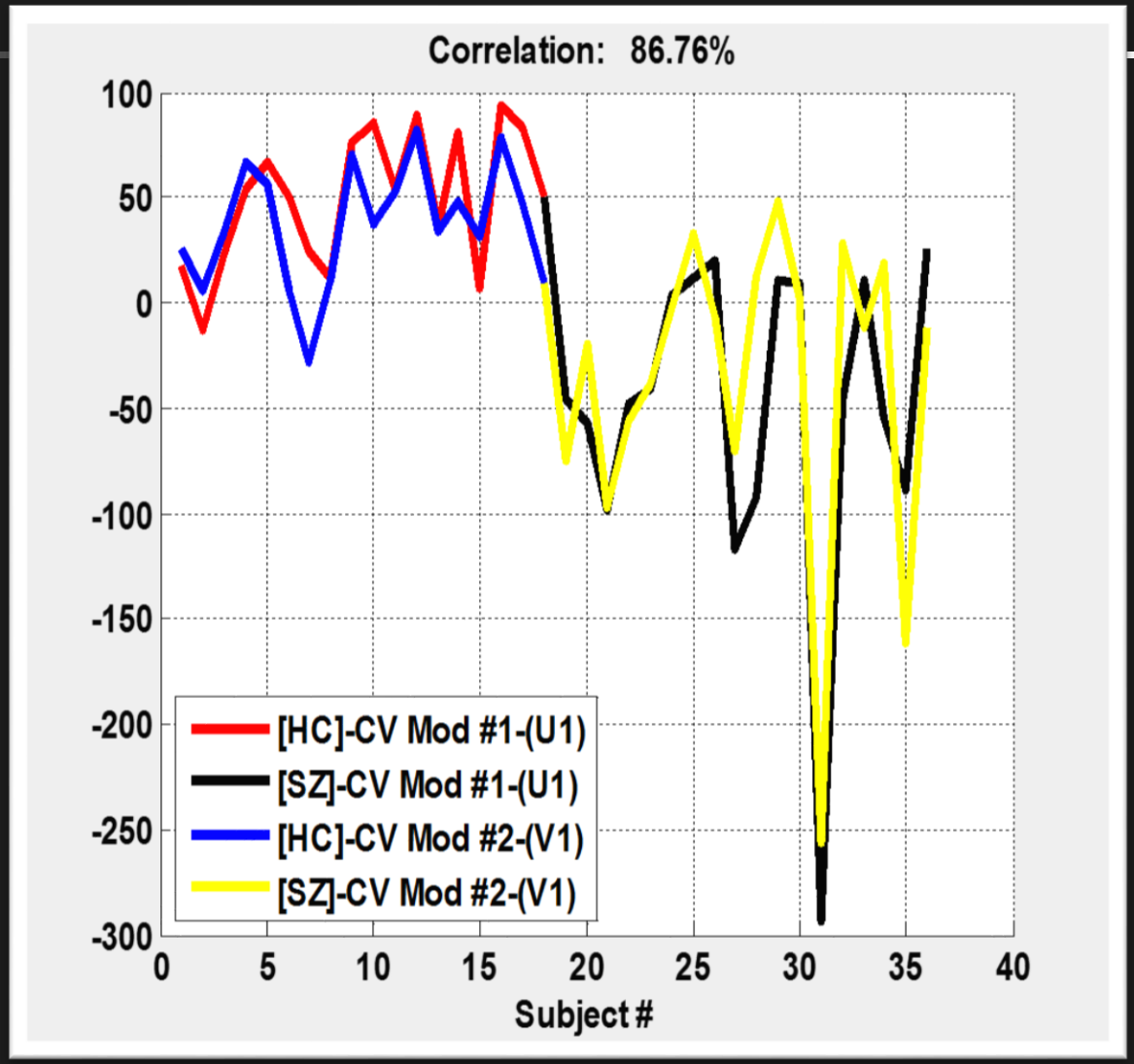


- dominant eigenvector is unique
- coefficients and eigenvalue are positive and real-valued

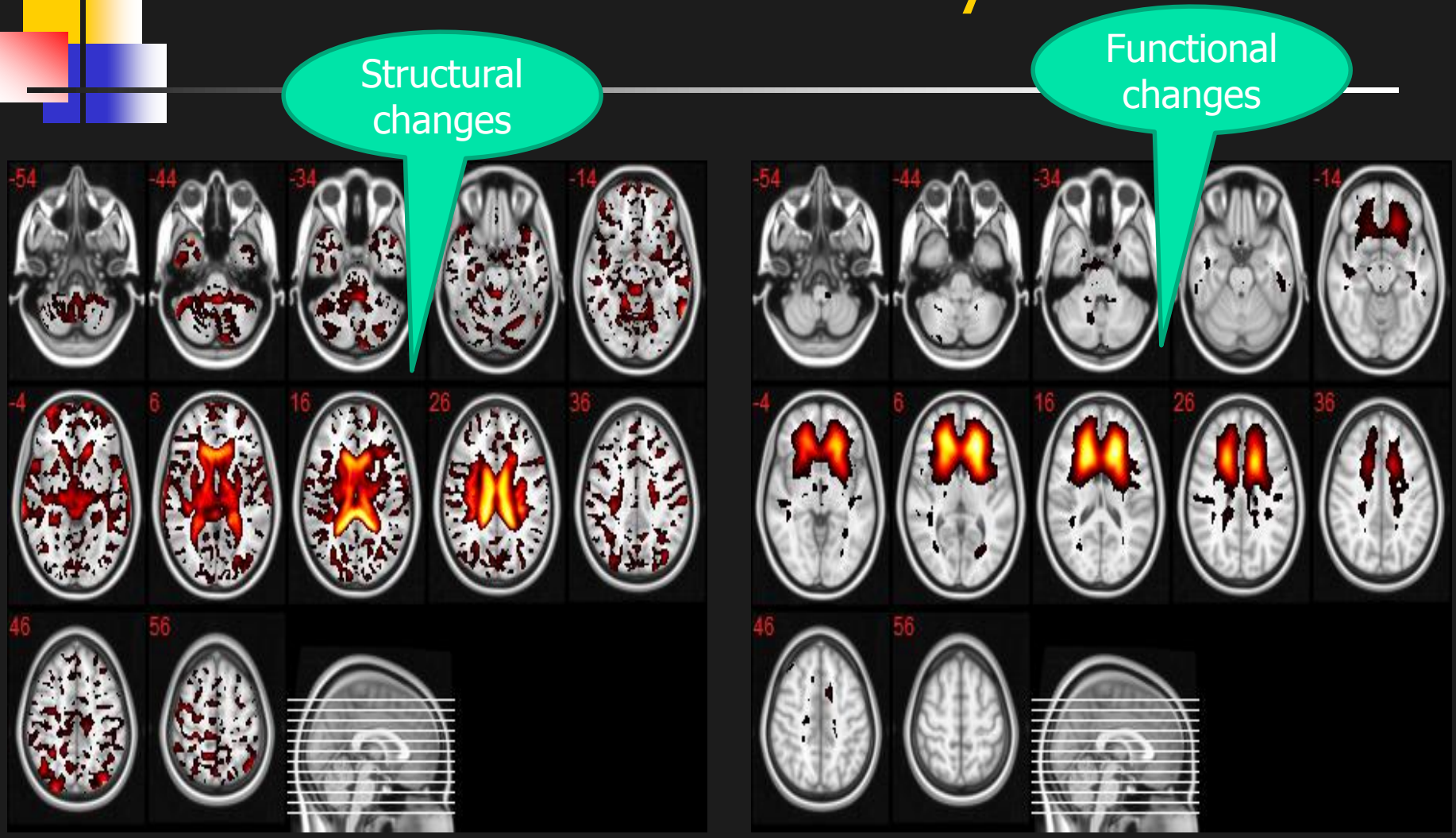
# Data Fusion Schematic



# Experimental Results
# The first Cannonical Variate

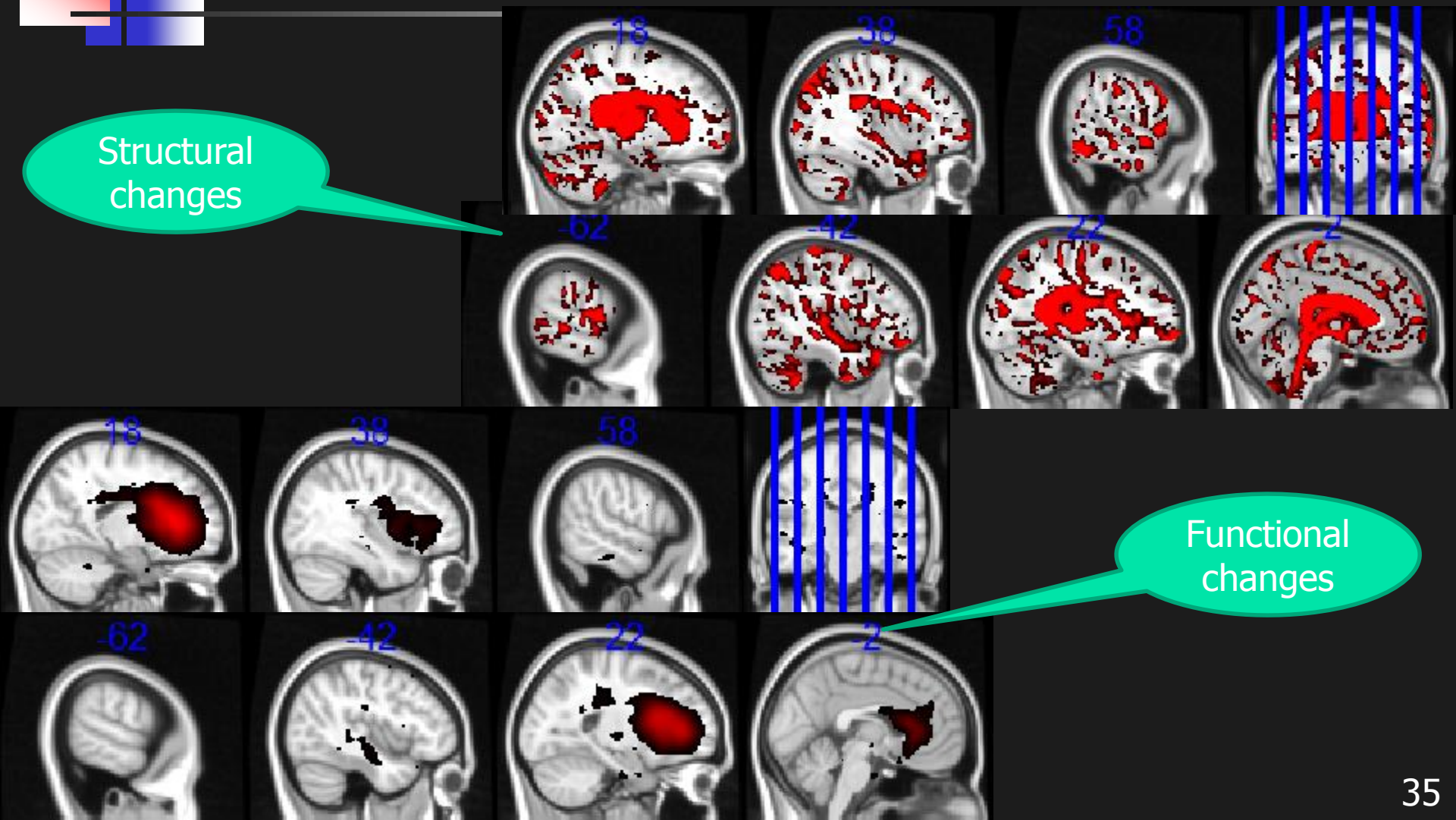


# Results of Fusion of Structural and functional data by ssCCA




The multi-slice view of the first canonical correlation coefficients of (a) structural, and (b) functional modality, produced by ssCCA approach.

# Results of Fusion of Structural and functional data by ssCCA

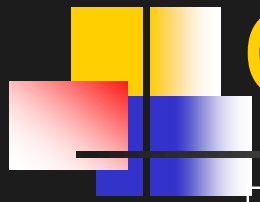


# Structural Regions

| Region | position | Parents |
|---|---|---|
| Lateral Ventricle | Left / Right | Subcortical |
| Caudate | Left / Right | |
| Thalamus | Left / Right | |
| Accumbens | Left / Right | |
| Pallidum | Left / Right | |
| Putamen | Left / Right | |
| Amygdala | Right | |
| Cerebral White Matter | Left / Right | |
| Hippocampus | Left / Right | |
| Brain Stem | ------- | |
| Superior Temporal Gyrus | (Anterior / posterior) division | Superior Temporal Gyrus |
| Heschls Gyrus | ------- | |
| Planum Polare | ------- | |
| Planum Temporale | ------- | |
| Inferior Temporal Gyrus | anterior division | Inferior Temporal Gyrus |
| Middle Temporal Gyrus | posterior division | Middle Temporal Gyrus |
| Temporal Pole | ------- | Temporal lobe |
| Parietal Operculum Cortex | ------- | Parietal lobe |
| Inferior Frontal Gyrus | pars opercularis | Inferior Frontal Gyrus |
| Frontal Medial Cortex | | |
| Frontal Operculum Cortex | | |
| Central Opercular Cortex | | |
| Supramarginal Gyrus | anteri | |
| Lateral Occipital Cortex | super | |
| Cuneal Cortex | | |
| Supracalcarine Cortex | | |
| Lingual Gyrus | | |
| Cerebellum | (Left / Right) IX | Cerebellum |
| | (Left / Right) X | |
| | (Left / Right) V | |
| | (Left / Right) VIIIb | |
| | (Left / Right) VI | |
| | Left Crus I | |
| | Right Crus II | |
| | Vermis Crus II | |
| | Right VIIIa | |
| | Right Crus II | |
| | Vermis VI | |

# Functional Regions

| Region | Position | Parents |
|---|---|---|
| Caudate | Left / Right | Subcortical |
| Putamen | Left / Right | |
| Pallidum | Left / Right | |
| Accumbens | Left / Right | |
| Cerebral White Matter | Left / Right | |
| Lateral Ventricle | Left | |
| Cingulate Gyrus | anterior division | Cingulate gyrus |
| Frontal Operculum Cortex | ------- | Frontal lobe |
| Frontal Orbital Cortex | ------- | Prefrontal cortex |
| Subcallosal Cortex | ------- | Cerebral cortex |
| Paracingulate Gyrus | ------- | |
| Insular Cortex | ------- | |



# Conclusion

- Multimodality provides added value for precise diagnosis/planning and comprehensive insight to brain function
- Multimodal simultaneous acquisition degrades the data of each modality and adds the experiment cost
- For popular use, technical issues of acquisition and analysis must be addressed

# Acknowledgement


- Ms. Afsoon Khodaee
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- Dr. Hamid Soltanian-Zadeh

# Thank You for Your Attention