

Are All Brains Wired Equally?

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Motivation

- Connectomics -- creation of brain connectivity maps.
- Analyzing the connectomes to understand how the brain functions.
 - Are there differences between different people?
 - Female vs. male
 - High math skills vs. normal
 - Artists vs. scientists...
 - Are all parts of the brain connected similarly?
 - Left hemisphere
 - Right hemisphere

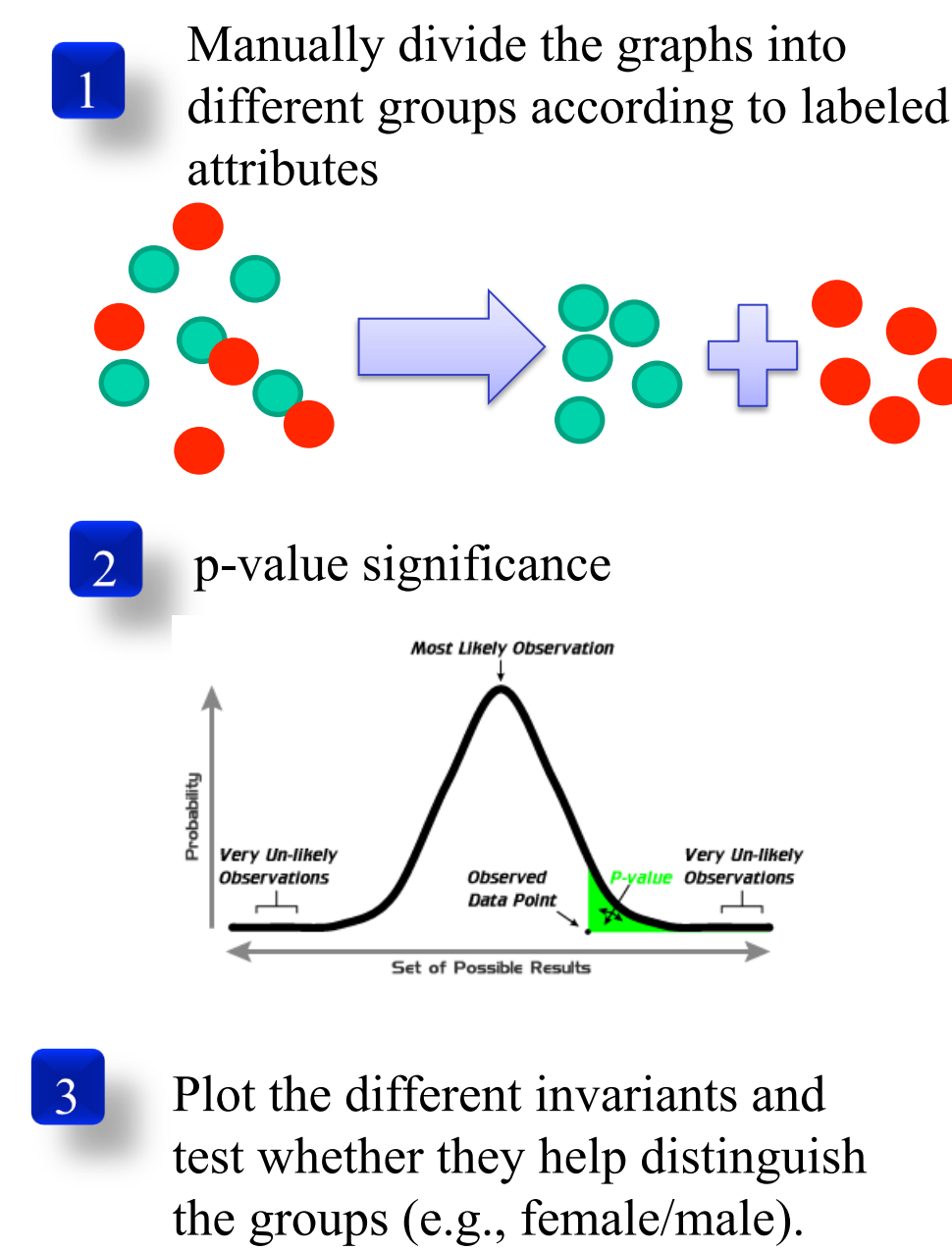


Our Approach

Step 1: Brain Difference

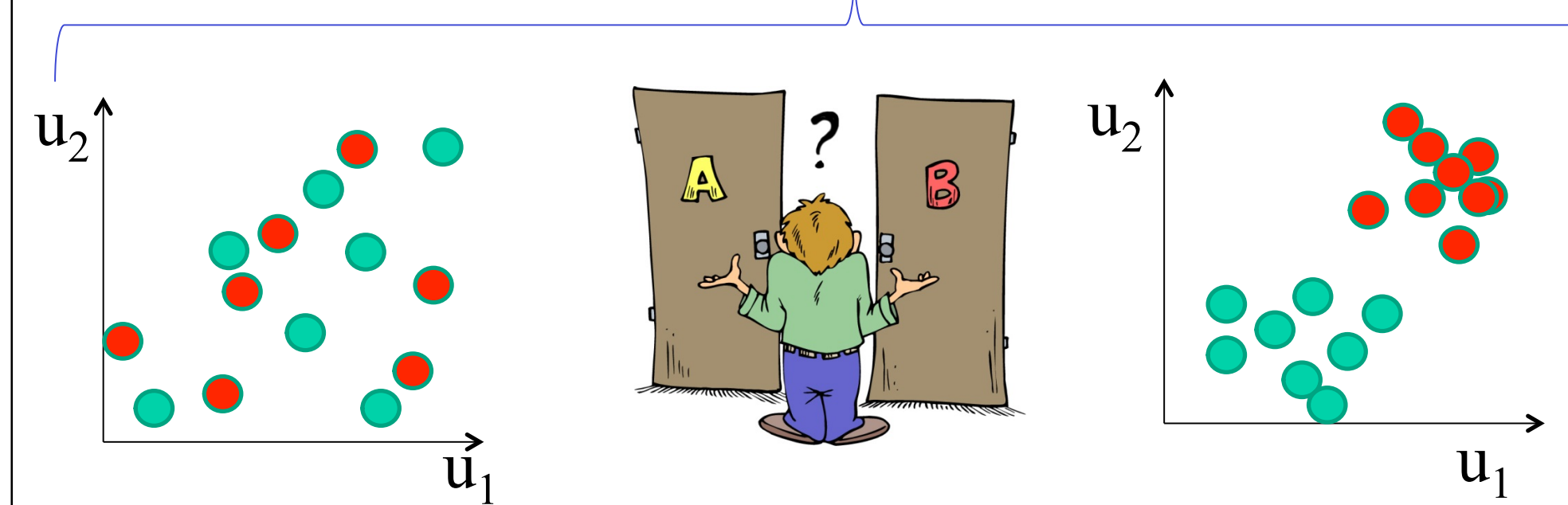
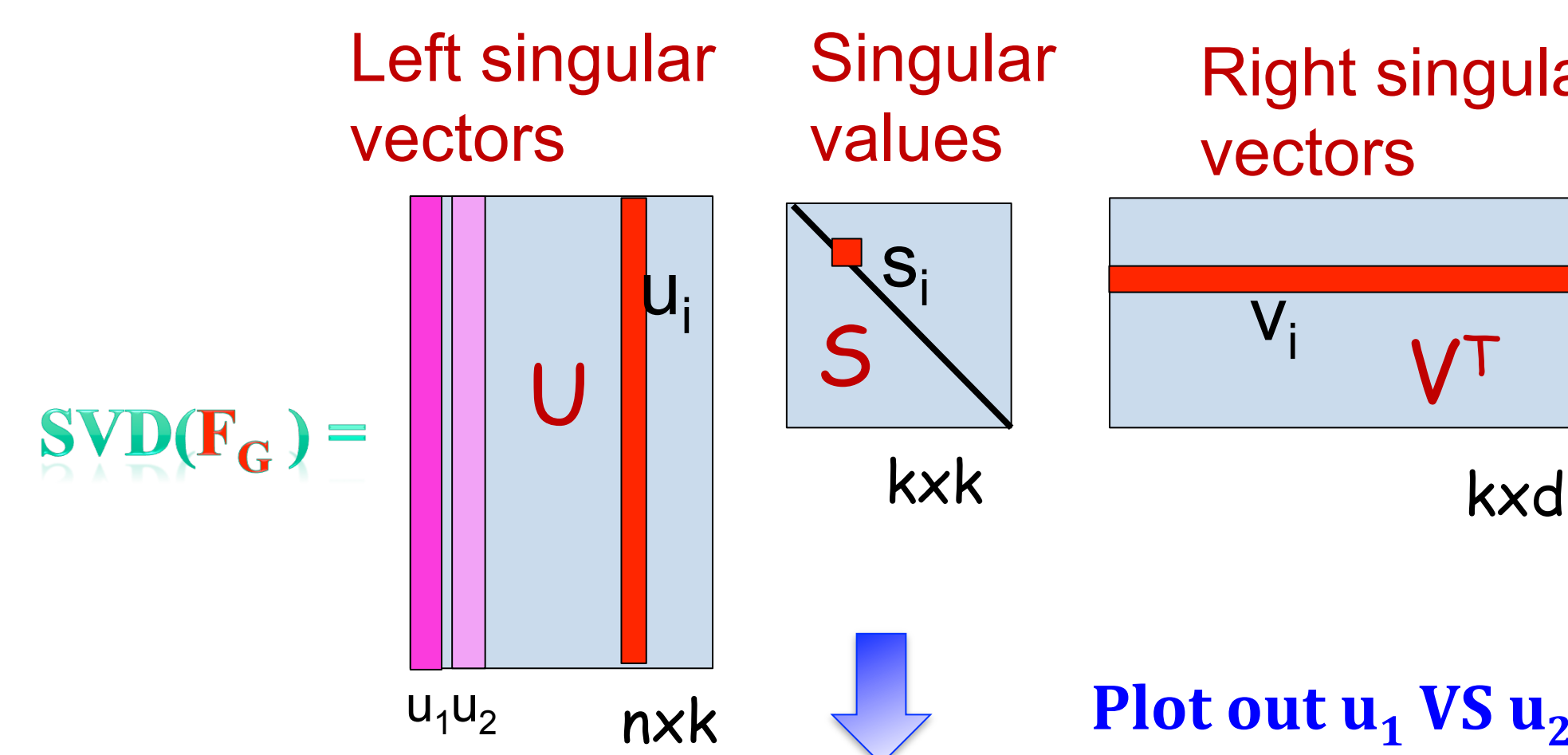
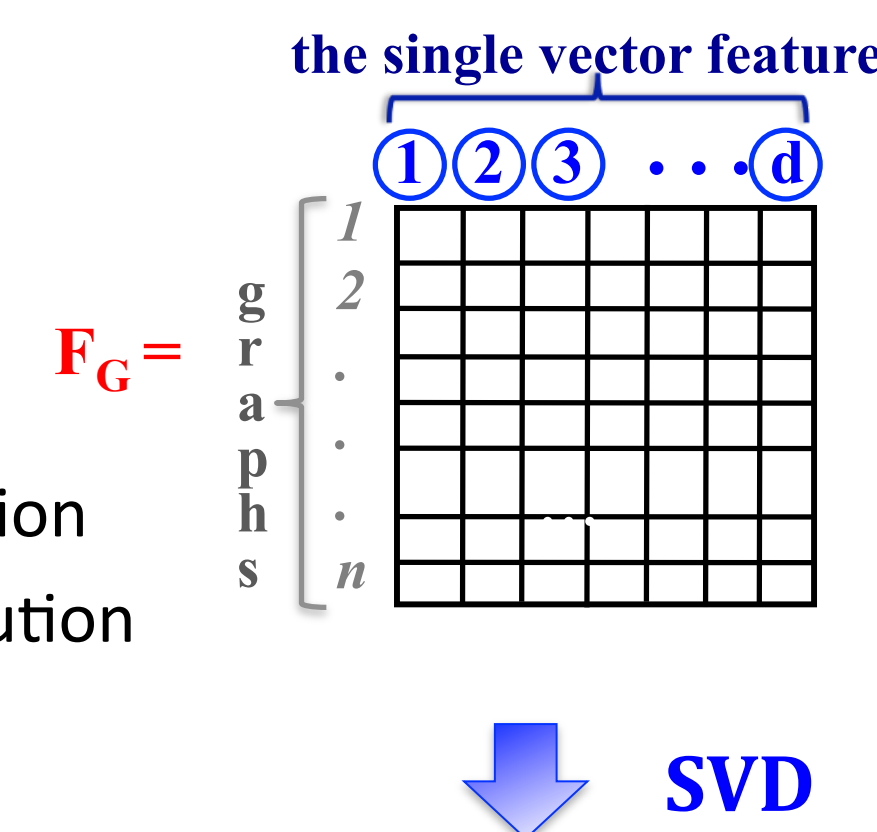
Scalar Features Analysis

- number of nodes
- number of edges
- largest eigenvalue
- number of triangles
- number of connected components
- maximum pagerank
- minimum pagerank



Vector Features

- degree distribution
- pagerank distribution
- radius distribution
- approximate radius distribution
- first n-th eigenvalues distribution
- triangle distribution



Possible conclusion 1

The feature cannot distinguish different groups

Possible conclusion 2

The feature contributes in predicting the group memberships.

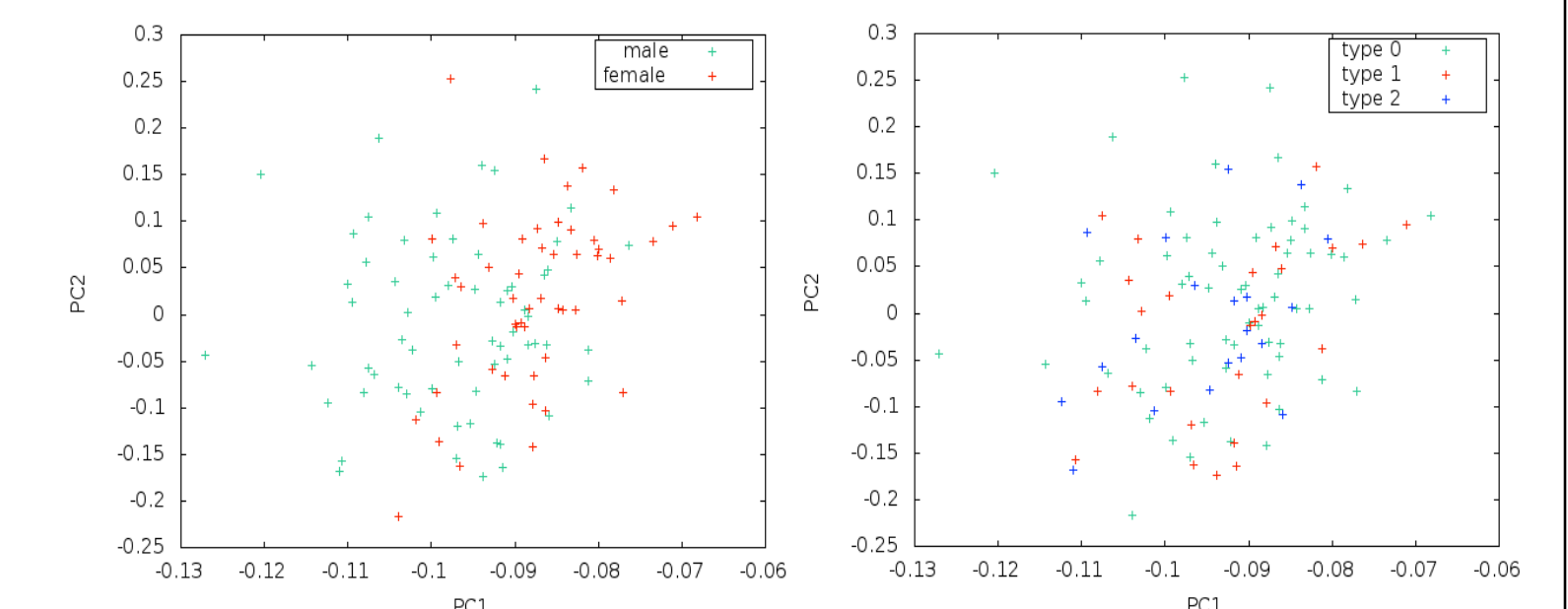
Experimental Results

Preliminaries

- 114 connectomes in total
- Groups divided in two ways:
 - Gender
 - 50 females: red dots and 64 males: green dots
 - Subject Type:
 - ~ Level of math skills
 - Normal: green dots
 - Low: red dots
 - High: blue dots

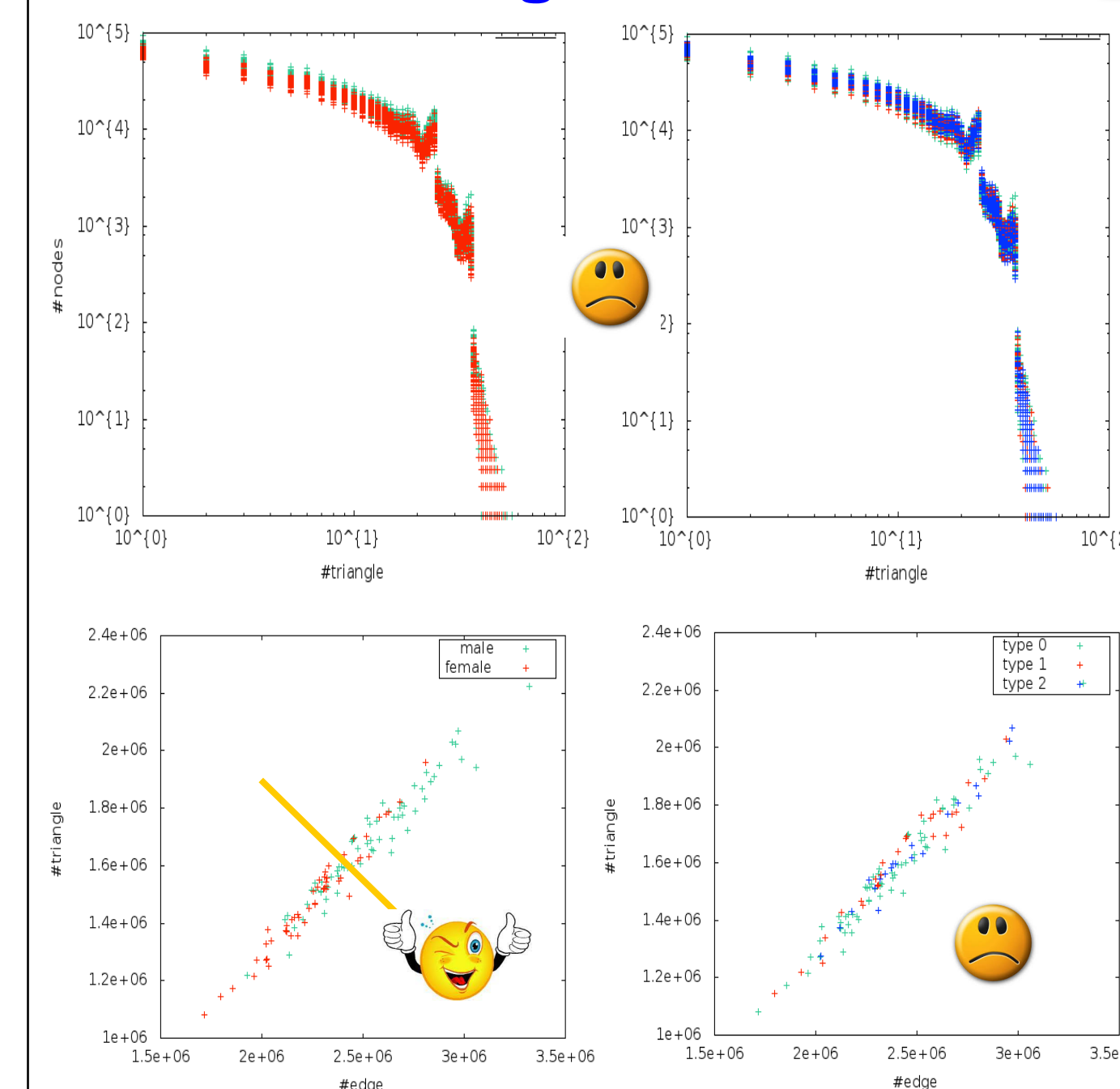
Degree Distribution

First vs. second principal component of the matrix brain scan X node-degree-distr.



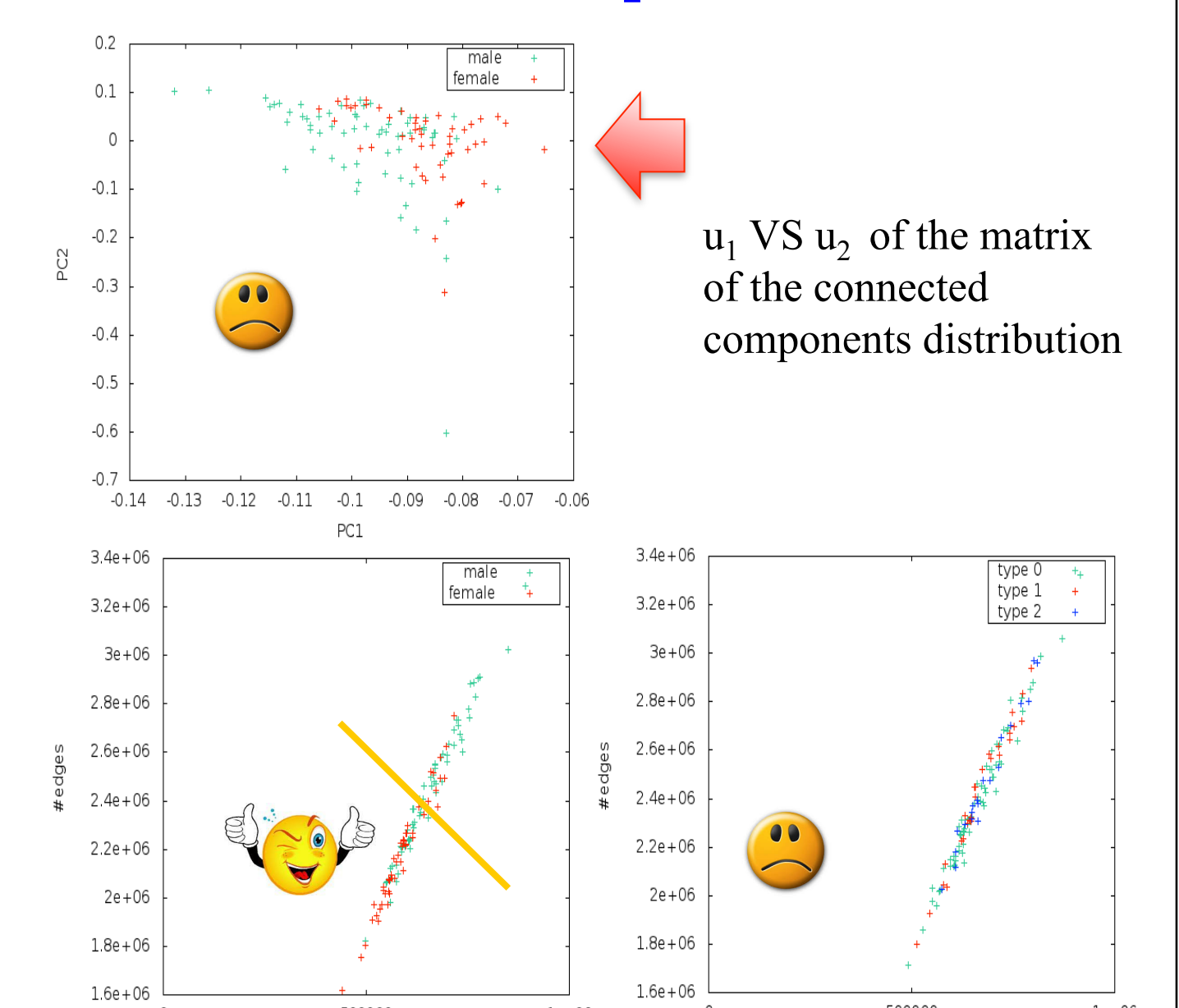
Observation: The extreme cases of female and male connectomes are well separated. However, the degree distribution cannot separate connectomes w.r.t. the mastery of math.

Triangles Plots



Observation: Triangle distribution cannot separate the groups. Total # of triangles vs. # of edges can help separate females from males, but cannot distinguish the groups w.r.t. the level of math skills.

Connected Components



Observations:

- The distribution of connected components does not differ significantly between males and females.
- The #of edges vs. nodes in the giant connected component of each connectome reveals two clusters corresponding to males and females.

The two genders differ significantly in this feature (2-sample t-test: p-value 0.0002).

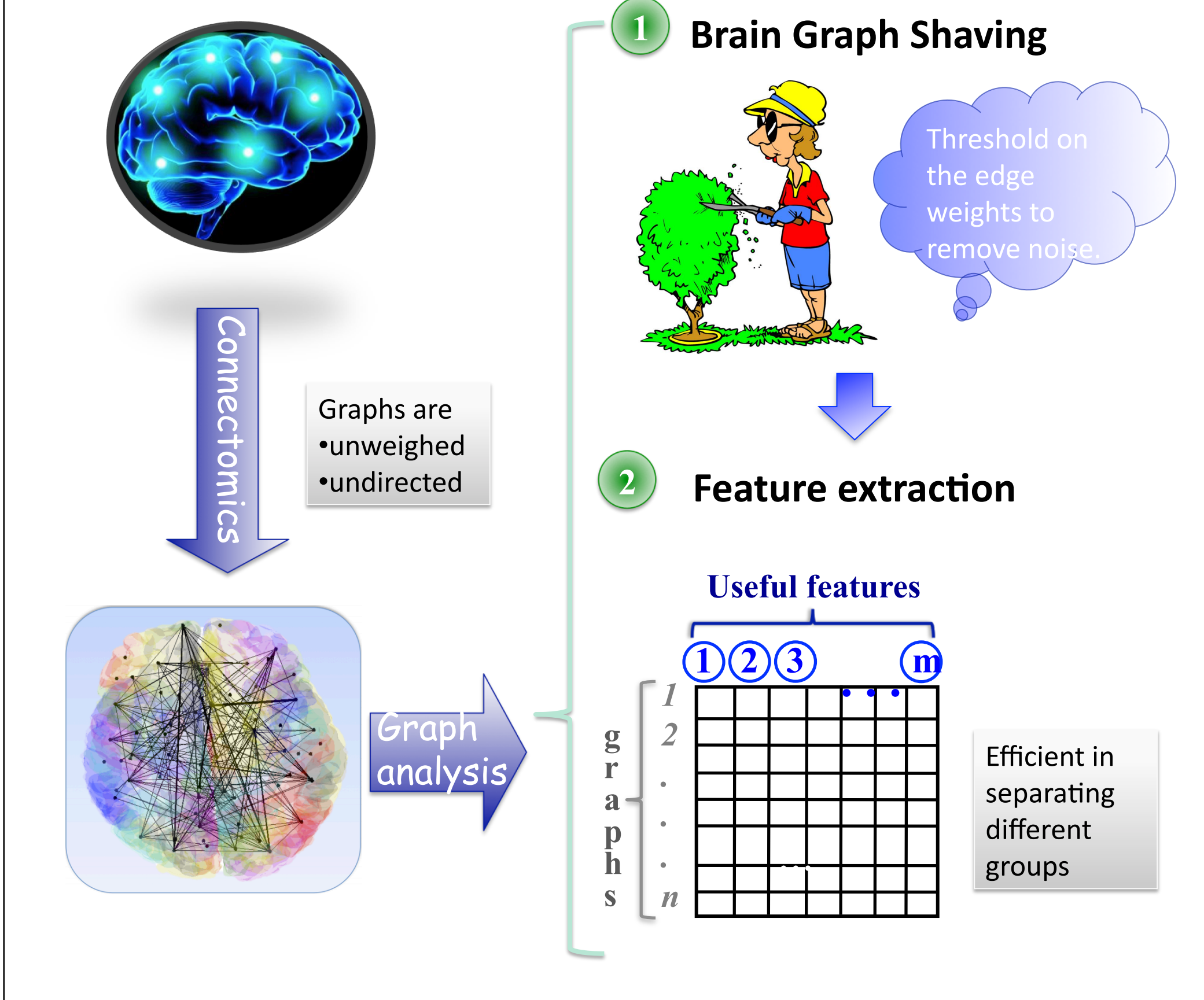
Largest Eigenvalue of Graph Matrix

Group	Male	Female
Mean	12.984	12.853
SD	0.177	0.189
SEM	0.022	0.027
Number	64	50

CONCLUSIONS

- Novel approach:** analyze invariants of numerous, big-scale brain graphs (connectomes) in order to do clustering and classification.
- Observations:**
 - The size (number of edges), as well as the maximum eigenvalues of the brain graphs differ significantly between males and females.
 - The degree distribution, and the number of triangles are features that can contribute towards the classification of the scans by gender.

Methodology



Dataset

- Connectomes of 114 people
 - Obtained by Multimodal Magnetic Resonance Imaging (MRI)
 - Each connectome is represented as unweighted and undirected graph.
 - Voxels/nodes: 492K-916K
 - Connections/edges: 9.14M-17.42M
 - Attributes per person: age, gender, IQ, creativity index, ...
- Toolkit
 - PEGASUS
 - Networkx



References

- Gray W, Bogovic JA, Vogelstein JT, Landman BA, Prince JL, Vogelstein RJ, 'Magnetic resonance connectome automated pipeline: An overview', Pulse, IEEE, vol. 3, no. 2, pp. 4248, 2012.
- Kang U, Tsourakakis C, Faloutsos C., 'PEGASUS: A Peta-Scale Graph Mining System - Implementation and Observations.', IEEE International Conference on Data Mining (ICDM), Miami, Florida, USA, 2009.