

Graph Var

GraphVar: A user-friendly toolbox for comprehensive graph analyses of functional brain connectivity.

- *features:*

- I. Pipeline construction of graph networks
- II. Calculation of network topological measures
- III. Generation of subject specific random networks
- IV. Perform statistical tests with a GLM framework
- V. Calculations on raw connectivity matrices (Network based statistics)
- VI. Parametric and non-parametric testing
- VII. Dynamic graph analyses (sliding windows)
- VIII. Interactive and visual results exploration

- Kruschwitz, J.D ^{1,2*}, List, D. ^{1,2*}, Waller, L. ², Rubinov, M. ³, Walter, H ¹.

*equal contribution

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² Technische Universität Dresden, Dresden, Germany

³ University of Cambridge, Cambridge, United Kingdom

The Analysis Setup GUI

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

[Select Subjects (Conn Matrix)]
 [Create Connectivity Matrix]

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left)
 Precentral gyrus (Right)
 Superior frontal gyrus, dorsolateral
 Superior frontal gyrus, dorsolateral
 Superior frontal gyrus, orbital part
 Superior frontal gyrus, orbital part
 Middle frontal gyrus (Left)
 Middle frontal gyrus (Right)

Network thresholds

0.1
 0.11
 0.12
 0.13
 0.14
 0.15
 0.16
 0.17
 0.18
 0.19

Generate 1 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir
 with 1 iterations.
 Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables

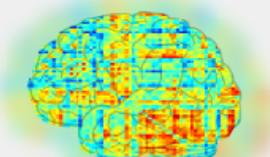
age
 sex
 research_site
 IQ
 eating_contest_chilli
 beer_pong_score
 fantasy_score

Between covariates
Between factors
Within covariates
Nuisance covariates

Select Within ID
 No Interactions

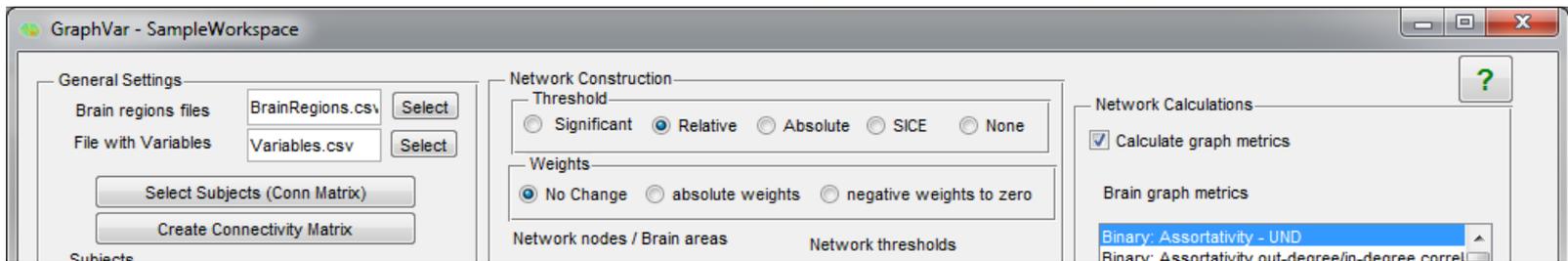
Graph metrics
 parametric rand NW permutation #Rep
Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

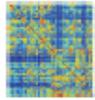


Graph Var

Setup panel



Input:

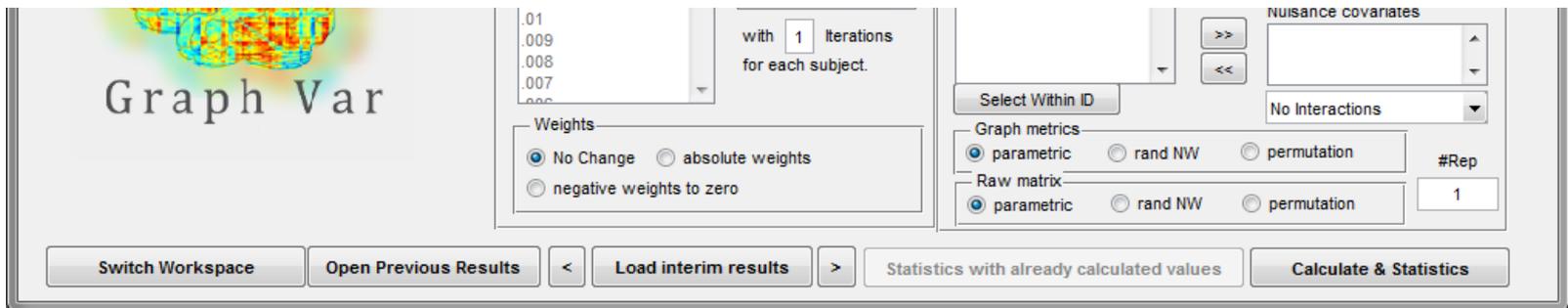
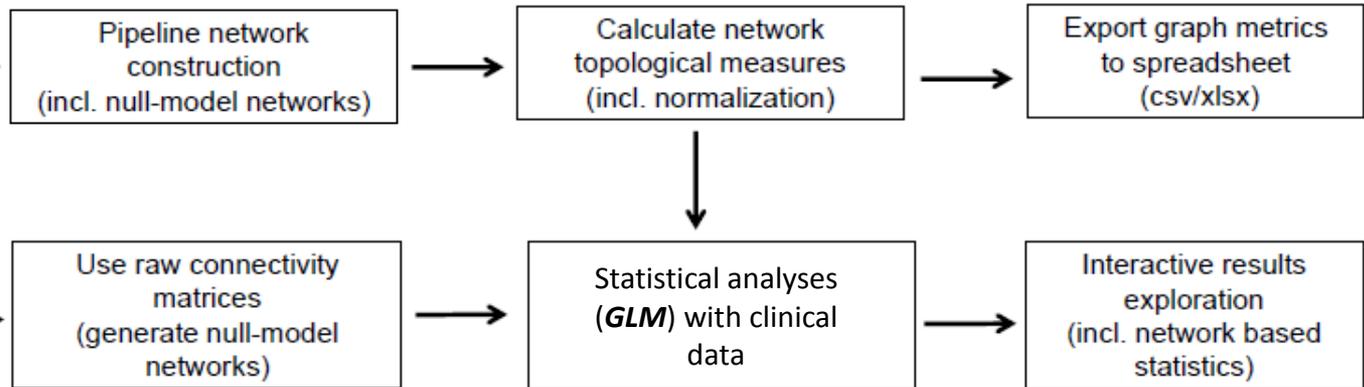


or

Node 1	Node 2	Node 3	Node n
Time course...	Time course...	Time course...	Time course...

and

Subject data
(e.g. clinical data)



Workflows

The screenshot shows the GraphVar software interface with several workflow annotations:

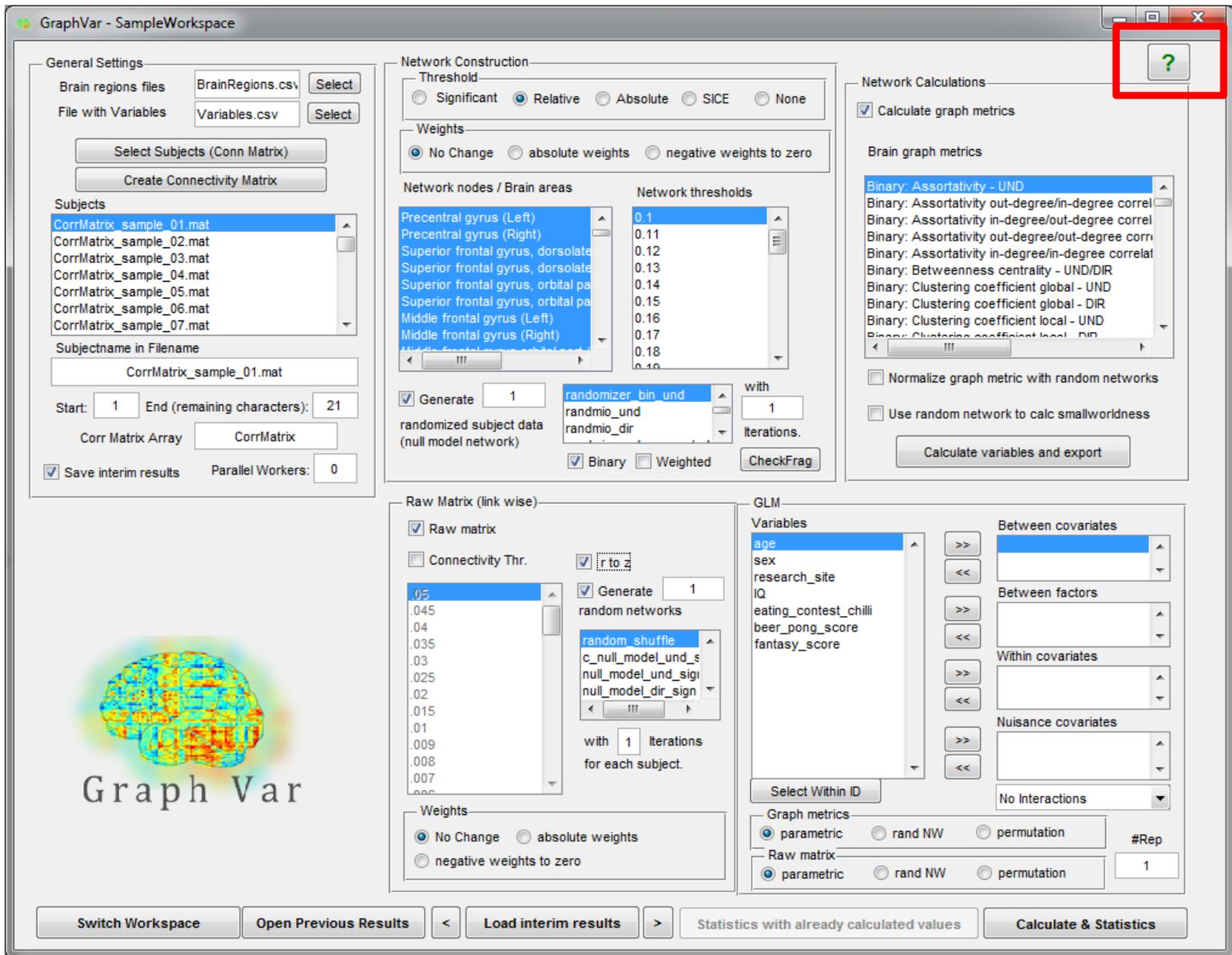
- Calculate and export graph metrics:** A large green arrow points from the 'General Settings' and 'Network Calculations' panels towards the 'Calculate variables and export' button.
- Statistics on raw matrix:** A large green arrow points from the 'Raw Matrix (link wise)' panel towards the 'Calculate & Statistics' button.
- Statistics with graph metrics:** A vertical green arrow points downwards from the 'Network Calculations' panel towards the 'Calculate & Statistics' button.

The interface includes the following sections:

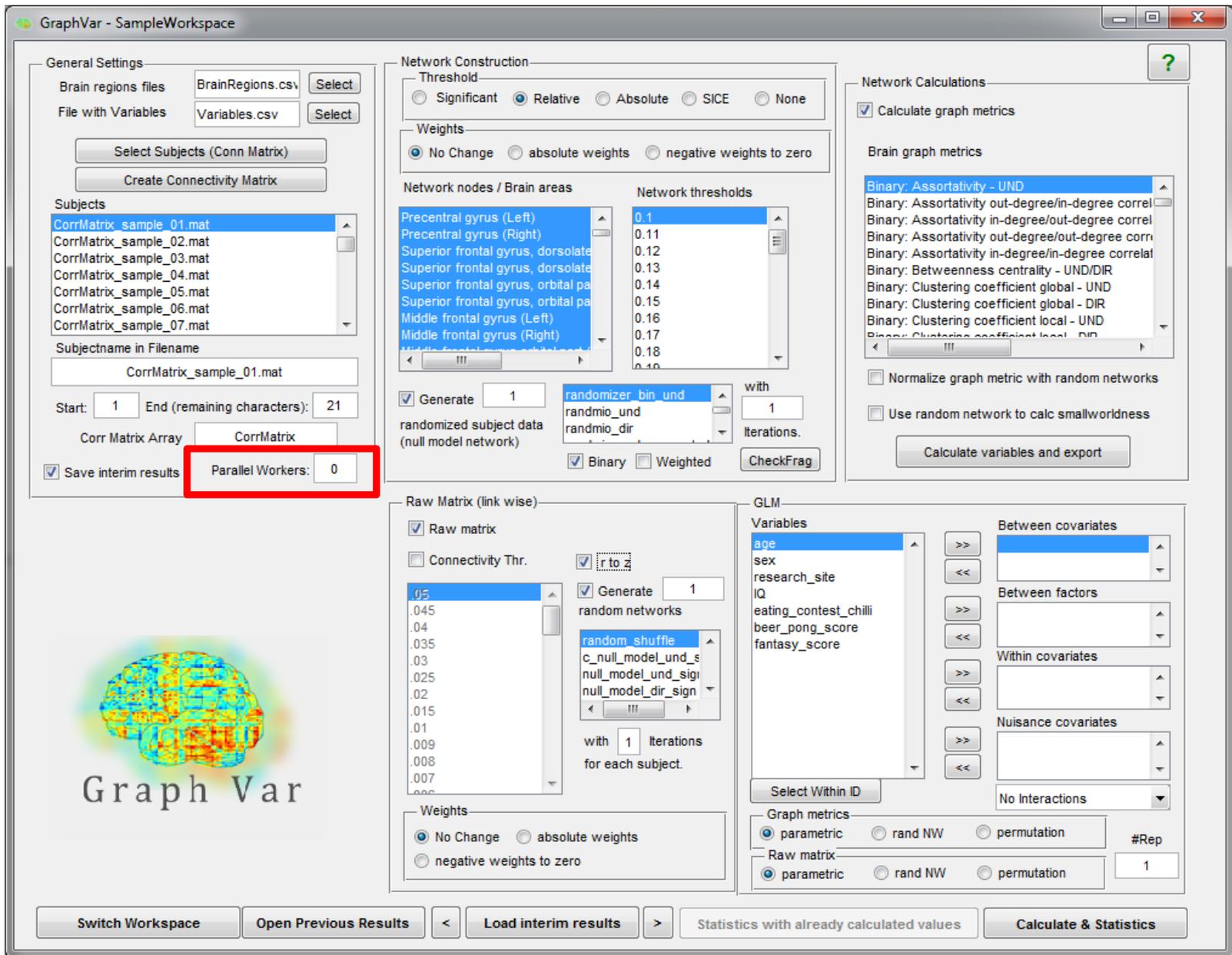
- General Settings:** Brain regions files (BrainRegions.csv), File with Variables (Variables.csv), Select Subjects (Conn Matrix), Create Connectivity Matrix, Subjects list (CorrMatrix_sample_01.mat), Subjectname in Filename (CorrMatrix_sample_01.mat), Start (1), End (21), Corr Matrix Array (CorrMatrix), Save interim results, Parallel Workers (0).
- Network Construction:** Threshold (Relative), Weights (No Change), Network nodes / Brain areas (Precentral gyrus (Left)), Network thresholds (0.1), Generate (1), randomized subject data (null model network), Binary/Weighted options, CheckFrag button.
- Network Calculations:** Calculate graph metrics, Brain graph metrics list (Binary: Assortativity - UND, etc.), Normalize graph metric with random networks, Use random network to calculate statistics, Calculate variables and export button.
- Raw Matrix (link wise):** Raw matrix, Connectivity Thr. (0.5), r to z, Generate (1), random networks, with 1 iterations for each subject, Weights (No Change).
- GLM:** Variables list (age, sex, research_site, IQ, eating_contest_chilli, beer pong score), Between covariates, Within covariates, Nuisance covariates, No Interactions, Select Within ID, Graph metrics (parametric, rand NW, permutation), #Rep (1), Raw matrix (parametric, rand NW, permutation).

At the bottom, there are buttons for: Switch Workspace, Open Previous Results, Load interim results, Statistics with already calculated values, and Calculate & Statistics.

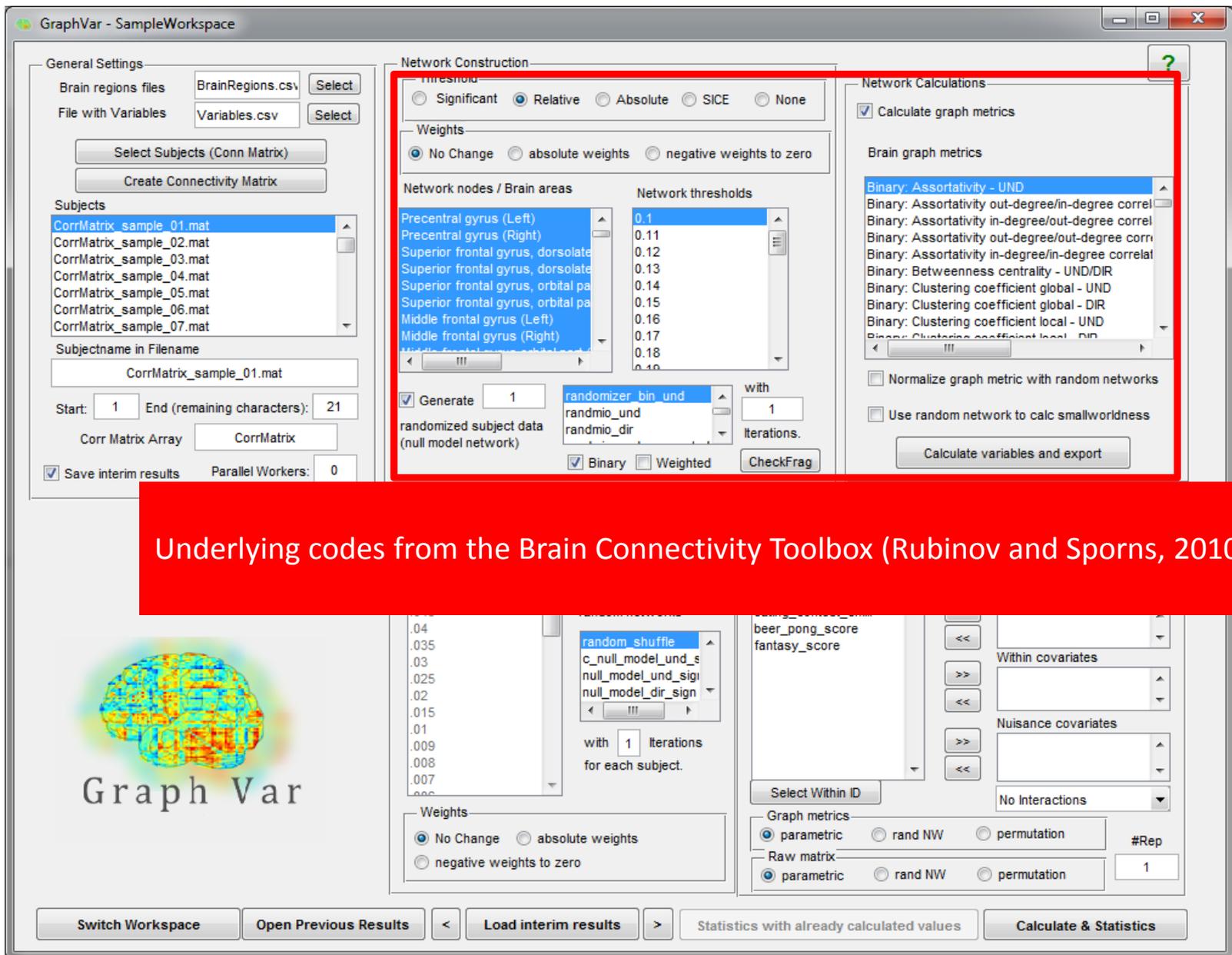
Workflows



Setup panel (mouse over help)



Parallel Computing (with toolbox)



Setup panel

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
- CorrMatrix_sample_02.mat
- CorrMatrix_sample_03.mat
- CorrMatrix_sample_04.mat
- CorrMatrix_sample_05.mat
- CorrMatrix_sample_06.mat
- CorrMatrix_sample_07.mat

Subjectname in Filename

CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold: Significant Relative Absolute SICE None

Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas

- Precentral gyrus (Left) 0.1
- Precentral gyrus (Right) 0.11
- Superior frontal gyrus, dorsolateral 0.12
- Superior frontal gyrus, dorsolateral 0.13
- Superior frontal gyrus, orbital part 0.14
- Superior frontal gyrus, orbital part 0.15
- Middle frontal gyrus (Left) 0.16
- Middle frontal gyrus (Right) 0.17
- Middle frontal gyrus (Right) 0.18
- Middle frontal gyrus (Right) 0.19

Network thresholds

Generate 1 with randomizer bin und randomized subject data (null model network) with 1 iterations.

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

- Binary: Assortativity - UND
- Binary: Assortativity out-degree/in-degree correl
- Binary: Assortativity in-degree/out-degree correl
- Binary: Assortativity out-degree/out-degree correl
- Binary: Assortativity in-degree/in-degree correl
- Binary: Betweenness centrality - UND/DIR
- Binary: Clustering coefficient global - UND
- Binary: Clustering coefficient global - DIR
- Binary: Clustering coefficient local - UND
- Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks

Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix

Connectivity Thr.

r to z

Generate 1 random networks

random_shuffle

c_null_model_und_s

null_model_und_sigi

null_model_dir_sign

with 1 iterations for each subject.

Weights: No Change absolute weights negative weights to zero

GLM

Variables

- age
- sex
- research_site
- IQ
- eating_contest_chilli
- beer_pong_score
- fantasy_score

Between covariates

Between factors

Within covariates

Nuisance covariates

No Interactions

Select Within ID

Graph metrics: parametric rand NW permutation #Rep

Raw matrix: parametric rand NW permutation #Rep 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

General settings

GraphVar - SampleWorkspace

General Settings
Brain regions files: BrainRegions.csv [Select]
File with Variables: Variables.csv [Select]
[Select Subjects (Conn Matrix)]
[Create Connectivity Matrix]

Subjects
CorrMatrix_sample_01.mat
CorrMatrix_sample_02.mat
CorrMatrix_sample_03.mat
CorrMatrix_sample_04.mat
CorrMatrix_sample_05.mat
CorrMatrix_sample_06.mat
CorrMatrix_sample_07.mat
Subjectname in Filename: CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
Corr Matrix Array: CorrMatrix
 Save interim results Parallel Workers: 0

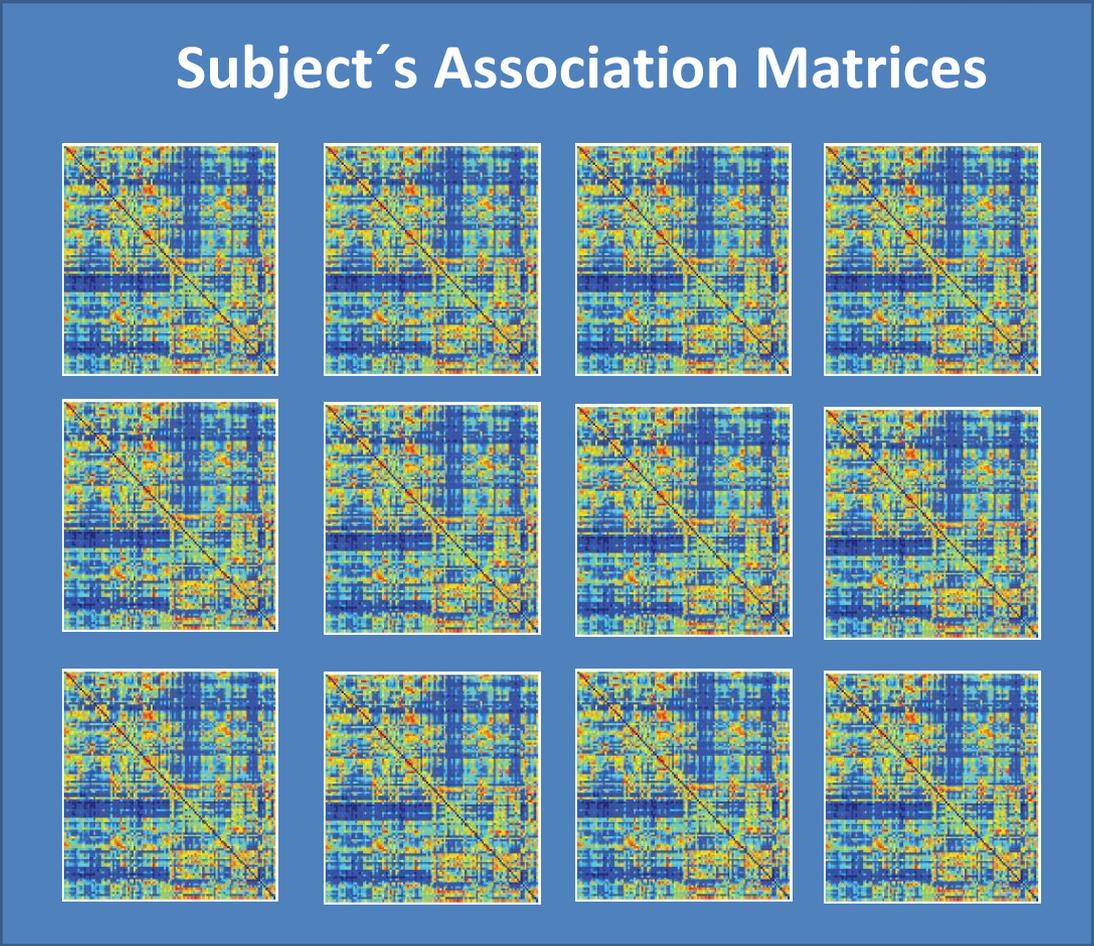
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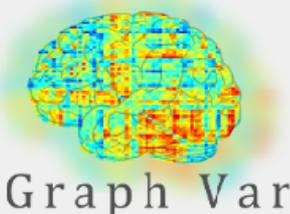
Weights
 No Change absolute weights
 negative weights to zero

Select Within ID: No Interactions
Graph metrics: parametric rand NW permutation #Rep
Raw matrix: parametric rand NW permutation #Rep: 1

[Switch Workspace] [Open Previous Results] [Load interim results] [Calculate & Statistics]



Subject's Association Matrices



Graph Var

Load (existing) Connectivity Matrices

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
- CorrMatrix_sample_02.mat
- CorrMatrix_sample_03.mat
- CorrMatrix_sample_04.mat
- CorrMatrix_sample_05.mat
- CorrMatrix_sample_06.mat
- CorrMatrix_sample_07.mat

Subjectname in Filename: CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Partial corr Covariance Matrix

Spearman corr SICE target density:

Bend corr 0.2

Mutual Inf

Create random time series

Randomize Shuffle FFT

Number of random series: 1

Sliding Windows (Dynamic GraphVar)

Window Size: 50 Step Size: 10

Generate Conn Matrix (default: Pearson)

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With iterations

for each subject.

Weights

No Change absolute weights

negative weights to zero

Select Within ID

No Interactions

Graph metrics

parametric rand NW permutation #Rep

Raw matrix

parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

Individual nodal time courses

	Node 1	Node 2	Node 3	Node n
Time course...				

Generate Connectivity Matrices

GraphVar - SampleWorkspace

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
- CorrMatrix_sample_02.mat
- CorrMatrix_sample_03.mat
- CorrMatrix_sample_04.mat
- CorrMatrix_sample_05.mat
- CorrMatrix_sample_06.mat
- CorrMatrix_sample_07.mat

Subjectname in Filename: CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

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Weight

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Brain.xlsx - Microsoft Excel

Datei Start Einfügen Seitenlayout Formeln Daten Überprüfen Ansicht

Calibri 11

Einfügen Zwischenabl... Schriftart Ausrichtung Zahl Formatvorlagen Zellen Bearbeiten

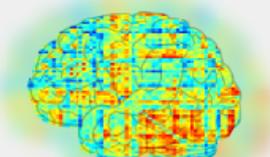
E22

	A	B	C
1	1	Precentral_L	Precentral gyrus (Left)
2	1	Precentral_R	Precentral gyrus (Right)
3	1	Frontal_Sup_L	Superior frontal gyrus, dorsolateral (Left)
4	1	Frontal_Sup_R	Superior frontal gyrus, dorsolateral (Right)
5	1	Frontal_Sup_Orb_L	Superior frontal gyrus, orbital part (Left)
6	1	Frontal_Sup_Orb_R	Superior frontal gyrus, orbital part (Right)
7	1	Frontal_Mid_L	Middle frontal gyrus (Left)
8	1	Frontal_Mid_R	Middle frontal gyrus (Right)
9	1	Frontal_Mid_Orb_L	Middle frontal gyrus orbital part (Left)
10	1	Frontal_Mid_Orb_R	Middle frontal gyrus orbital part (Right)
11	1	Frontal_Inf_Oper_L	Inferior frontal gyrus, opercular part (Left)
12	1	Frontal_Inf_Oper_R	Inferior frontal gyrus, opercular part (Right)
13	1	Frontal_Inf_Tri_L	Inferior frontal gyrus, triangular part (Left)
14	1	Frontal_Inf_Tri_R	Inferior frontal gyrus, triangular part (Right)
15	1	Frontal_Inf_Orb_L	Inferior frontal gyrus, orbital part (Left)
16	1	Frontal_Inf_Orb_R	Inferior frontal gyrus, orbital part (Right)
17	1	Rolandic_Oper_L	Rolandic operculum (Left)
18	1	Rolandic_Oper_R	Rolandic operculum (Right)

Bereit

Load interim results > Statistics with already calculated values Calculate & Statistics

Graph Var



Label nodes

GraphVar - SampleWorkspace

General Settings

BrainRegions.csv Select

File with Variables Variables.csv Select

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
- CorrMatrix_sample_02.mat
- CorrMatrix_sample_03.mat
- CorrMatrix_sample_04.mat
- CorrMatrix_sample_05.mat
- CorrMatrix_sample_06.mat
- CorrMatrix_sample_07.mat

Subjectname in Filename

CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold

Significant Relative Absolute SICC None

Network Calculations

Variables - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J	K
1	Subj_ID	age	sex	research_site	IQ	eating_co	beer_pon	fantasy_score			
2	sample_01	21	male	New York	100	48	13	68,1			
3	sample_02	43	male	New York	130	47	15	23,9			
4	sample_03	26	male	New York	115	53	21	28,8			
5	sample_04	25	male	Paris	98	56	10	40,2			
6	sample_05	22	male	Paris	55	62	20	48,4			
7	sample_06	33	male	Paris	120	66	17	43,5			
8	sample_07	36	male	Paris	80	68	16	32,1			
9	sample_08	33	male	Paris	99	73	15	37			
10	sample_09	39	male	Paris	65	63	25	46,8			
11	sample_10	46	male	Paris	140	48	23	43,5			
12	sample_11	33	male	London	122	64	18	48,4			
13	sample_12	46	male	London	130	58	23	46,8			
14	sample_13	42	male	London	111	51	19	46,8			
15	sample_14	47	male	London	82	46	14	41,9			
16	sample_15	35	male	New York	79	71	16	40,2			
17	sample_16	43	female	New York	83	54	9	41,9			
18	sample_17	32	female	New York	69	58	16	48,4			
19	sample_18	22	female	New York	68	59	18	30,4			
20	sample_19	22	female	New York	110	64	18	51,7			
21	sample_20	38	female	New York	109	44	17	46,8			
22	sample_21	38	female	New York	55	56	22	32,1			

Graph Var

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

parametric rand NW permutation 1

Variable Selection

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
- CorrMatrix_sample_02.mat
- CorrMatrix_sample_03.mat
- CorrMatrix_sample_04.mat
- CorrMatrix_sample_05.mat
- CorrMatrix_sample_06.mat
- CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas

- Precentral gyrus (Left) 0.1
- Precentral gyrus (Right) 0.11
- Superior frontal gyrus, dorsolateral 0.12
- Superior frontal gyrus, dorsolateral 0.13
- Superior frontal gyrus, orbital part 0.14
- Superior frontal gyrus, orbital part 0.15
- Middle frontal gyrus (Left) 0.16
- Middle frontal gyrus (Right) 0.17
- Middle frontal gyrus (Right) 0.18
- Middle frontal gyrus (Right) 0.19

Network thresholds

Generate 1 with randomizer bin und
 randomized subject data (null model network) with randomio_und
 randomio_dir iterations. 1

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

- Binary: Assortativity - UND
- Binary: Assortativity out-degree/in-degree correl
- Binary: Assortativity in-degree/out-degree correl
- Binary: Assortativity out-degree/out-degree correl
- Binary: Assortativity in-degree/in-degree correl
- Binary: Betweenness centrality - UND/DIR
- Binary: Clustering coefficient global - UND
- Binary: Clustering coefficient local - DIR
- Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1
 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables

- age
- sex
- research_site
- IQ
- eating_contest_chilli
- beer_pong_score
- fantasy_score

Between covariates
 Between factors
 Within covariates
 Nuisance covariates

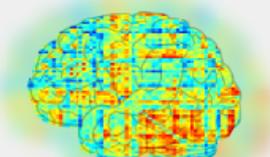
Select Within ID

No Interactions

Graph metrics
 parametric rand NW permutation #Rep

Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Network construction

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
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Subjectname in Filename

CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold

Significant Relative Absolute SICE None

Weights

No Change absolute weights negative weights to zero

Network thresholds

- 0.1
- 0.11
- 0.12
- 0.13
- 0.14
- 0.15
- 0.16
- 0.17
- 0.18
- 0.19

Network nodes

- Precentral gyrus (Left)
- Precentral gyrus (Right)
- Superior frontal gyrus, dorsolateral
- Superior frontal gyrus, dorsolateral
- Superior frontal gyrus, orbital part
- Superior frontal gyrus, orbital part
- Middle frontal gyrus (Left)
- Middle frontal gyrus (Right)

Generate 1 randomized subject data (null model network)

randomizer bin und with 1

randomio_und iterations.

randomio_dir

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

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- Binary: Betweenness centrality - UND/DIR
- Binary: Clustering coefficient global - UND
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Normalize graph metric with random networks

Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix

Connectivity Thr.

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Generate 1 random networks

random_shuffle

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with 1 iterations for each subject.

Weights

No Change absolute weights

negative weights to zero

GLM

Variables

- age
- sex
- research_site
- IQ
- eating_contest_chilli
- beer_pong_score
- fantasy_score

Between covariates

Between factors

Within covariates

Nuisance covariates

No Interactions

Select Within ID

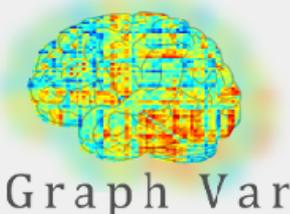
Graph metrics

parametric rand NW permutation #Rep

Raw matrix

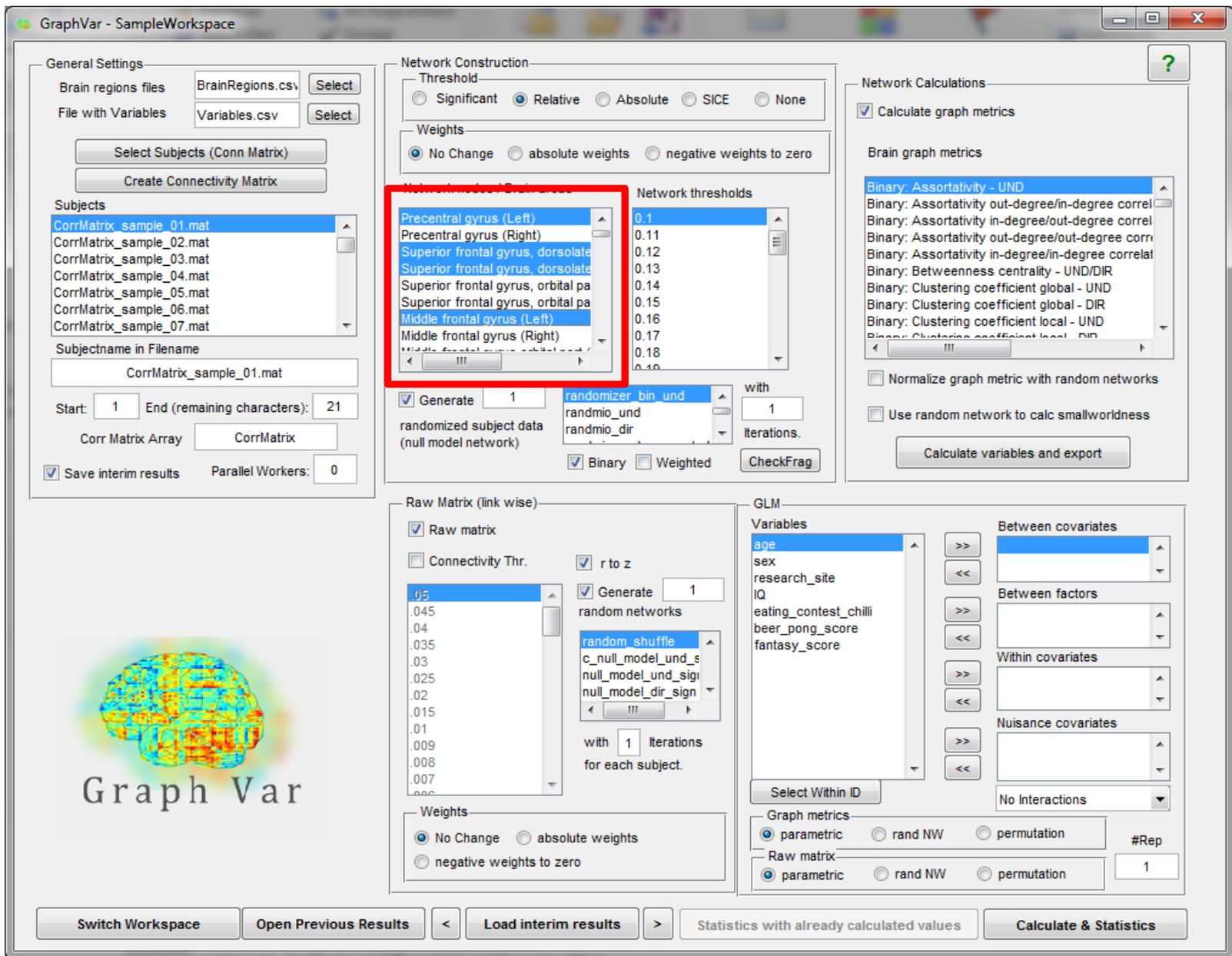
parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Network nodes



Redefine Network (Subnetwork analyses)

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

- CorrMatrix_sample_01.mat
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- CorrMatrix_sample_05.mat
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- CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold: Significant Relative Absolute SICE None

Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas

- Precentral gyrus (Left) 0.1
- Precentral gyrus (Right) 0.11
- Superior frontal gyrus, dorsolateral 0.12
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- Superior frontal gyrus, orbital part 0.14
- Superior frontal gyrus, orbital part 0.15
- Middle frontal gyrus (Left) 0.16
- Middle frontal gyrus (Right) 0.17
- Middle frontal gyrus (Right) 0.18

Network thresholds

Generate 1 randomized subject data (null model network) with randomizer bin und randomio_und randomio_dir with 1 iterations.

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

- Binary: Assortativity - UND
- Binary: Assortativity out-degree/in-degree correl
- Binary: Assortativity in-degree/out-degree correl
- Binary: Assortativity out-degree/out-degree correl
- Binary: Assortativity in-degree/in-degree correl
- Binary: Betweenness centrality - UND/DIR
- Binary: Clustering coefficient global - UND
- Binary: Clustering coefficient global - DIR
- Binary: Clustering coefficient local - UND
- Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights: No Change absolute weights negative weights to zero

GLM

Variables

- age
- sex
- research_site
- IQ
- eating_contest_chilli
- beer_pong_score
- fantasy_score

Between covariates
 Between factors
 Within covariates
 Nuisance covariates

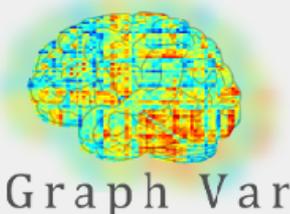
No Interactions

Select Within ID

Graph metrics: parametric rand NW permutation #Rep

Raw matrix: parametric rand NW permutation #Rep 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Network thresholds

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

[Select Subjects (Conn Matrix)]
 [Create Connectivity Matrix]

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename: CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold: Significant Relative Absolute SICE None

Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left) 0.1
 Precentral gyrus (Right) 0.11
 Superior frontal gyrus, dorsolateral 0.12
 Superior frontal gyrus, dorsolateral 0.13
 Superior frontal gyrus, orbital part 0.14
 Superior frontal gyrus, orbital part 0.15
 Middle frontal gyrus (Left) 0.16
 Middle frontal gyrus (Right) 0.17
 Middle frontal gyrus (Right) 0.18
 Middle frontal gyrus (Right) 0.19

Network thresholds

0.1
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19

Generate 1 randomized subject data (null model network) with randomizer bin und randomio_und randomio_dir iterations. 1

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1 random networks random_shuffle c_null_model_und_s null_model_und_sigi null_model_dir_sign

with 1 iterations for each subject.

Weights: No Change absolute weights negative weights to zero

GLM

Variables

age
sex
research_site
IQ
eating_contest_chilli
beer_pong_score
fantasy_score

Between covariates

Between factors

Within covariates

Nuisance covariates

Select Within ID

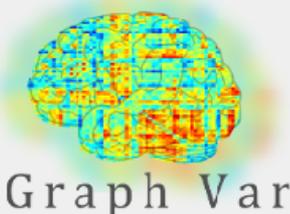
Graph metrics

parametric rand NW permutation #Rep

Raw matrix

parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Subject specific null model networks

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas
 Precentral gyrus (Left)
 Precentral gyrus (Right)
 Superior frontal gyrus, dorsolate
 Superior frontal gyrus, dorsolate
 Superior frontal gyrus, orbital pa
 Superior frontal gyrus, orbital pa
 Middle frontal gyrus (Left)
 Middle frontal gyrus (Right)

Network thresholds
 0.1
 0.11
 0.12
 0.13
 0.14
 0.15
 0.16
 0.17
 0.18
 0.19

Generate 1 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir
 with 1 iterations.
 Binary Weighted [CheckFrag]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables
 age
 sex
 research_site
 IQ
 eating_contest_chilli
 beer_pong_score
 fantasy_score

Between covariates
 Between factors
 Within covariates
 Nuisance covariates
 No Interactions

Select Within ID

Graph metrics
 parametric rand NW permutation #Rep
 Raw matrix
 parametric rand NW permutation 1

Network Calculations

Calculate graph metrics

Brain graph metrics
 Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree corr
 Binary: Assortativity in-degree/in-degree correlat
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Graph Var

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

Network topological measures

GraphVar - SampleWorkspace

General Settings
Brain regions files: BrainRegions.csv [Select]

Network Construction
Threshold

ExportData.xlsx - Microsoft Excel

Network Calculations
 Calculate graph metrics
 Brain graph metrics:
 Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR
 Normalize graph metric with random networks

Calculate variables and export

Between covariates
 Between factors
 Within covariates
 Nuisance covariates
 No Interactions

Weights
 No Change absolute weights
 negative weights to zero

Graph metrics
 parametric rand NW permutation #Rep
 Raw matrix
 parametric rand NW permutation

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

clustering	Corrected AI	0,05																	
0,1	-0,07237061	0,09357033	-0,04627269	-0,00182195	-0,01050473	0,01379858	0,08164257	-0,03847343	-0,0544339	-0,02977521	0,07549174	0,00852406	0,00846319	0,11717267	0,0722				
0,11	-0,07502656	0,0965873	-0,04119779	0,01382449	-0,01258913	0,01688709	0,09898348	-0,05137778	-0,06825057	-0,04164273	0,06610055	0,03442335	-0,01435543	0,09281828	0,0894				
0,12	0,0120058	0,10466911	-0,00895391	0,05711628	0,01955126	-0,01148392	0,00500131	0,01365077	-0,04494219	-0,03273493	0,06353858	0,03103569	0,00875535	0,10324542	0,0827				
0,13	0,04582824	0,13772624	-0,02306489	0,00408741	0,02521199	-0,05174935	0,09288706	-0,02283654	-0,04284299	0,04495615	0,02025344	0,00380567	0,13499298	0,1110					
0,14	0,05113111	0,14548641	-0,01061045	0,02692522	0,02569613	-0,07578842	0,08611047	0,05729156	-0,00061421	-0,03408272	0,0344073	0,03682116	-0,00855096	0,13497625	0,0966				
0,15	0,03443045	0,15909194	-0,02614552	0,01287442	0,03147307	-0,0258052	0,11819733	0,01723583	-0,01730789	-0,01061199	0,022515	0,03183292	-0,01734021	0,14352523	0,1060				
0,16	0,0218163	0,14646699	-0,00873069	-0,00431096	0,04221829	-0,00731211	0,10055191	0,00001491	0,033381	-0,00616201	0,02677757	0,03036297	-0,01787866	0,1497228	0,1063				
0,17	0,03632444	0,1164809	0,00718125	-0,00913568	0,07146096	0,00725661	0,01765865	0,01369501	0,02569157	-0,00414277	0,03320073	0,02824449	0,00300353	0,14970207	0,1084				
0,18	0,02603423	0,09428395	0,00556482	-0,00146251	0,0687442	0,01148425	0,06401952	0,01504792	0,02779036	-0,00971193	0,0384917	0,0363997	0,02119241	0,14140577	0,0841				
0,19	0,02785595	0,06774574	0,01046093	-0,0019819	0,09621474	0,01773432	0,0489363	0,03839059	0,04745267	-0,01980946	0,04508741	0,03606135	0,01092866	0,1287091	0,0685				
0,2	0,04587938	0,06213632	0,02744064	0,02045259	0,08726685	0,00666983	0,03770598	0,06392727	0,05961167	-0,03766387	0,06244042	0,02195677	0,0353122	0,11020771	0,0577				
0,21	0,06486796	0,05679674	0,03397945	0,02358691	0,09775207	0,01422356	0,02519688	0,06564341	0,05814384	-0,04080787	0,09320703	-0,00321626	0,02166131	0,0950827	0,0351				
0,22	0,058714	0,06224944	0,02695073	0,03135441	0,08862638	-0,000302	0,02549718	0,0543516	0,06134	-0,0428498	0,08729143	0,00418408	0,05731638	0,08314445	0,0331				
0,23	0,06397301	0,06654521	0,03523234	0,03290413	0,09133735	-0,02562673	0,03423818	0,06629271	0,0523437	-0,01926428	0,08666938	0,00315677	0,0456275	0,08901868	0,3032				
0,24	0,03414516	0,06251224	0,03274688	0,04781523	0,09005042	-0,03851445	0,03342348	0,06758784	0,06171202	-0,00469014	0,0823768	0,00389042	0,03907998	0,1073557	0,1912				
0,25	0,03672875	0,05469995	0,04586182	0,04821612	0,10420865	-0,03477186	0,01981998	0,07321033	0,0740143	-0,00227927	0,08060812	0,00425395	0,04007534	0,0997519	0,0231				
0,26	0,01747424	0,05420209	0,03590311	0,05848589	0,11140885	-0,03168225	0,04042244	0,05653371	0,07195734	-0,01144387	0,07356878	0,00915254	0,05270245	0,10546793	0,0262				
0,27	0,01580328	0,04428071	0,02435566	0,0591568	0,11038857	-0,0237298	0,05063582	0,05978296	0,05091287	-0,00782718	0,06159207	0,01121745	0,04329407	0,1127613	0,0323				
0,28	0,02351684	0,0356175	0,03276314	0,04944245	0,10747968	-0,00769363	0,04713653	0,04672004	0,04336767	-0,01603001	0,04059843	0,03825618	0,05411508	0,12770844	0,0415				
0,29	0,02501842	0,0541967	0,013575911	0,06100097	0,1129911	-0,00507062	0,04674411	0,05679719	0,06639136	-0,00657019	0,03380128	0,02901097	0,05217609	0,14174836	0,0460				
0,3	0,02430434	0,0494022	0,06852582	0,0776597	0,12693814	-0,02032829	0,04167152	0,0657082	0,08286791	-0,01113351	0,03437705	0,03653748	0,06064945	0,12811081	0,0258				
0,31	0,00693066	0,02564519	0,08129845	0,09324079	0,14914071	-0,02309732	0,03303592	0,07074533	0,10005378	-0,01823477	0,02453839	0,03148339	0,06669698	0,12782989	0,0177				
0,32	0,00702119	0,02400809	0,07047841	0,09937963	0,13675138	-0,02462539	0,03000154	0,05665468	0,09490111	-0,01605606	0,01217858	0,0564574	0,08390448	0,1354271	0,0214				
0,33	0,01336929	0,01539236	0,06829281	0,07508637	0,13250768	-0,02808616	0,02756673	0,05730859	0,09260112	-0,01710199	0,01383824	0,05297749	0,09024623	0,14352187	0,0234				
0,34	0,00758848	0,02620812	0,0677071	0,06722012	0,11887481	-0,02634262	0,02178227	0,0570474	0,08692257	-0,01313068	0,02254991	0,05385351	0,08473614	0,13690635	0,0253				
0,35	0,00403113	0,0156379	0,06408451	0,08246356	0,10838639	-0,03190663	0,02185981	0,04931325	0,09016646	-0,00524305	0,01547352	0,05881251	0,07077454	0,13851337	0,034				
0,36	0,0093267	0,00792909	0,07722194	0,06850733	0,11061845	-0,0300424	0,01639147	0,05207328	0,0833444	-0,01508398	0,01029145	0,04980996	0,0768634	0,14426683	0,0341				
0,37	0,01949276	0,00897587	0,08104787	0,05788151	0,10418969	-0,02780511	0,00976737	0,04727594	0,09857292	-0,00550516	0,0138434	0,04876302	0,07859713	0,13771213	0,0414				
0,38	0,02512363	0,00565759	0,08665301	0,05995017	0,11002747	-0,02254784	0,00577523	0,06047557	0,10444508	-0,00464431	0,01052914	0,05035265	0,07995829	0,14693308	0,0373				
0,39	0,03258273	-0,01398505	0,12322896	0,05839135	0,11256864	-0,00146909	-0,00772905	0,07112827	0,11100946	0,00538085	0,00522468	0,05031163	0,08216537	0,1596968	0,0430				
0,4	0,03844288	-0,03084499	0,13936289	0,05984102	0,12575051	-0,00349272	-0,02011598	0,06892946	0,10571306	0,0071975	-0,01069931	0,05261179	0,09250208	0,16254033	0,0385				
0,41	0,03232405	-0,03001284	0,14826075	0,05671577	0,11100961	-0,00867801	-0,02075038	0,06779047	0,10862153	0,00900181	-0,0123612	0,05957104	0,08808113	0,15288403	0,0472				
0,42	0,03442605	-0,03124535	0,14955826	0,05777968	0,11737508	-0,00861044	-0,01660732	0,06027197	0,11223547	0,02865632	-0,01393756	0,05839311	0,08426504	0,15594679	0,0463				
0,43	0,03383731	-0,01160574	0,14320655	0,05820829	0,10247971	-0,00534149	-0,00457463	0,0543487	0,10226185	0,01270905	0,00883996	0,04419414	0,07440936	0,14708955	0,0352				
0,44	0,03900943	-0,00949087	0,1524302	0,04309986	0,09263541	-0,01198801	-0,01211833	0,09707691	0,01916385	0,01370553	0,0500744	0,06583277	0,14473706	0,0513					
0,45	0,04282273	-0,01193977	0,16573786	0,04274644	0,08926346	-0,01339523	-0,01416005	0,05151339	0,11079359	0,02471677	0,00942234	0,06619623	0,06094685	0,1517514	0,057				

Export network topological measures

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left)	0.1
Precentral gyrus (Right)	0.11
Superior frontal gyrus, dorsolate	0.12
Superior frontal gyrus, dorsolate	0.13
Superior frontal gyrus, orbital pa	0.14
Superior frontal gyrus, orbital pa	0.15
Middle frontal gyrus (Left)	0.16
Middle frontal gyrus (Right)	0.17
Middle frontal gyrus, orbital pa	0.18
Middle frontal gyrus, orbital pa	0.19

Network thresholds

0.1

Generate 1 with 1 iterations.
 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1
 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables
 sex
 eating_contest_chilli

Between covariates
 age
 IQ

Between factors
 research_site

Within covariates

Nuisance covariates
 fantasy_score
 beer_pong_score

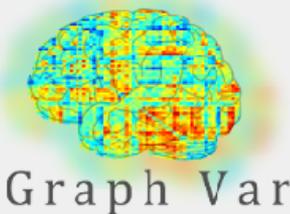
No Interactions

Select Within ID

Graph metrics
 parametric rand NW permutation #Rep

Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Statistical analyses (GLM)

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]
 Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

Subjects list: CorrMatrix_sample_01.mat, CorrMatrix_sample_02.mat, CorrMatrix_sample_03.mat, CorrMatrix_sample_04.mat, CorrMatrix_sample_05.mat, CorrMatrix_sample_06.mat, CorrMatrix_sample_07.mat
 Subjectname in Filename: CorrMatrix_sample_01.mat
 Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix
 Save interim results Parallel Workers: 0

Network Construction

Threshold: Significant Relative Absolute SICE None

Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas: Precentral gyrus (Left), Precentral gyrus (Right), Superior frontal gyrus, dorsolateral, Superior frontal gyrus, orbital part, Middle frontal gyrus (Left), Middle frontal gyrus (Right)

Network thresholds: 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19

Generate 1 randomized subject data (null model network) with randomizer bin und, randmio_und, randmio_dir iterations: 1
 Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics: Binary: Assortativity - UND, Binary: Assortativity out-degree/in-degree correl, Binary: Assortativity in-degree/out-degree correl, Binary: Assortativity out-degree/out-degree correl, Binary: Assortativity in-degree/in-degree correl, Binary: Betweenness centrality - UND/DIR, Binary: Clustering coefficient global - UND, Binary: Clustering coefficient global - DIR, Binary: Clustering coefficient local - UND, Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness
 Calculate variables and export

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr. r to z
 .05, .045, .04, .035, .03, .025, .02, .015, .01, .009, .008, .007, .006

Generate 1 random networks with random_shuffle, c_null_model_und_s, null_model_und_sigi, null_model_dir_sign iterations: 1 for each subject.
 Binary Weighted

Weights: No Change absolute weights negative weights to zero

GLM

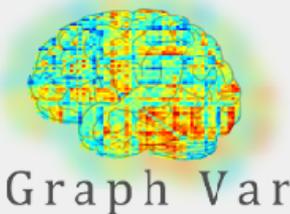
Variables: sex, eating_contest_chilli

Between covariates: age, IQ
 Between factors: research_site
 Within covariates:
 Nuisance covariates: fantasy_score, beer_pong_score
 No Interactions

Select Within ID

Graph metrics: parametric rand NW permutation #Rep
 Raw matrix: parametric rand NW permutation #Rep 1

Switch Workspace Open Previous Results < Load interim results > Statistics with already calculated values Calculate & Statistics



Graph Var

Non-parametric testing

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas
 Precentral gyrus (Left) 0.1
 Precentral gyrus (Right) 0.11
 Superior frontal gyrus, dorsolate 0.12
 Superior frontal gyrus, dorsolate 0.13
 Superior frontal gyrus, orbital pa 0.14
 Superior frontal gyrus, orbital pa 0.15
 Middle frontal gyrus (Left) 0.16
 Middle frontal gyrus (Right) 0.17
 Middle frontal gyrus (Right) 0.18
 Middle frontal gyrus (Right) 0.19

Network thresholds
 0.1

Generate 1 with 1 iterations.
 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics
 Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correlat
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient local - DIR
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1
 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables
 sex
 eating_contest_chilli

Between covariates
 age
 IQ

Between factors
 research_site

Within covariates

Nuisance covariates
 fantasy_score
 beer_pong_score

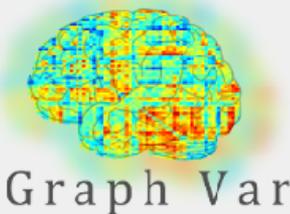
No Interactions

Select Within ID

Graph metrics
 parametric rand NW permutation #Rep

Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Statistical analyses of graph measures

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas

Network nodes / Brain areas	Network thresholds
Precentral gyrus (Left)	0.1
Precentral gyrus (Right)	0.11
Superior frontal gyrus, dorsolateral	0.12
Superior frontal gyrus, dorsolateral	0.13
Superior frontal gyrus, orbital part	0.14
Superior frontal gyrus, orbital part	0.15
Middle frontal gyrus (Left)	0.16
Middle frontal gyrus (Right)	0.17
Middle frontal gyrus, orbital part	0.18
Middle frontal gyrus, orbital part	0.19

Generate 1 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir

Binary Weighted

with 1 iterations.
 CheckFrag

Network Calculations

Calculate graph metrics

Brain graph metrics

Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient local - DIR
 Binary: Clustering coefficient local - UND

Normalize graph metric with random networks
 Use random network to calc smallworldness

Calculate variables and export

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr.

r to z
 Generate 1 random networks
 random_shuffle
 c_null_model_und_s
 null_model_und_sigi
 null_model_dir_sign

with 1 iterations for each subject.

Weights
 No Change absolute weights
 negative weights to zero

GLM

Variables
 sex
 eating_contest_chilli

Between covariates
 age
 IQ

Between factors
 research_site

Within covariates

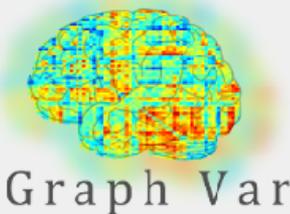
Nuisance covariates
 fantasy_score
 beer_pong_score

Select Within ID

Graph metrics
 parametric rand NW permutation #Rep

Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Graph Var

Statistics on the raw conn matrices

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold
 Significant Relative Absolute SICE None

Weights
 No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left)	0.1
Precentral gyrus (Right)	0.11
Superior frontal gyrus, dorsolate	0.12
Superior frontal gyrus, dorsolate	0.13
Superior frontal gyrus, orbital pa	0.14
Superior frontal gyrus, orbital pa	0.15
Middle frontal gyrus (Left)	0.16
Middle frontal gyrus (Right)	0.17
Middle frontal gyrus, orbital pa	0.18
Middle frontal gyrus, orbital pa	0.19

Network thresholds

0.1

Generate 1 with 1 iterations.
 randomized subject data (null model network)
 randomizer bin und
 randmio_und
 randmio_dir

Binary Weighted [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics

Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient local - DIR
 Binary: Clustering coefficient local - UND

Normalize graph metric with random networks
 Use random network to calc smallworldness

[Calculate variables and export]

Raw Matrix (link wise)

R
 C

0.05
 .045
 .04
 .035
 .03
 .025
 .02
 .015
 .01
 .009
 .008
 .007
 .006

Graph component

GLM

Variables
 sex
 eating_contest_chilli

Between covariates
 age
 IQ

Between factors
 research_site

Within covariates

Nuisance covariates
 fantasy_score
 beer_pong_score

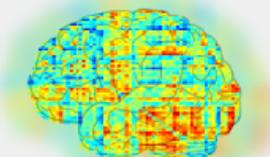
No Interactions

Select Within ID

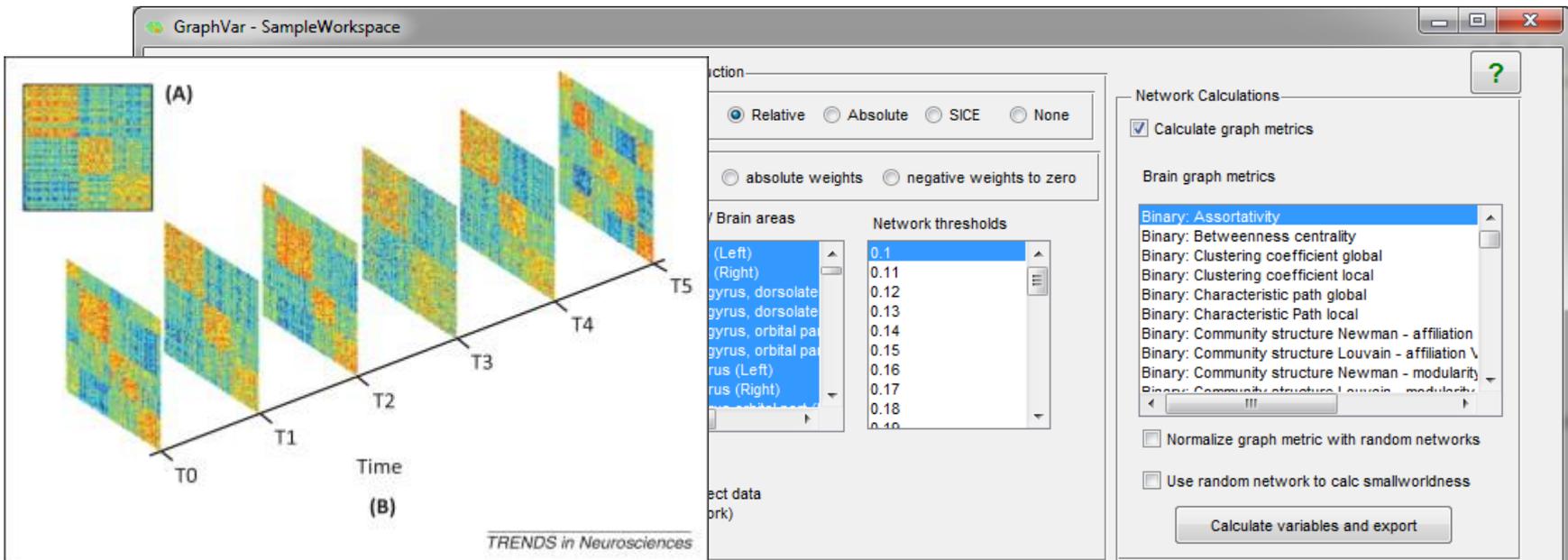
Graph metrics
 parametric rand NW permutation #Rep

Raw matrix
 parametric rand NW permutation 1

Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics



Network-Based-Statistics



Generate the Sliding Window matrices with the „connectivity“ measure you desire:

- Pearson corr
- Partial corr
- Covariance
- Mutual inf
- etc.....

Create Connectivity matrix -> **sliding windows**

The screenshot shows the GraphVar software interface with the following sections:

- General Settings:** Includes fields for 'Brain regions files' (BrainRegions.csv) and 'File with Variables' (Variables.csv). It has buttons for 'Select Subjects (Conn Matrix)' and 'Create Connectivity Matrix'. A list of subjects is shown, and a 'Subjectname in Filename' field contains 'CorrMatrix_ROISignals_sample_01.mat'. There are also fields for 'Start' (36) and 'End' (0), and a 'Corr Matrix Array' field with 'CorrMatrix'.
- Network Construction:** Includes a 'Threshold' section with radio buttons for 'Significant', 'Relative' (selected), 'Absolute', 'SICE', and 'None'. A 'Weights' section has radio buttons for 'No Change' (selected), 'absolute weights', and 'negative weights to zero'. Below is a table of 'Network nodes / Brain areas' and 'Network thresholds':

Network nodes / Brain areas	Network thresholds
Precentral gyrus (Left)	0.1
Precentral gyrus (Right)	0.11
Superior frontal gyrus, dorsolateral	0.12
Superior frontal gyrus, dorsolateral	0.13
Superior frontal gyrus, orbital part	0.14
Superior frontal gyrus, orbital part	0.15
Middle frontal gyrus (Left)	0.16
Middle frontal gyrus (Right)	0.17
Middle frontal gyrus, orbital part	0.18
Middle frontal gyrus, orbital part	0.19
- Network Calculations:** A checkbox 'Calculate graph metrics' is checked. A dropdown menu 'Brain graph metrics' is set to 'Select Dynamic'. A list of metrics is shown, including 'Binary: Assortativity', 'Binary: Betweenness centrality', 'Binary: Clustering coefficient global', 'Binary: Clustering coefficient local', 'Binary: Characteristic path global', 'Binary: Characteristic Path local', 'Binary: Community structure Newman - affiliation', 'Binary: Community structure Louvain - affiliation', and 'Binary: Community structure Louvain - modularity'. There are also checkboxes for 'Normalize graph metric with random networks' and 'Use random network to calc smallworldness', and a 'Calculate variables and export' button.
- Raw Matrix (link wise):** A checkbox 'Raw matrix' is checked, and its dropdown is set to 'Select Dynamic'. There are also checkboxes for 'Connectivity Thr.', 'r to z', and 'Generate random networks'. A list of values is shown: 0.05, 0.045, 0.04, 0.035, 0.03, 0.025, 0.02, 0.015, 0.01, 0.009, 0.008, 0.007, 0.006.

At the bottom, there is a 'Graph Var' logo with a brain image and buttons for 'Switch Workspace', 'Open Previous Results', 'Load interim results', and 'Statistics'.

If SW-matrices are loaded (also manually via „Select Subjects Corr Matrix“) the dynamic selection windows will appear in the GUI

Select dynamic summary measure (graph metrics/raw matrix)

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

CorrMatrix\CorrMatrix_ROISignals_sample_01.mat

CorrMatrix\CorrMatrix_ROISignals_sample_02.mat

CorrMatrix\CorrMatrix_ROISignals_sample_03.mat

CorrMatrix\CorrMatrix_ROISignals_sample_04.mat

CorrMatrix\CorrMatrix_ROISignals_sample_05.mat

CorrMatrix\CorrMatrix_ROISignals_sample_06.mat

Subjectname in Filename

CorrMatrix_ROISignals_sample_01.mat

Start: 36 End (remaining characters): 0

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold

Significant Relative Absolute SICE None

Weights

No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left) 0.1

Precentral gyrus (Right) 0.11

Superior frontal gyrus, dorsolate 0.12

Superior frontal gyrus, dorsolate 0.13

Superior frontal gyrus, orbital pa 0.14

Superior frontal gyrus, orbital pa 0.15

Middle frontal gyrus (Left) 0.16

Middle frontal gyrus (Right) 0.17

Middle frontal gyrus (Right) 0.18

Middle frontal gyrus (Right) 0.19

Generate

randomized subject data (null model network)

Raw Matrix (link wise)

Raw matrix [Select Dynamic]

Connectivity Thr. r to z

Weights

No Change absolute weights negative weights to zero

Network Calculations

Calculate graph metrics

Brain graph metrics [Select Dynamic]

Binary: Assortativity [Select Dynamic]

Binary: Betweenness [Variance over time]

Binary: Clustering coef [Standard Deviation]

Binary: Clustering coef [Periodicity]

Binary: Characteristic [PointProcess: rate]

Binary: Characteristic [PointProcess: intervall]

Binary: Community structure [Louvain - affiliation]

Binary: Community structure [Louvain - modularity]

Binary: Community structure [Louvain - modularity]

Normalize graph metric with random networks

Use random network to calc smallworldness

Calculate variables and export

Graph Var

Switch Workspace Open Previous Results Load interim results

Dynamic summary measures*:

- Variance
- Standard deviation
- Periodicity
- PointProcess: rate
- PointProcess: intervall
- Brain-Network Variability

* definition in Dynamic GraphVar Tutorial

Select dynamic summary measure (graph metrics/raw matrix)

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]

File with Variables: Variables.csv [Select]

Select Subjects (Conn Matrix)

Create Connectivity Matrix

Subjects

CorrMatrix\CorrMatrix_ROISignals_sample_01.mat

CorrMatrix\CorrMatrix_ROISignals_sample_02.mat

CorrMatrix\CorrMatrix_ROISignals_sample_03.mat

CorrMatrix\CorrMatrix_ROISignals_sample_04.mat

CorrMatrix\CorrMatrix_ROISignals_sample_05.mat

CorrMatrix\CorrMatrix_ROISignals_sample_06.mat

Subjectname in Filename

CorrMatrix_ROISignals_sample_01.mat

Start: 36 End (remaining characters): 0

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

Network Construction

Threshold

Significant Relative Absolute SICE None

Weights

No Change absolute weights negative weights to zero

Network nodes / Brain areas

Precentral gyrus (Left) 0.1

Precentral gyrus (Right) 0.11

Superior frontal gyrus, dorsolate 0.12

Superior frontal gyrus, dorsolate 0.13

Superior frontal gyrus, orbital pa 0.14

Superior frontal gyrus, orbital pa 0.15

Middle frontal gyrus (Left) 0.16

Middle frontal gyrus (Right) 0.17

Middle frontal gyrus (Right) 0.18

Middle frontal gyrus (Right) 0.19

Network thresholds

Generate

randomized subject data (null model network)

Raw Matrix (link wise)

Raw matrix **Select Dynamic**

Connectivity Thr. r to z

Generate random networks

Weights

No Change absolute weights negative weights to zero

Network Calculations

Calculate graph metrics

Brain graph metrics: **Select Dynamic**

Binary: Assortativity

Binary: Betweenness

Binary: Clustering coef

Binary: Clustering coef

Binary: Characteristic P

Binary: Characteristic P

Binary: Community str

Binary: Community str

Binary: Community structure (Louvain - affiliation)

Binary: Community structure (Louvain - modularity)

Binary: Community structure (Louvain - modularity)

Normalize graph metric with random networks

Use random networks to address

Calculate variables and export

Graph Var

Switch Workspace Open Previous Results < Load interim results > Statistics with already calculated values Calculate & Statistics

GraphVar will perform all the operations with respect to the dynamic summary measure:

e.g. compute the variance of the clustering coefficient across the sliding windows and export or do group statistics on this measure

Select dynamic summary measure (graph metrics/raw matrix)

GraphVar - SampleWorkspace

General Settings

Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]
 Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects

CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename: CorrMatrix_sample_01.mat

Start: 1 End (remaining characters): 21
 Corr Matrix Array: CorrMatrix
 Save interim results Parallel Workers: 0

Network Construction

Threshold: Significant Relative Absolute SICE None

Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas: Precentral gyrus (Left), Precentral gyrus (Right), Superior frontal gyrus, dorsolate, Superior frontal gyrus, orbital pa, Middle frontal gyrus (Left), Middle frontal gyrus (Right)

Network thresholds: 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19

Generate 1 randomized subject data (null model network)
 randomizer bin und, randmio_und, randmio_dir
 Binary Weighted with 1 iterations. [CheckFrag]

Network Calculations

Calculate graph metrics

Brain graph metrics: Binary: Assortativity - UND, Binary: Assortativity out-degree/in-degree correl, Binary: Assortativity in-degree/out-degree correl, Binary: Assortativity out-degree/out-degree correl, Binary: Assortativity in-degree/in-degree correl, Binary: Betweenness centrality - UND/DIR, Binary: Clustering coefficient global - UND, Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness
 Calculate variables and export

Raw Matrix (link wise)

Raw matrix
 Connectivity Thr. r to z
 .05, .045, .04, .035, .03, .025, .02, .015, .01, .009, .008, .007, .006

Generate 1 random networks
 random_shuffle, c_null_model_und_s, null_model_und_sigi, null_model_dir_sign
 with 1 iterations for each subject.

Weights: No Change absolute weights negative weights to zero

GLM

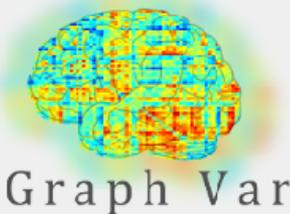
Variables: sex, eating_contest_chilli

Between covariates: age, IQ
 Between factors: research_site
 Within covariates:
 Nuisance covariates: fantasy_score, beer_pong_score
 No Interactions

Select Within ID

Graph metrics: parametric rand NW permutation #Rep
 Raw matrix: parametric rand NW permutation #Rep 1

Switch Workspace Open Previous Results < Load interim results > **Statistics with already calculated values** **Calculate & Statistics**



Graph Var

Ready to go!

GraphVar - SampleWorkspace

General Settings
 Brain regions files: BrainRegions.csv [Select]
 File with Variables: Variables.csv [Select]
 Select Subjects (Conn Matrix)
 Create Connectivity Matrix

Subjects
 CorrMatrix_sample_01.mat
 CorrMatrix_sample_02.mat
 CorrMatrix_sample_03.mat
 CorrMatrix_sample_04.mat
 CorrMatrix_sample_05.mat
 CorrMatrix_sample_06.mat
 CorrMatrix_sample_07.mat

Subjectname in Filename
 CorrMatrix_sample_01.mat

Start: 1 End (remaining characters)
 Corr Matrix Array: CorrMatrix

Save interim results Parallel Worker

Network Construction
 Threshold: Significant Relative Absolute SICE None
 Weights: No Change absolute weights negative weights to zero

Network nodes / Brain areas
 Precentral gyrus (Left) 0.1
 Precentral gyrus (Right) 0.11
 Superior frontal gyrus, dorsolate 0.12

Network thresholds

Network Calculations
 Calculate graph metrics
 Brain graph metrics
 Binary: Assortativity - UND
 Binary: Assortativity out-degree/in-degree correl
 Binary: Assortativity in-degree/out-degree correl
 Binary: Assortativity out-degree/out-degree correl
 Binary: Assortativity in-degree/in-degree correl
 Binary: Betweenness centrality - UND/DIR
 Binary: Clustering coefficient global - UND
 Binary: Clustering coefficient global - DIR
 Binary: Clustering coefficient local - UND
 Binary: Clustering coefficient local - DIR

Normalize graph metric with random networks
 Use random network to calc smallworldness
 Calculate variables and export

Between covariates
 >> age
 << IQ

Between factors
 >> research_site
 <<

Within covariates
 >>
 <<

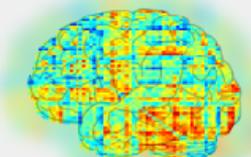
Nuisance covariates
 >> fantasy_score
 << beer_pong_score

No Interactions

Select Within ID
 Graph metrics: parametric rand NW permutation #Rep
 Raw matrix: parametric rand NW permutation 1

Switch Workspace Open Previous Results < Load interim results > Statistics with already calculated values Calculate & Statistics

Graph Var



Progress

All Tasks 1192 of 1449 Operations (82%) 2 secs

Thresholds 9 of 9

Thresholding Subject 30 of 30

Graph Function 1 of 1

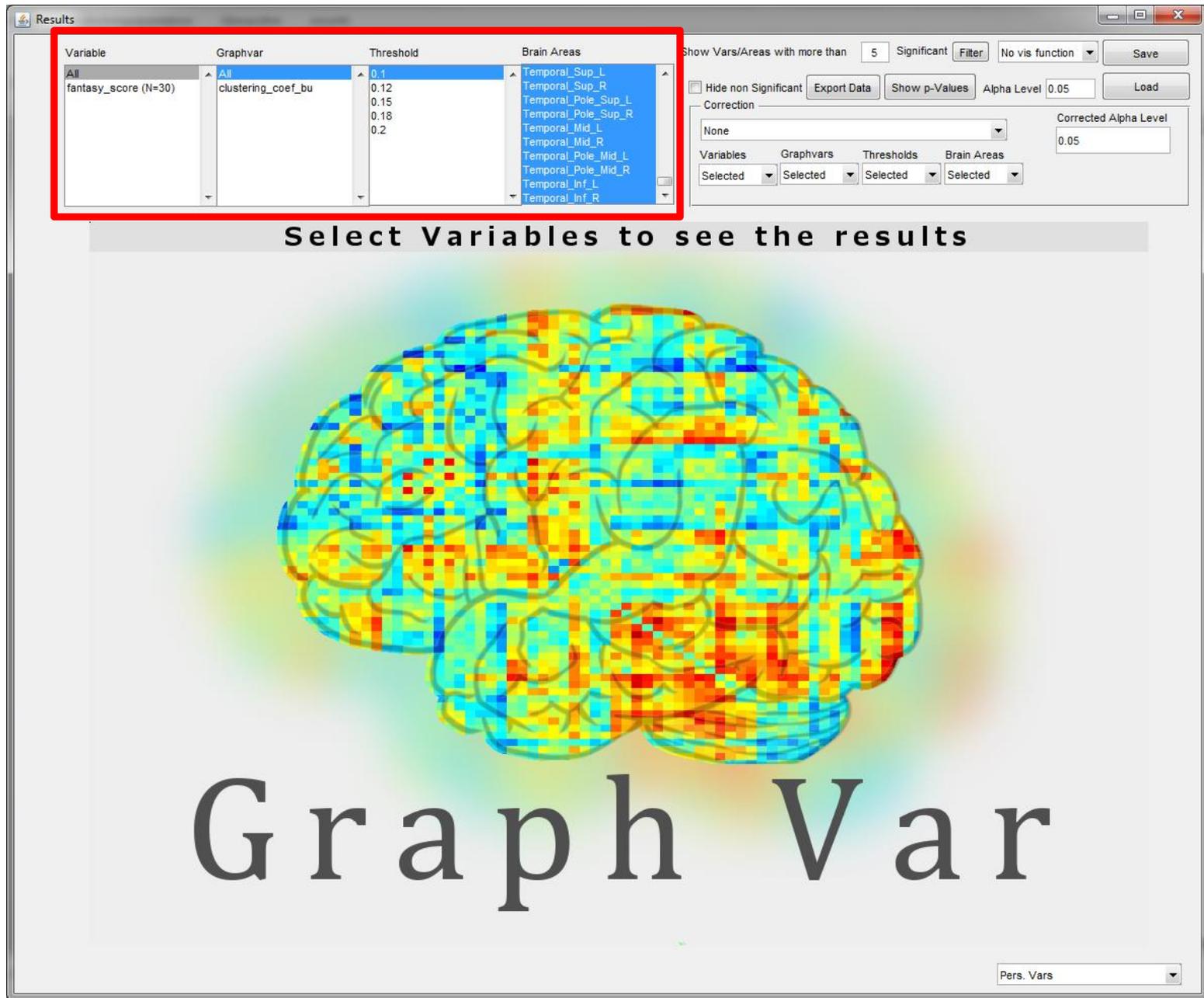
Subject 30 of 30

Correlating 652 of 909

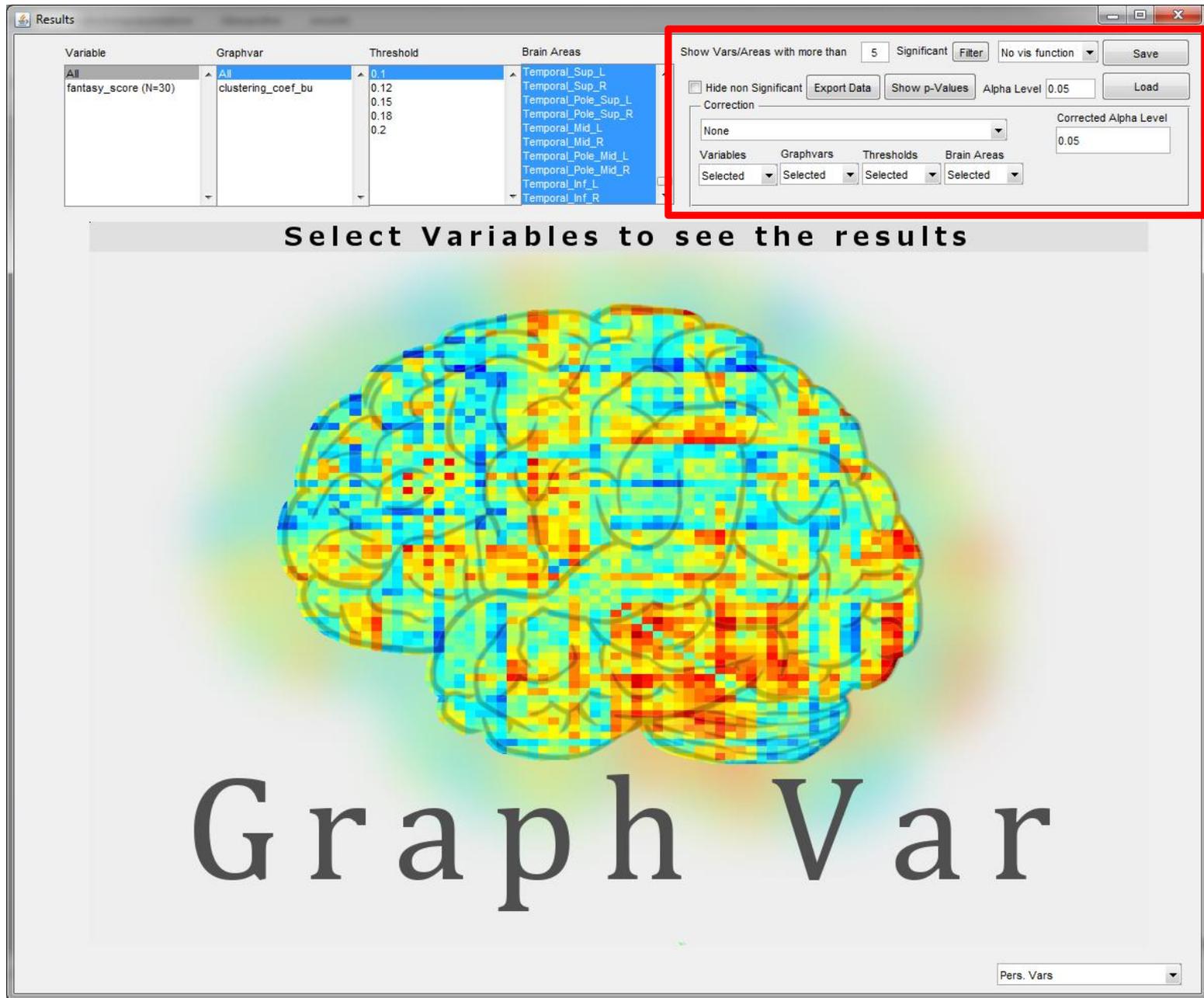
Cancel all operations

Status bar

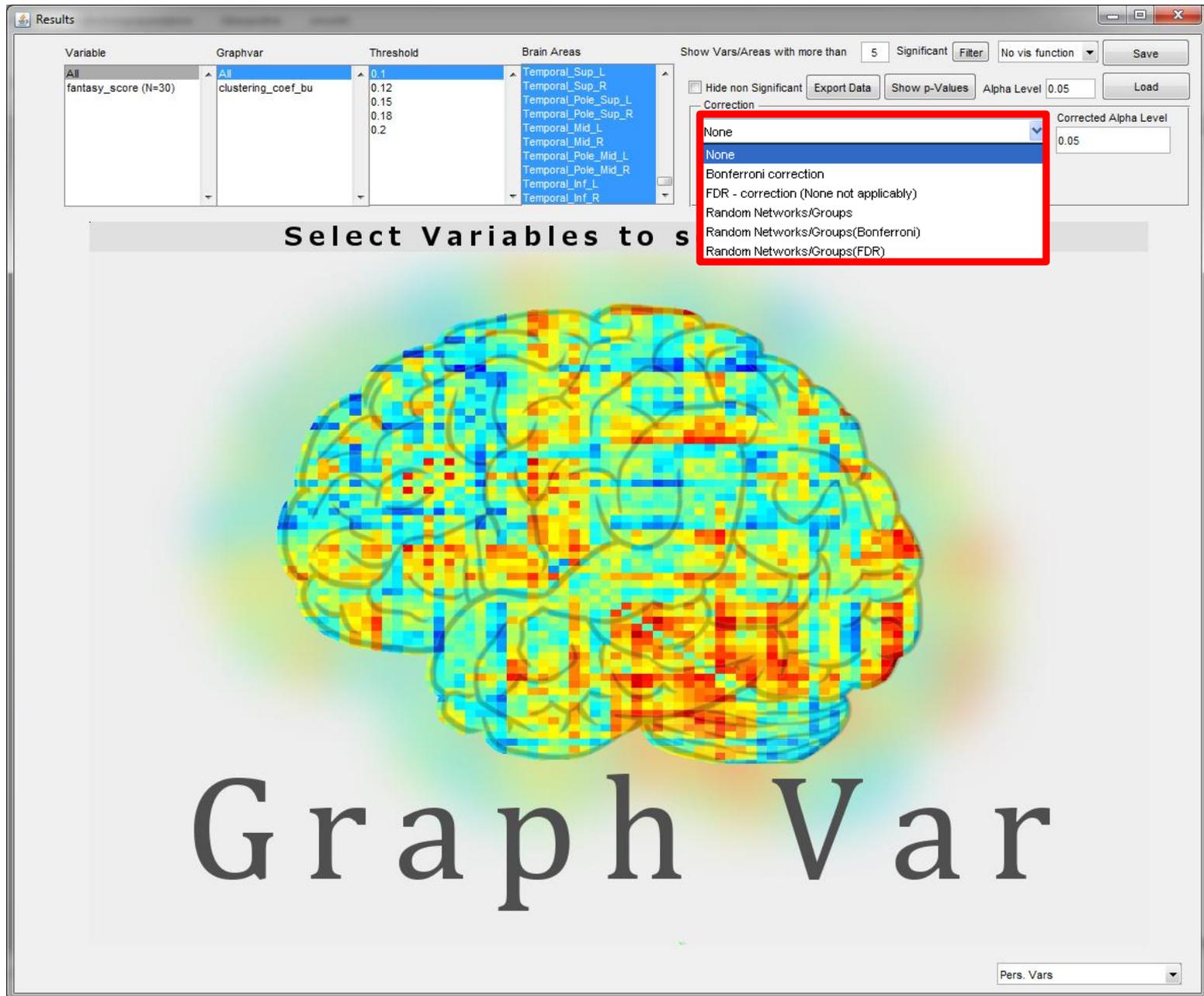
The Results Viewer GUI



Results selection box



General functions panel



Correction for multiple comparisons

Frontal_Sup_Orb_L
Variable: sex
d = 0.067693
t(16) = 0.365046
p = 0.719857

d: Difference between Group Means
F(df1,df2): F-value

Frontal_Inf_Orb_L
Variable: age*sex
d(b) = 0.047272
t(16) = 0.090257
p = 0.929203

d(b): Difference between Standardized Regression Weights

Cingulum_Ant_R
Variable: beer_pong_score
b = 0.491152
t(13) = 2.032979
p = 0.062999

b: Standardized Regression Weight

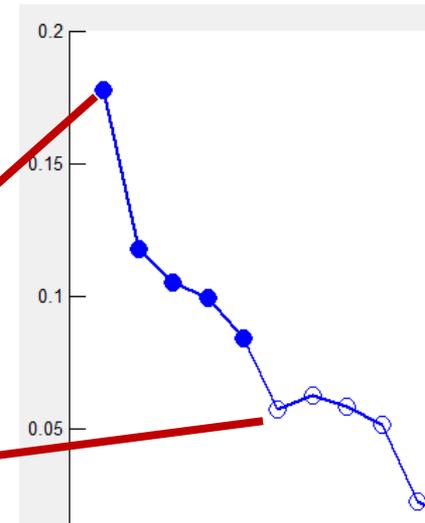
t(df): t-Value

p: p-Value

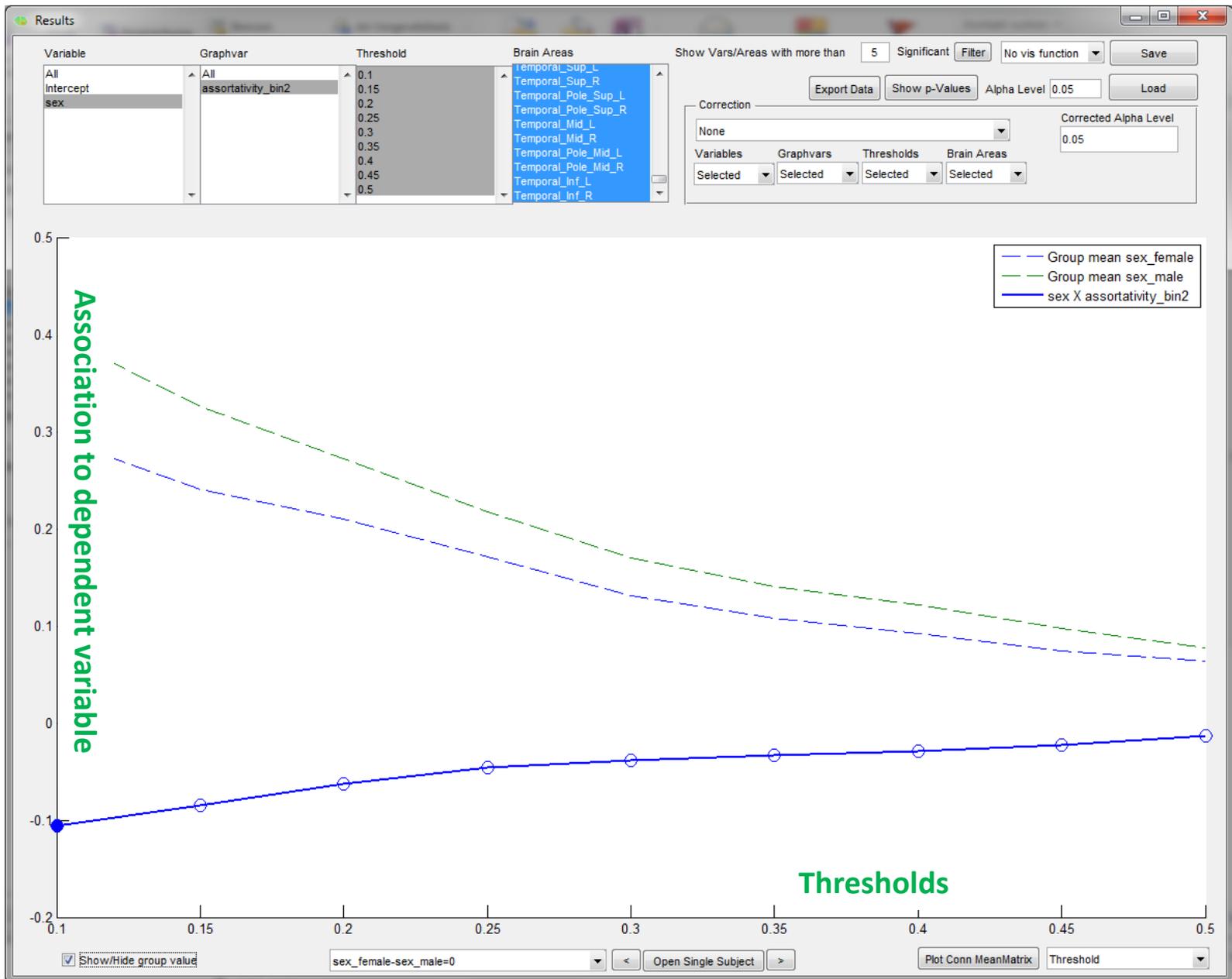
Rolandic_Oper_R
Variable: Intercept
m = 0.688668
t(16) = 6.904489
p = 0.000004

m: Mean

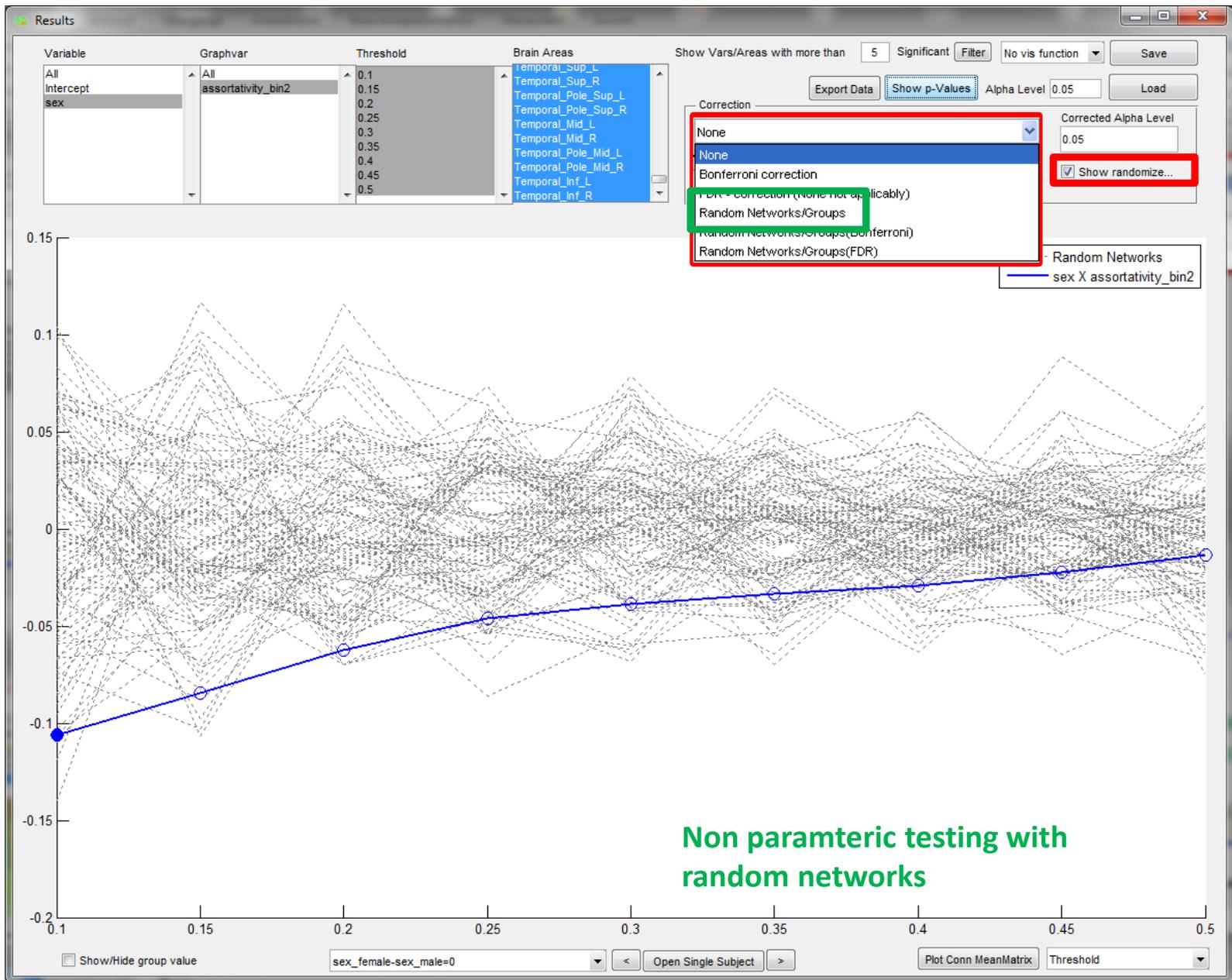
significant
not-significant



Interpreting GraphVar output

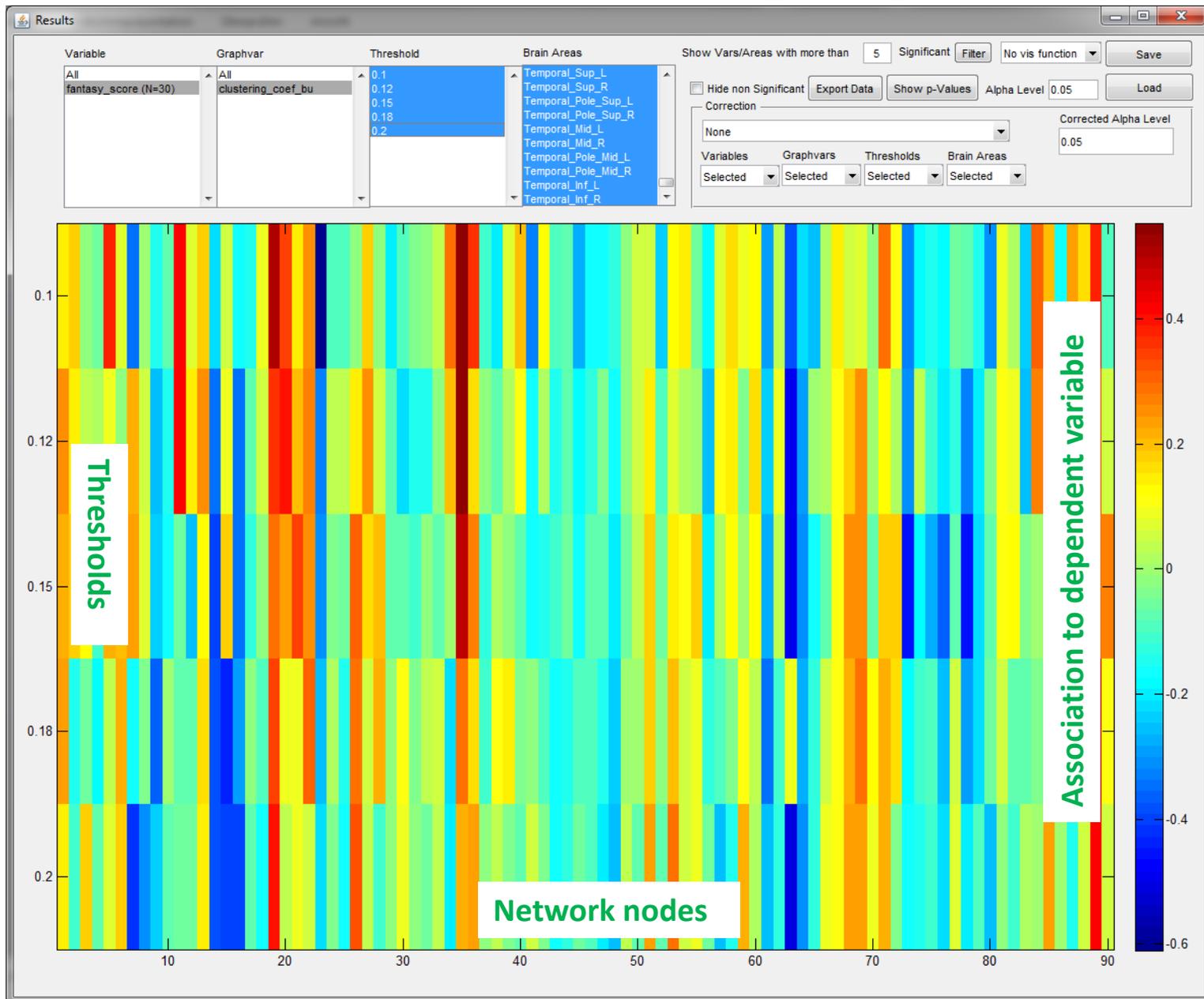


One dimensional graph metrics

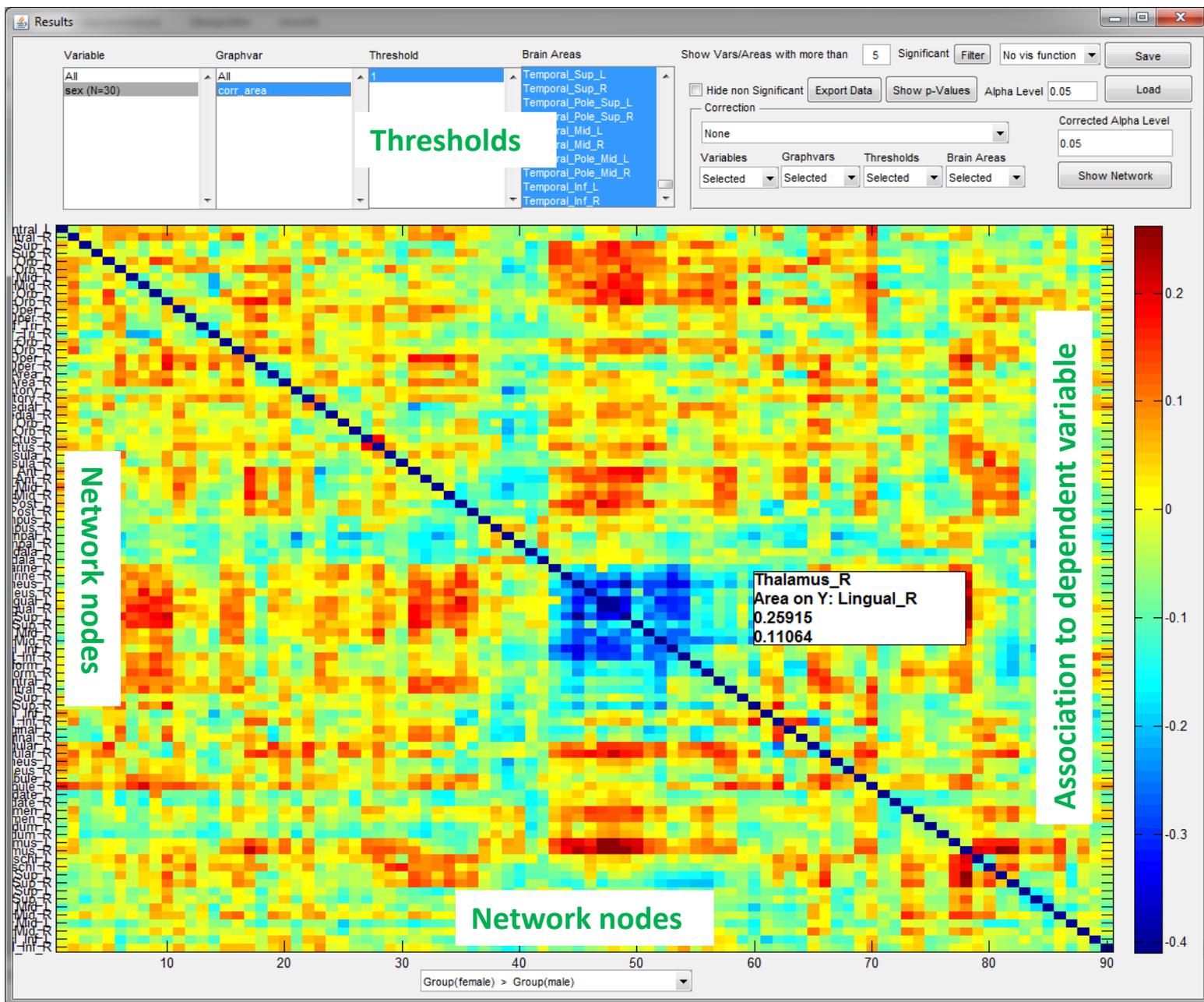


Non parametric testing with random networks

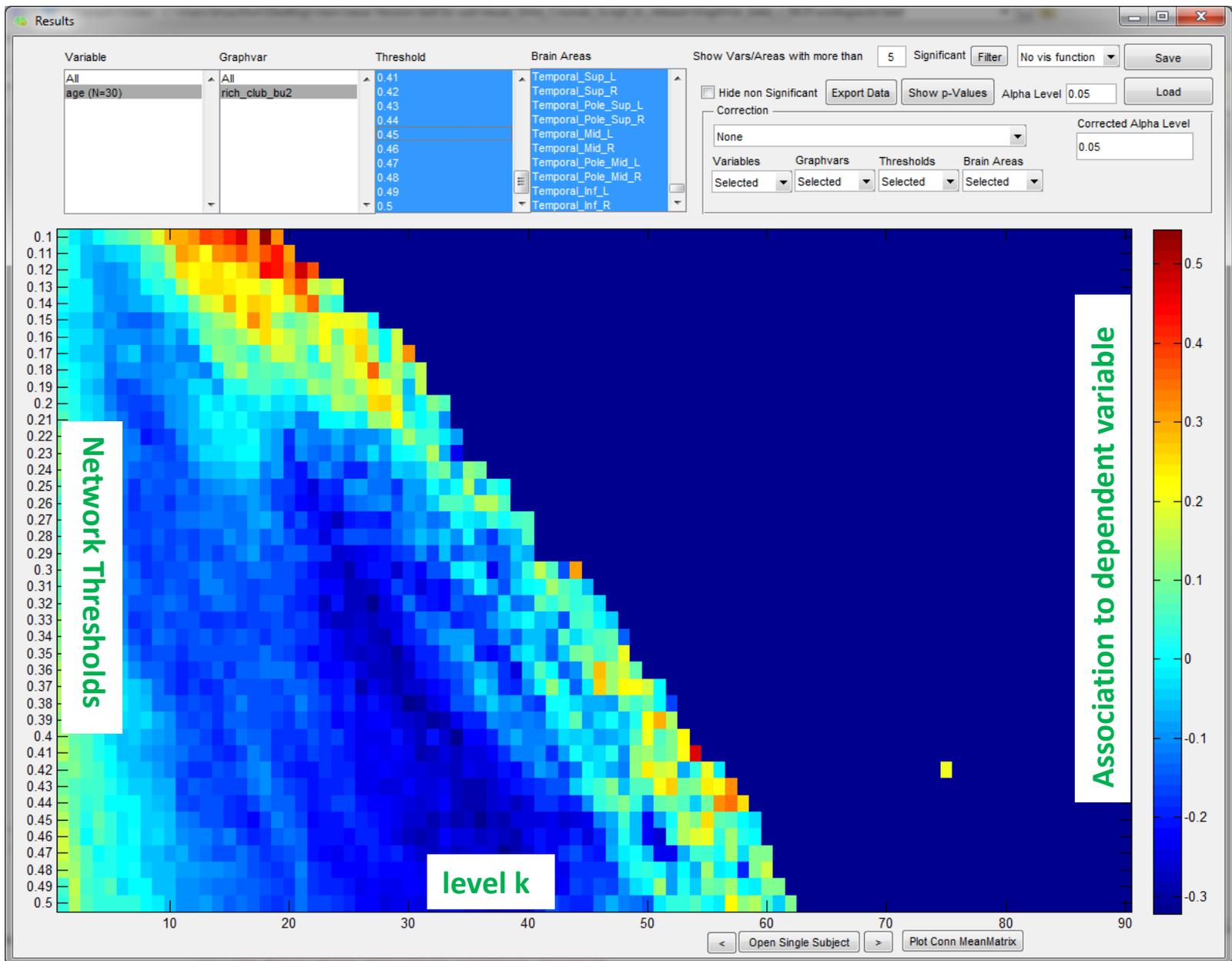
One dimensional graph metrics



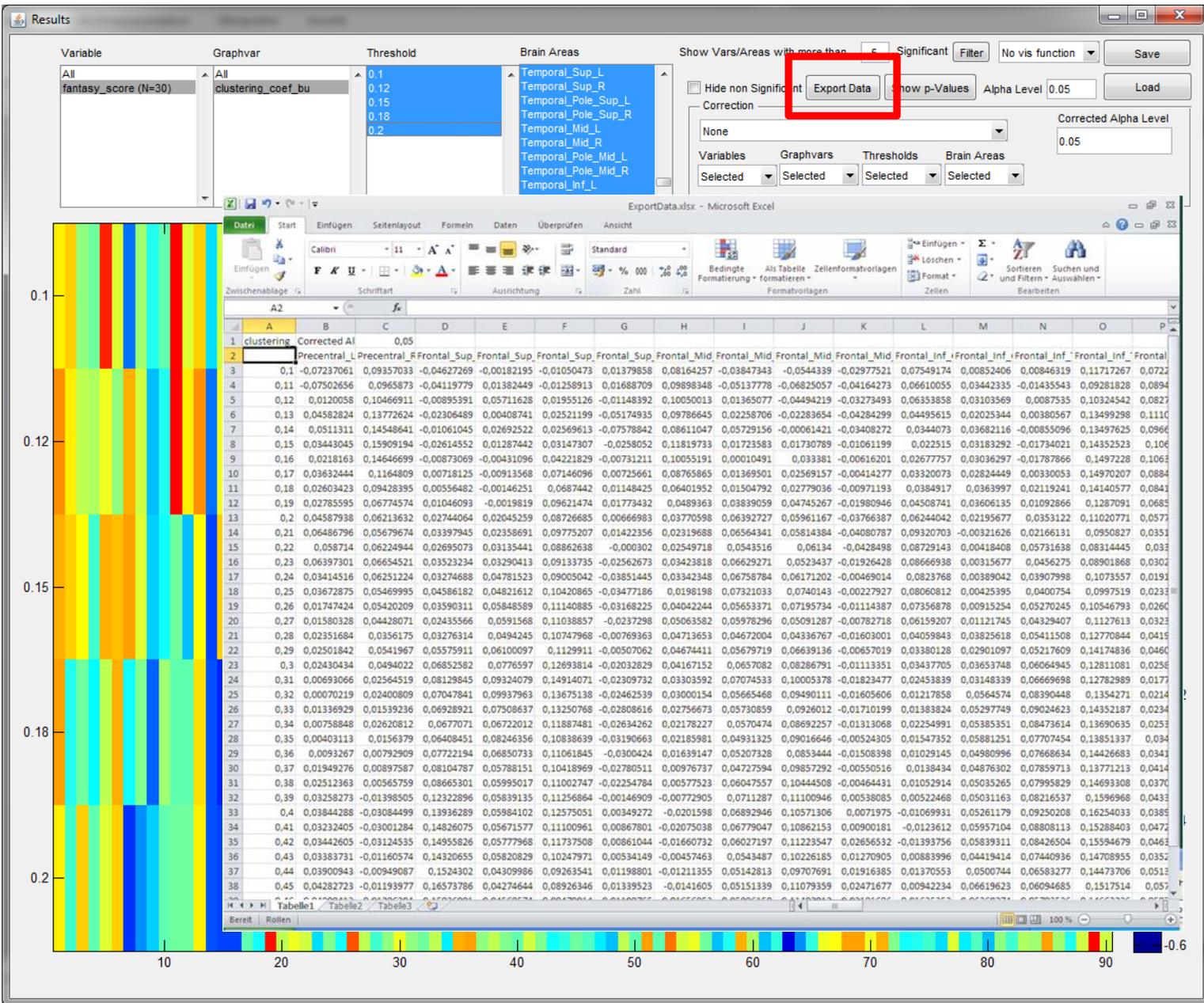
Two dimensional graph metrics



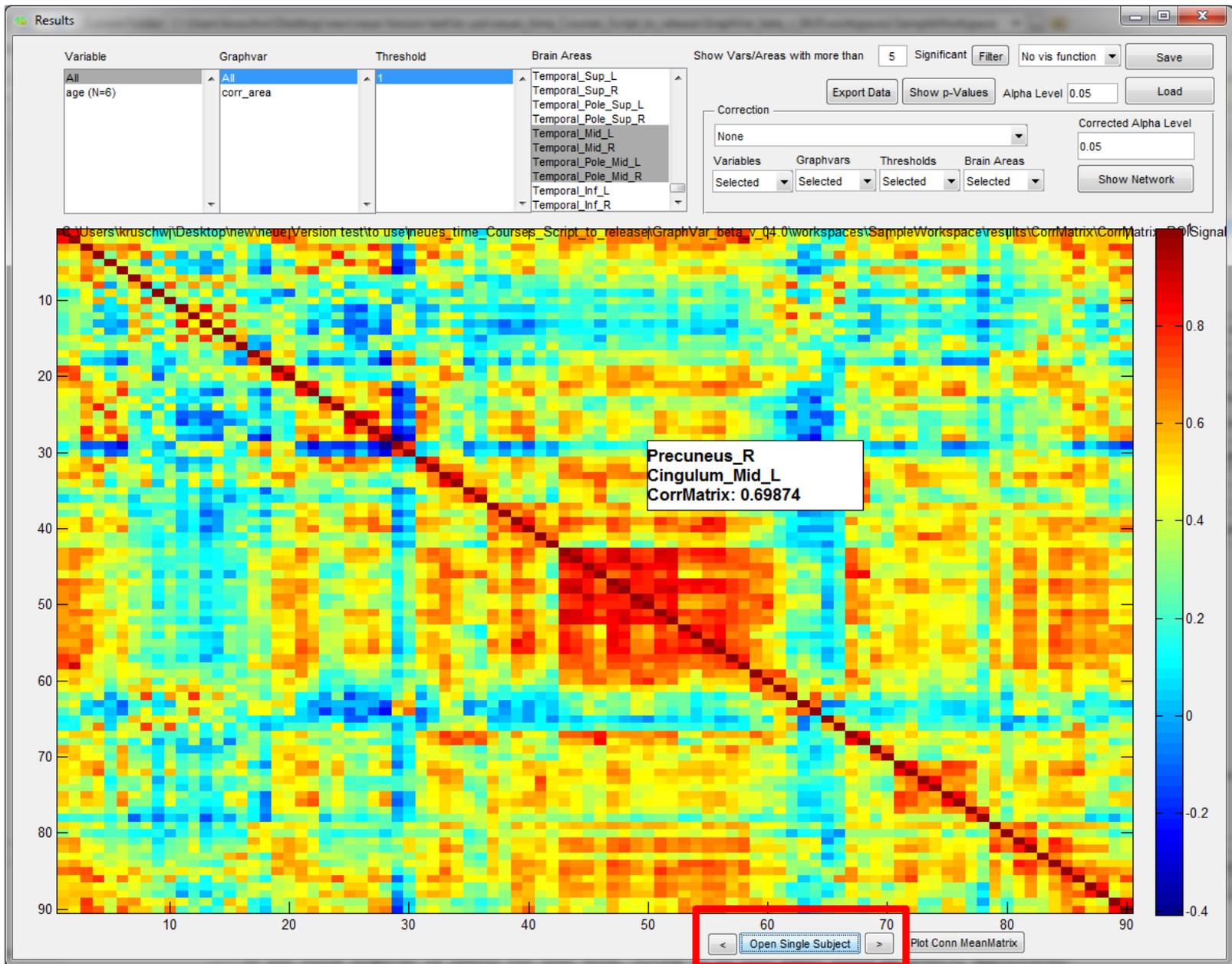
Three dimensional graph metrics



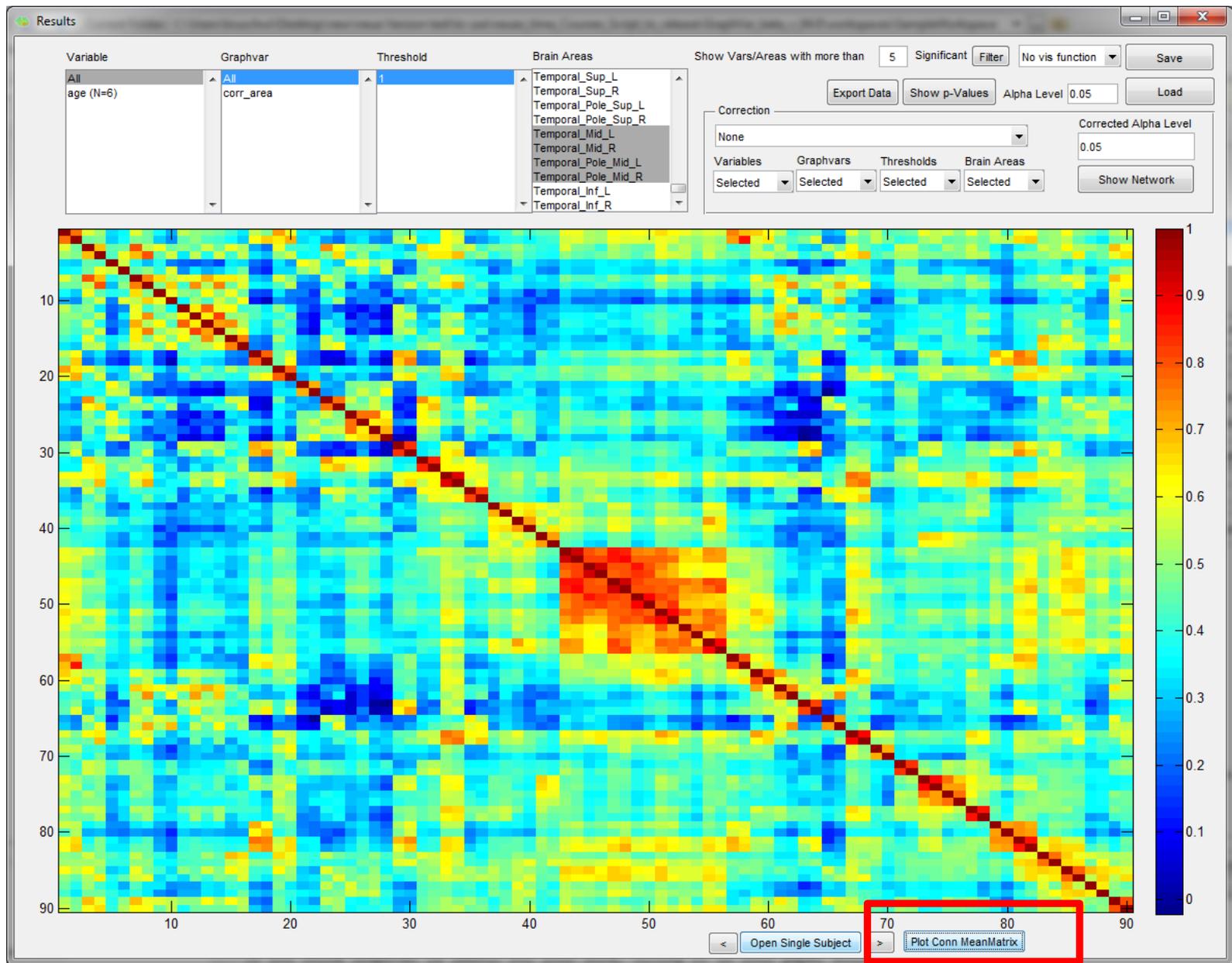
Associations to Rich club coefficients



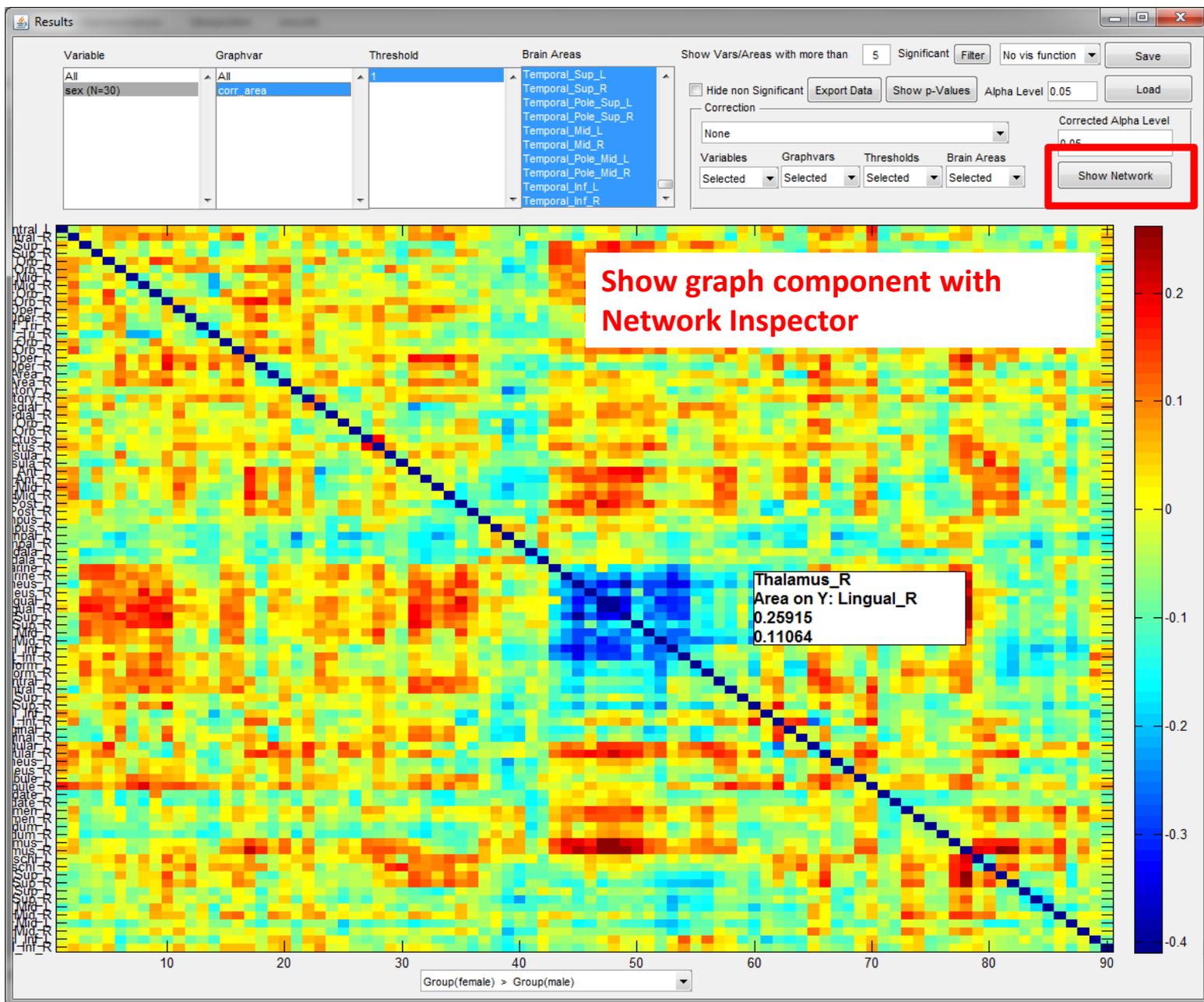
Export Results



Plot single subject association matrices

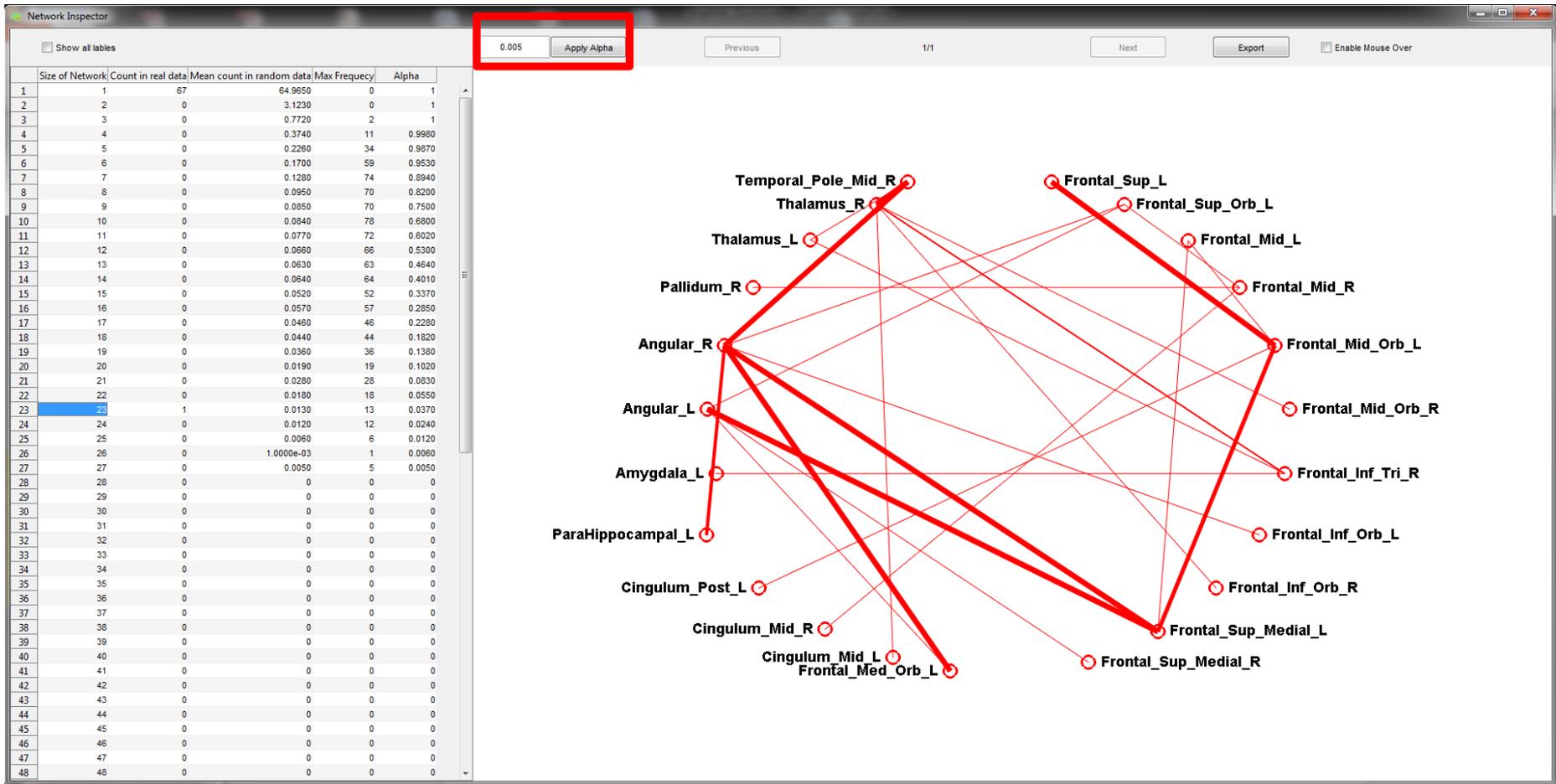


Plot mean connectivity matrix across subjects

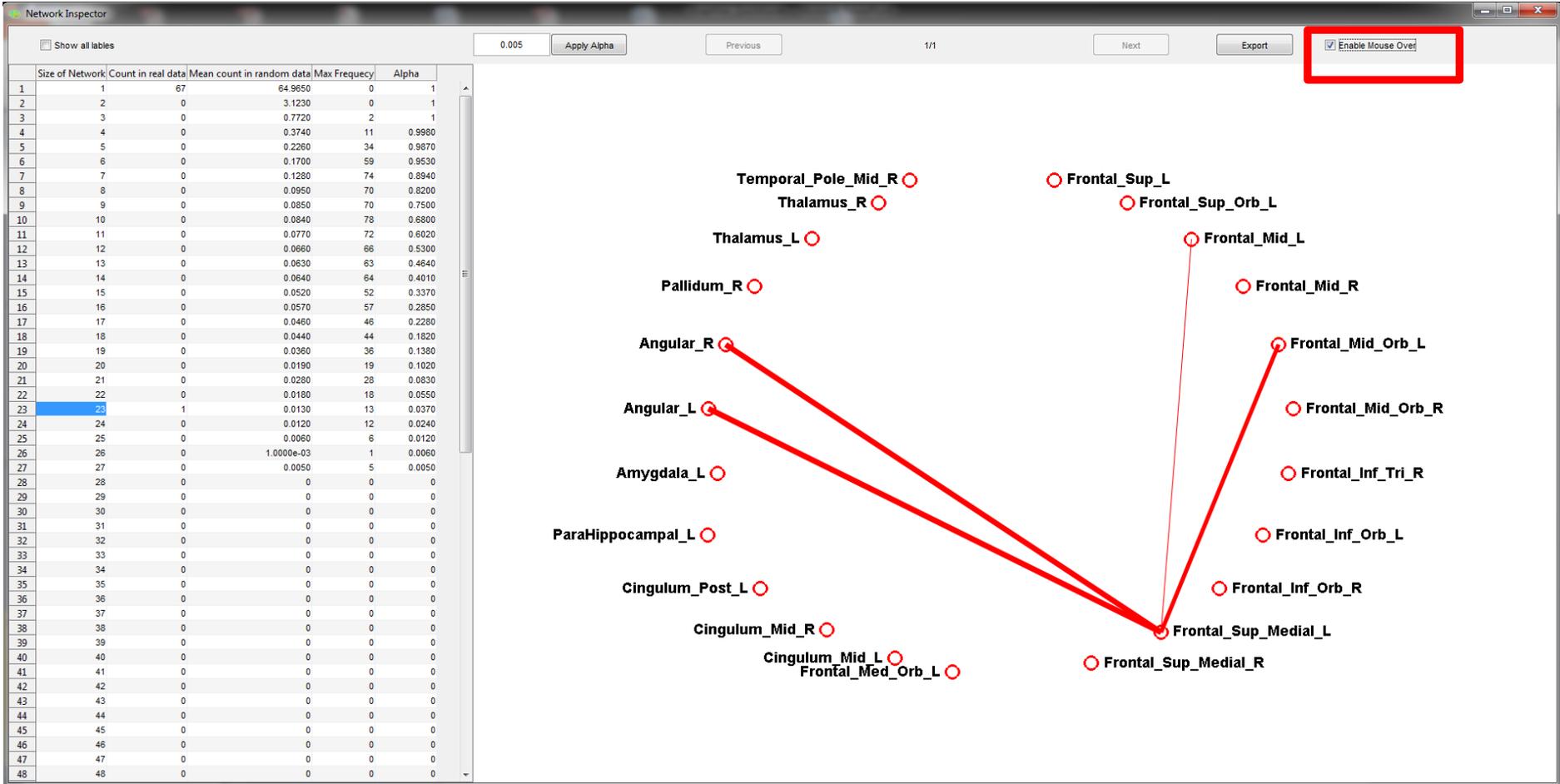


Identify Graph Components

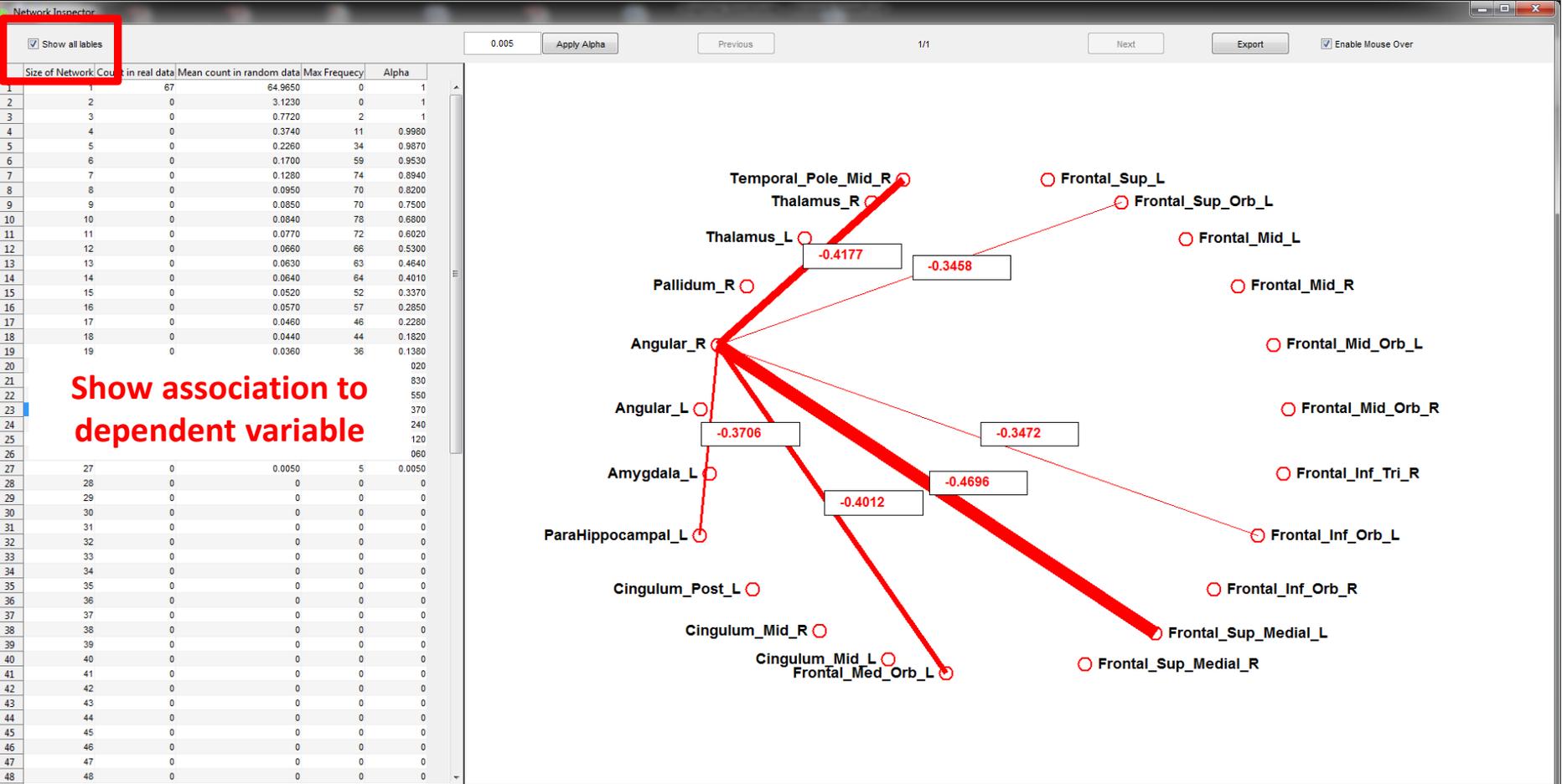
Network Inspector GUI



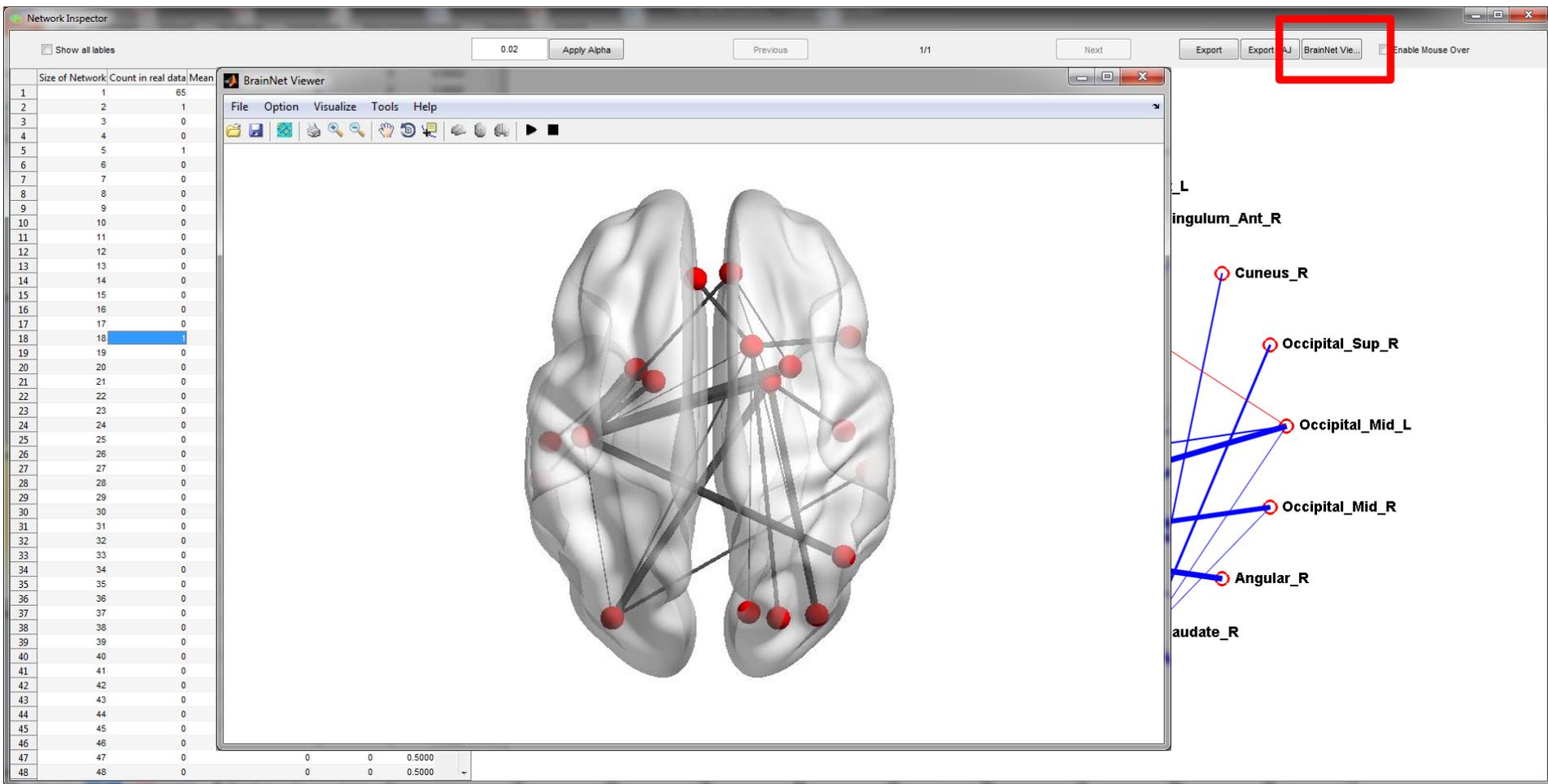
Identify Graph Components



Mouse over



Show association strenght



Open directly in BrainNetViewer
(Xia et al., 2013; PlosONE)



GraphVar -Team