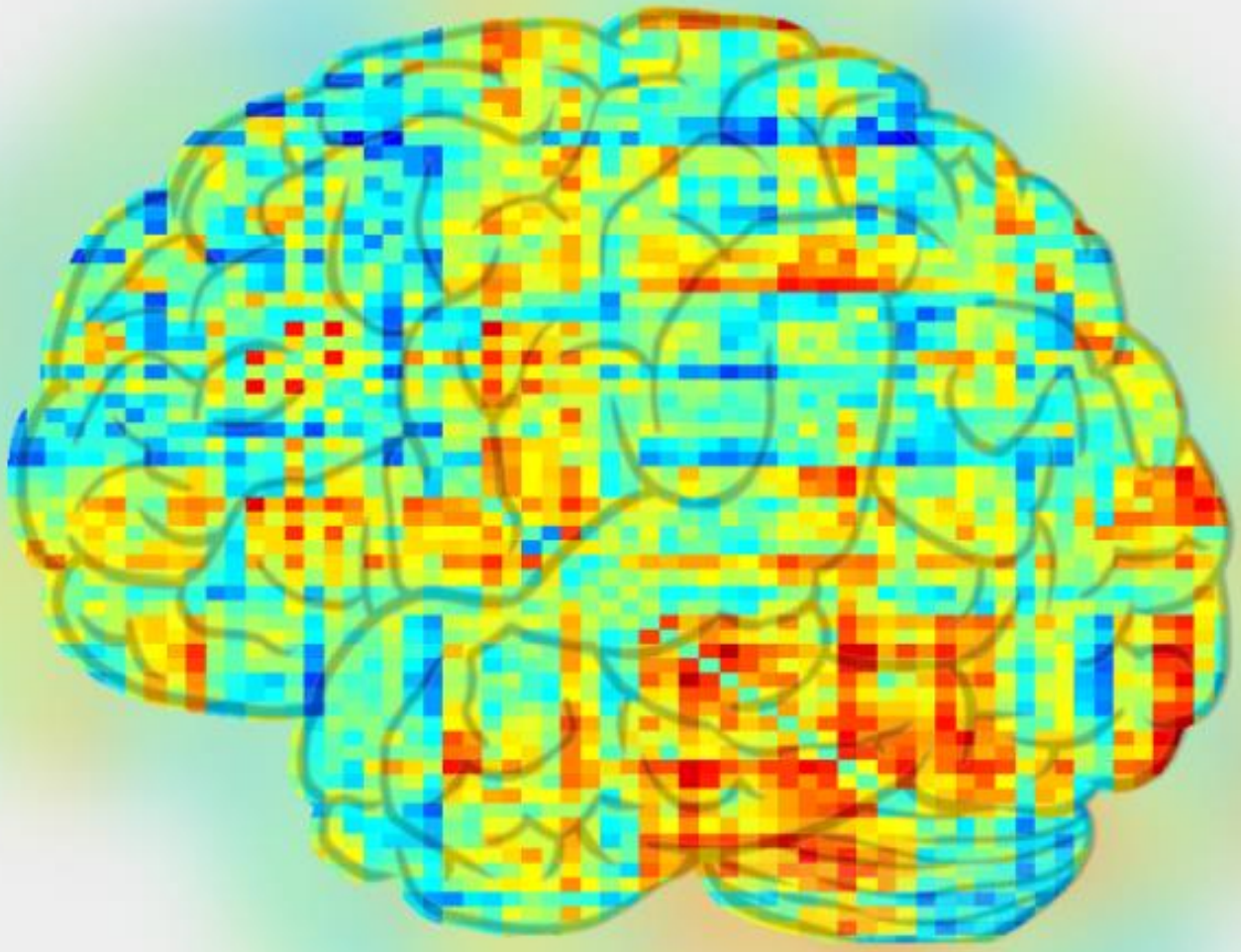


Graph Var

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].

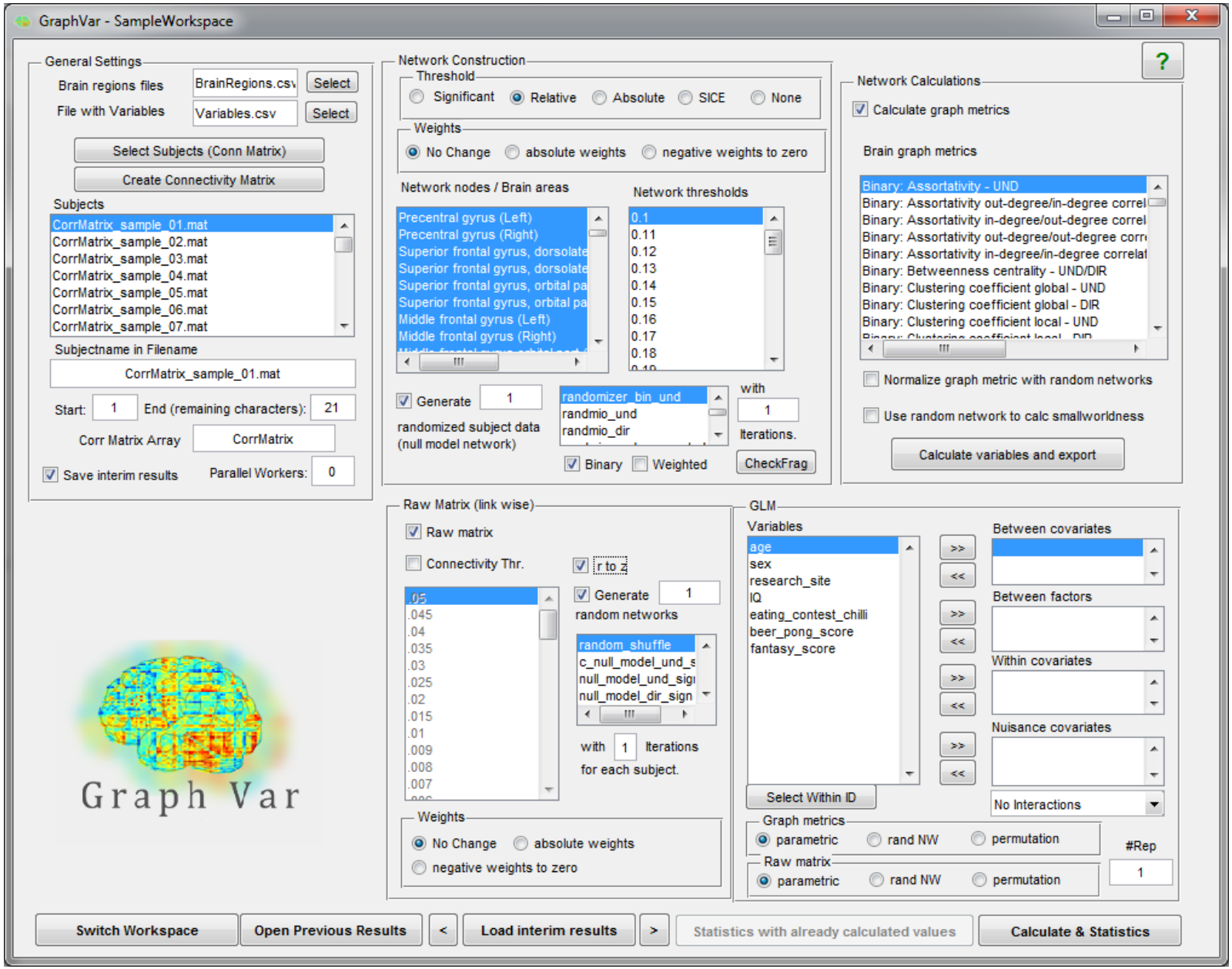
*equal contribution

1 Charité Universitätsmedizin, Berlin, Germany

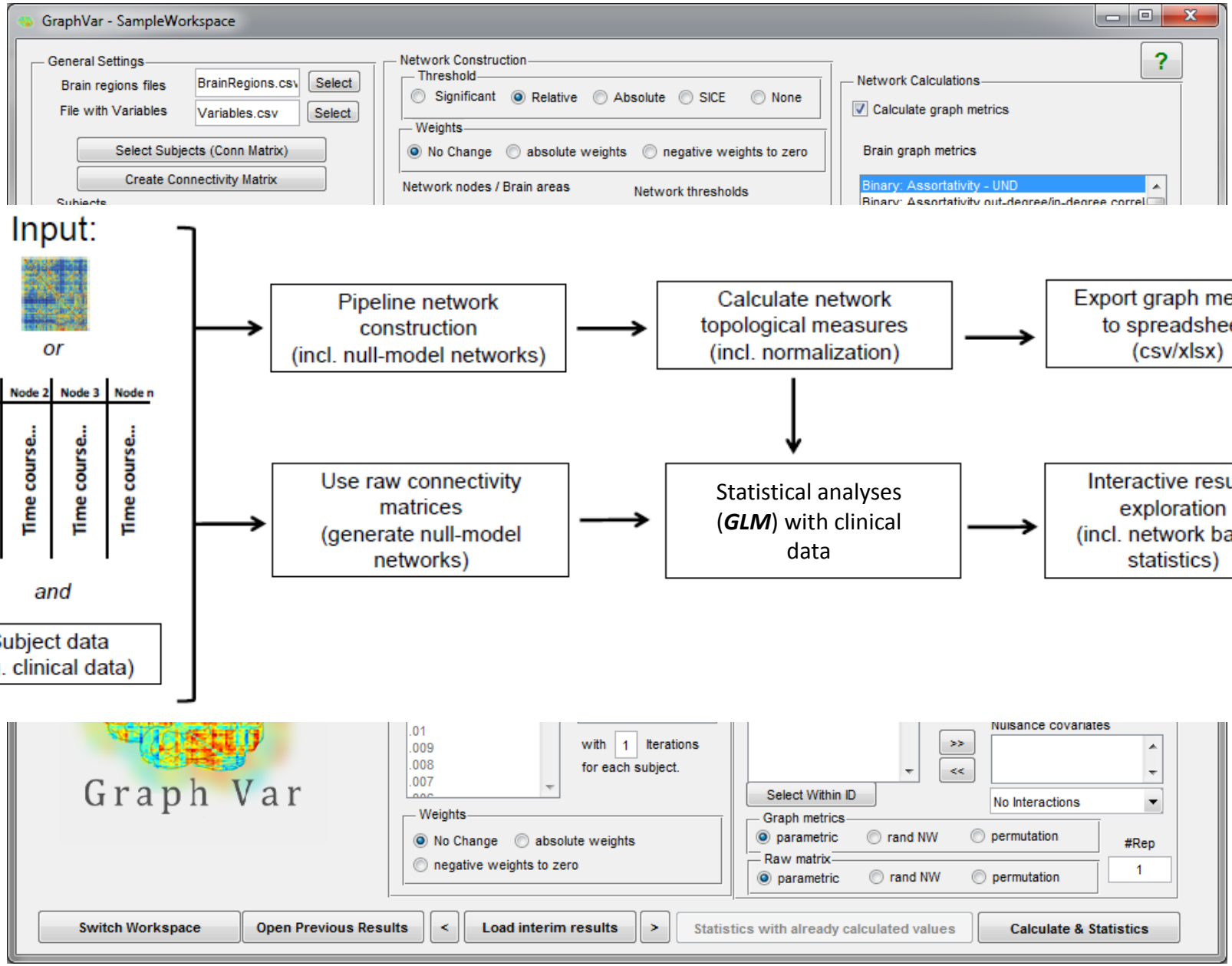
2 Technische Universität Dresden, Dresden, Germany

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, 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
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 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
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
Generate 1
random networks
random_shuffle
c_null_model_und_s
null_model_und_sign
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
Raw matrix
parametric
rand NW
permutation
#Rep
1
Graph Var
Switch Workspace
Open Previous Results
<
Load interim results
>
Statistics with already calculated values
Calculate & Statistics

Setup panel


GraphVar - SampleWorkspace
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Brain regions files
BrainRegions.csv
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Variables.csv
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Network Construction
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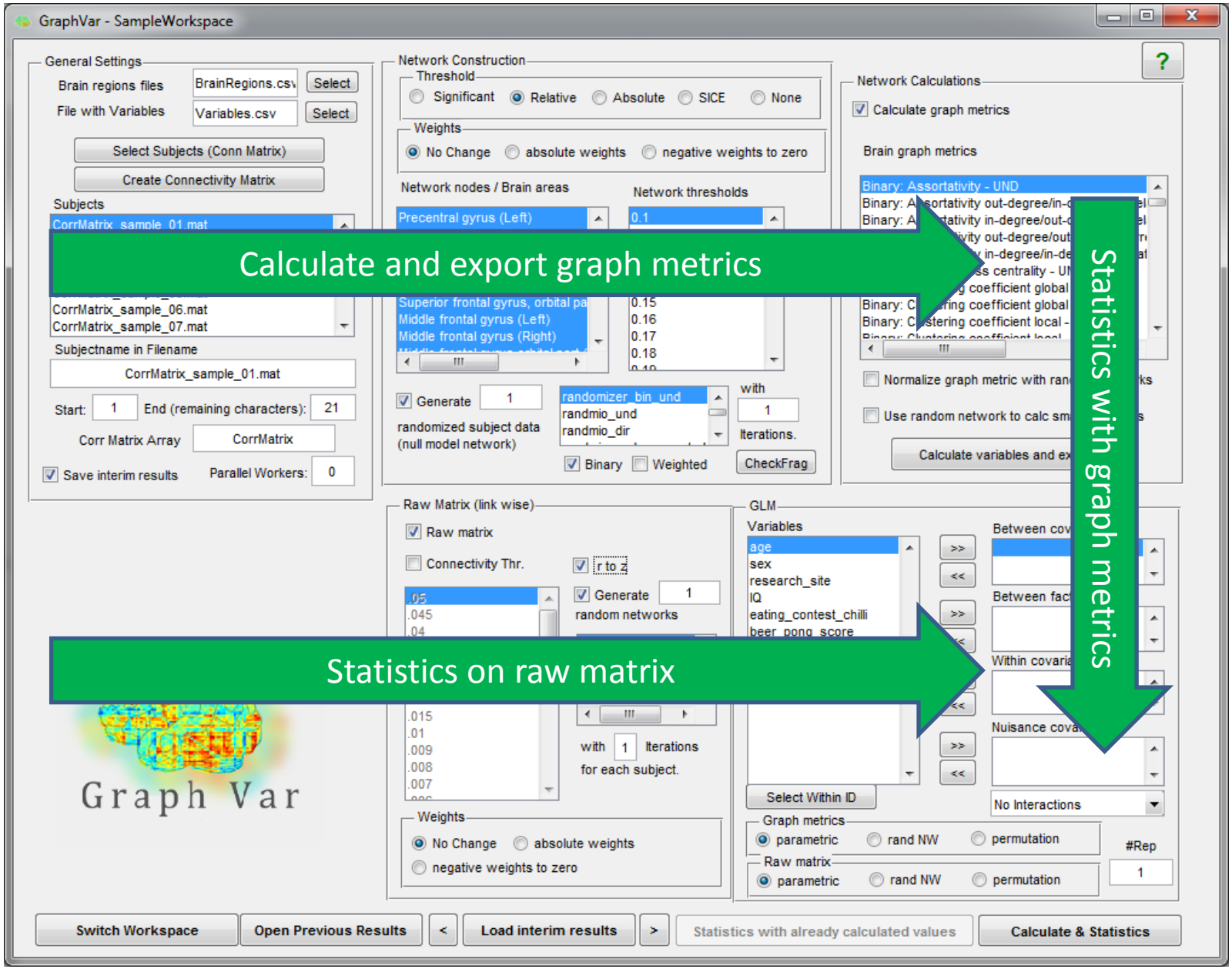
SICE
None
Weights
No Change
absolute weights
negative weights to zero
Network nodes / Brain areas
Network thresholds
Network Calculations
Calculate graph metrics
Brain graph metrics
Binary: Assortativity - UND
Input:
or
Node 1
Node 2
Node 3
Node n
Time course...
and
Subject data
(e.g. clinical data)
Pipeline network construction (incl. null-model networks)
Calculate network topological measures (incl. normalization)
Export graph metrics to spreadsheet (csv/xlsx)
Use raw connectivity matrices (generate null-model networks)
Statistical analyses (GLM) with clinical data
Interactive results exploration (incl. network based statistics)
Graph Var
with 1 Iterations
for each subject.
Nuisance covariates
Select Within ID
No Interactions
Weights
No Change
absolute weights
negative weights to zero
Graph metrics
parametric
rand NW
permutation
Raw matrix
parametric
rand NW
permutation
#Rep
1
Switch Workspace
Open Previous Results
<
Load interim results
>
Statistics with already calculated values
Calculate & Statistics

Workflows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randomizer_bin_und
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Normalize graph metric with ran
Use random network to calc sm
Calculate variables and ex
Calculate and export graph metrics
Statistics with graph metrics
Raw Matrix (link wise)
Raw matrix
Connectivity Thr.
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.045
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for each subject.
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No Change
absolute weights
negative weights to zero
Statistics on raw matrix
GLM
Variables
age
sex
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eating_contest_chilli
beer_pong_score
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Between fact
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Nuisance cova
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permutation
#Rep
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Graph Var
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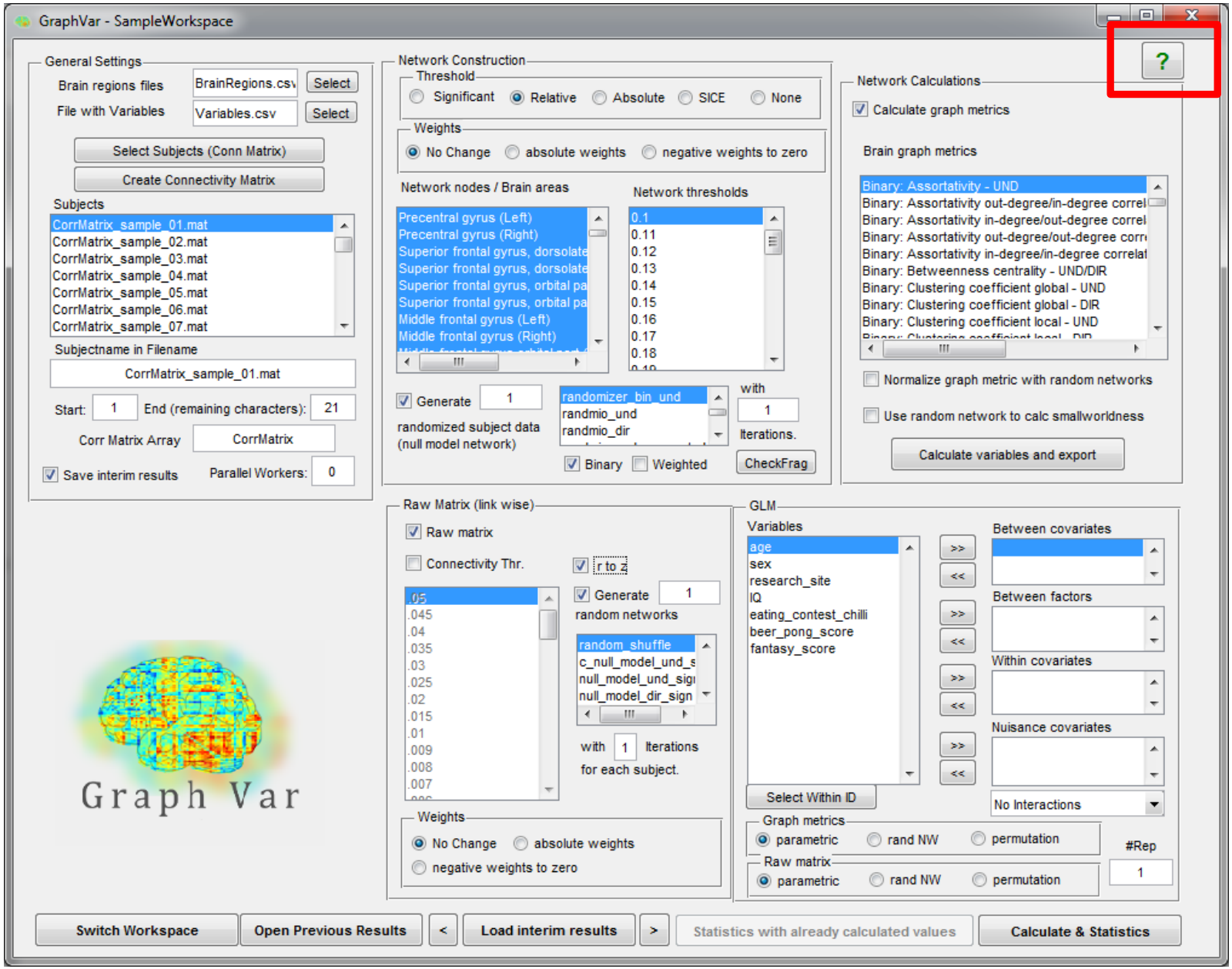
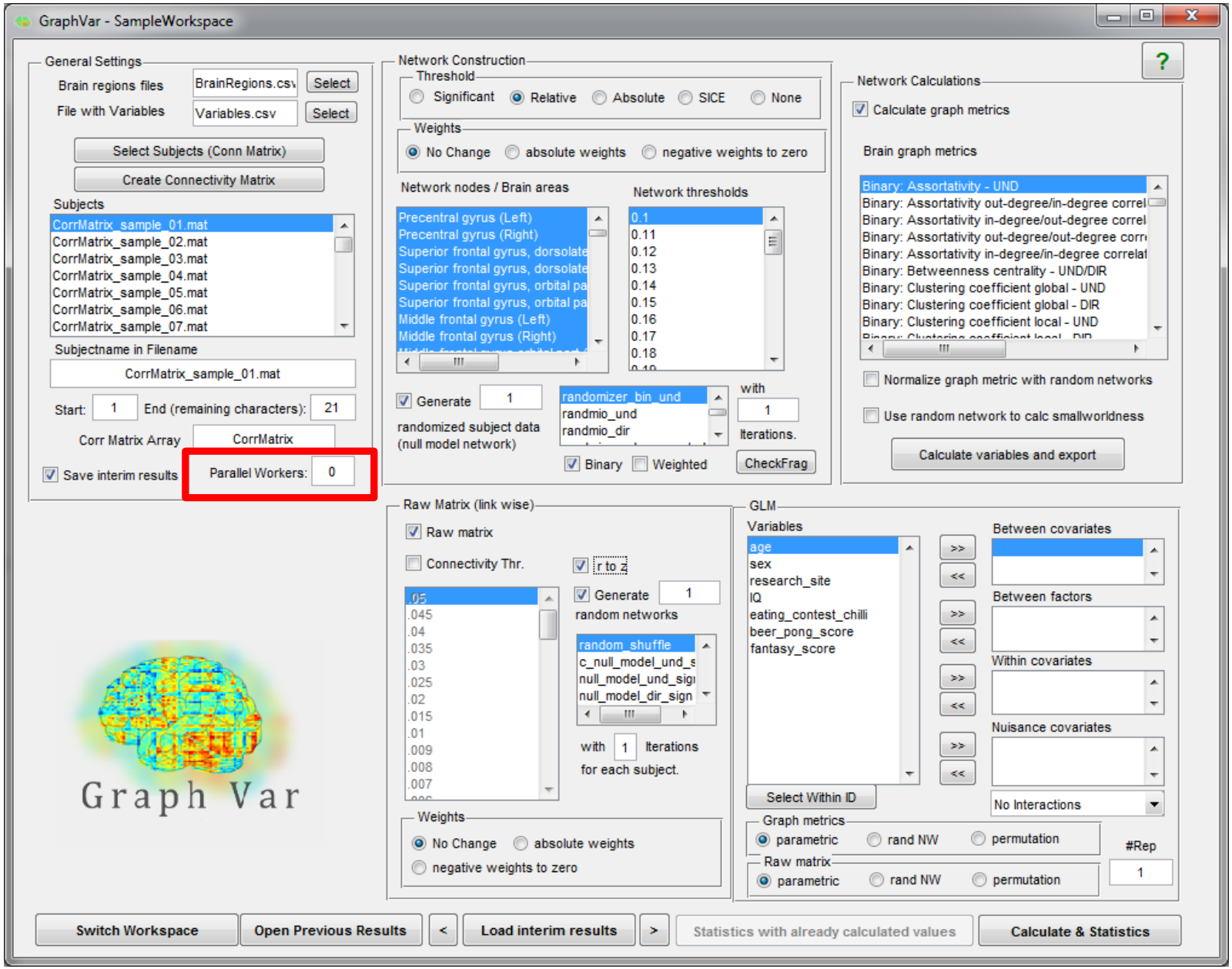
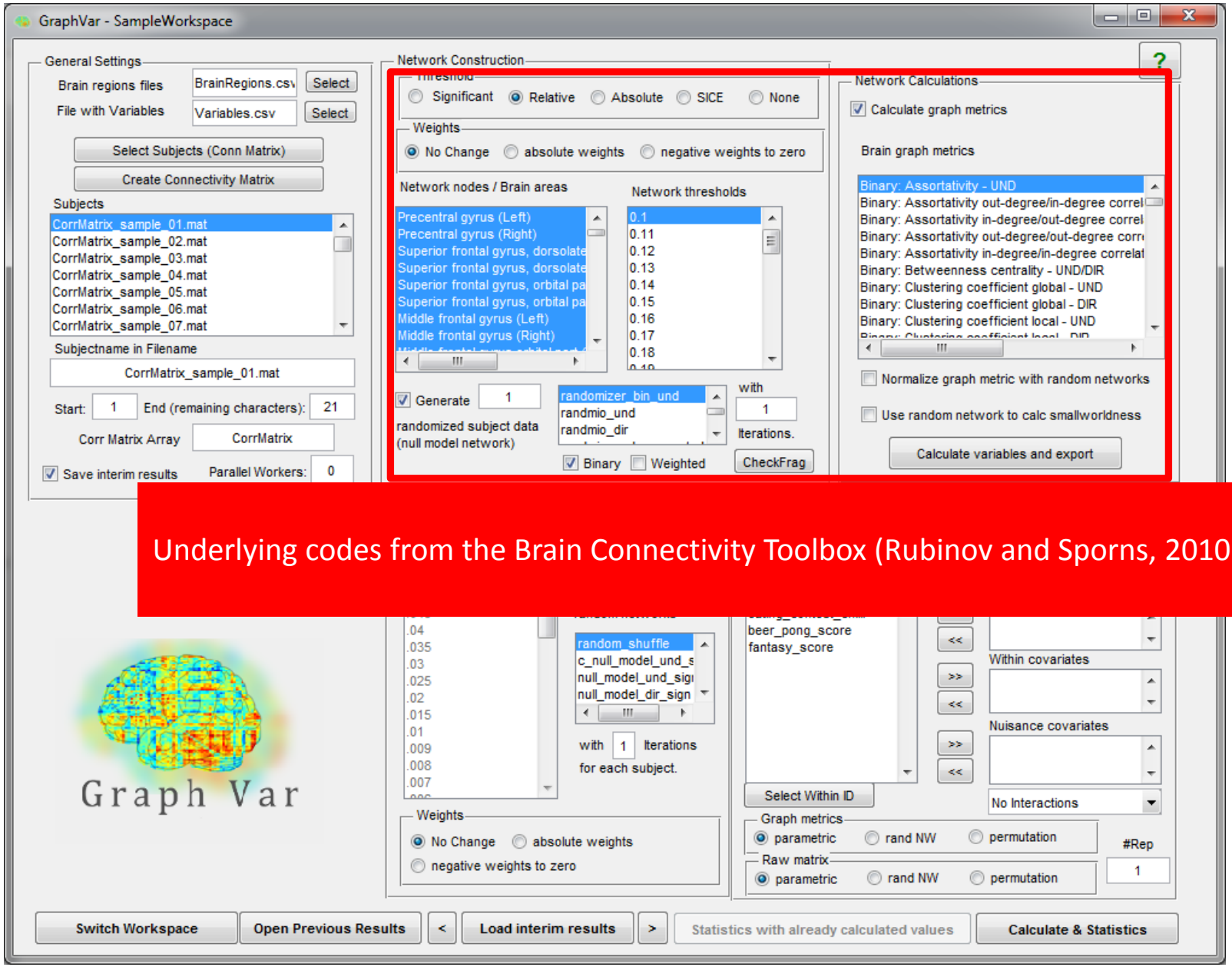
Workflows



Setup panel (mouse over help)



Parallel Computing (with toolbox)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randomizer_bin_und
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Binary: Clustering coefficient global - UND
Binary: Clustering coefficient global - DIR
Binary: Clustering coefficient local - UND
Normalize graph metric with random networks
Use random network to calc smallworldness
Calculate variables and export
Underlying codes from the Brain Connectivity Toolbox (Rubinov and Sporns, 2010)
Graph Var
.04
.035
.03
.025
.02
.015
.01
.009
.008
.007
random_shuffle
c_null_model_und_s
null_model_und_sig
null_model_dir_sign
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fantasy_score
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Raw matrix
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permutation
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Switch Workspace
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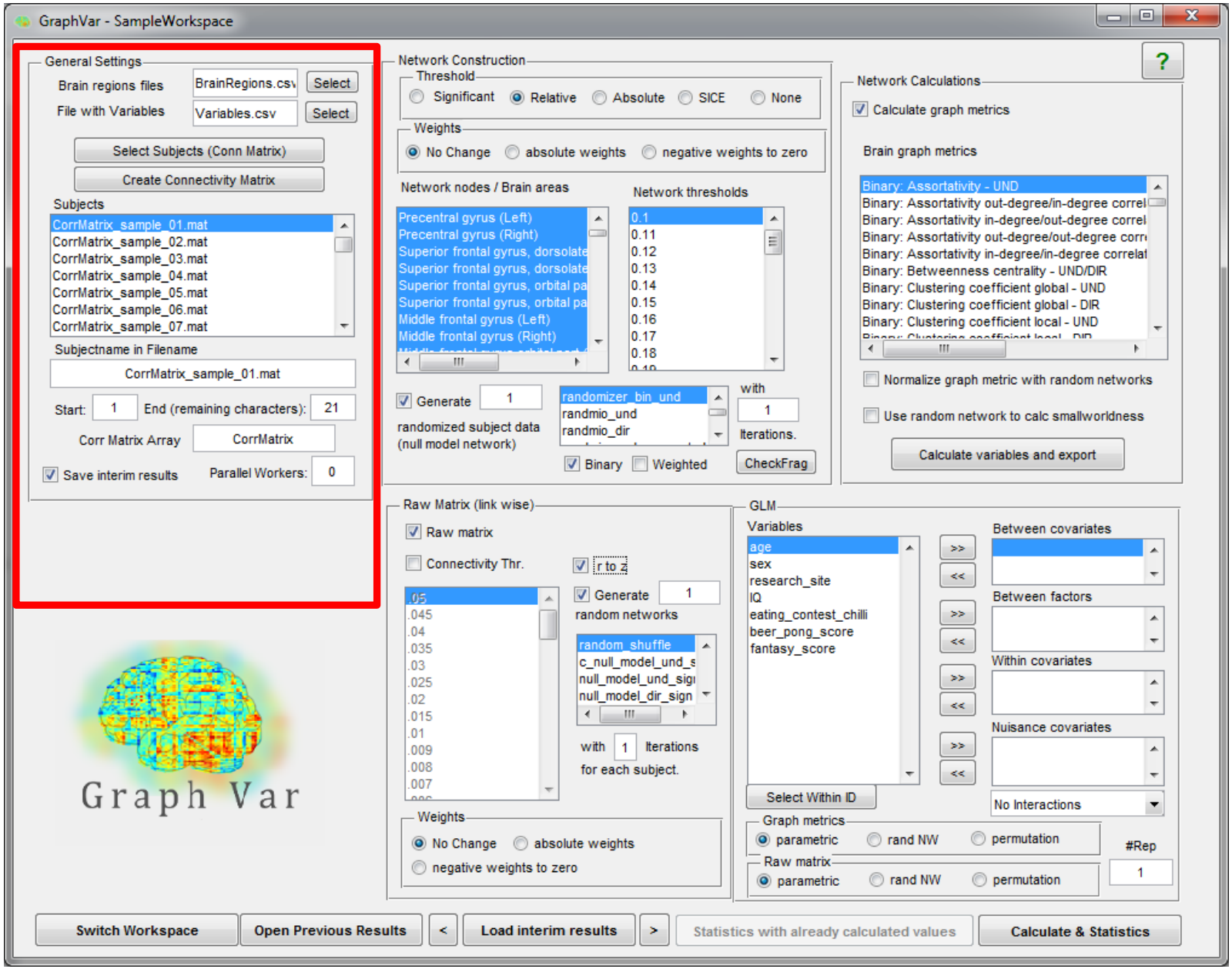
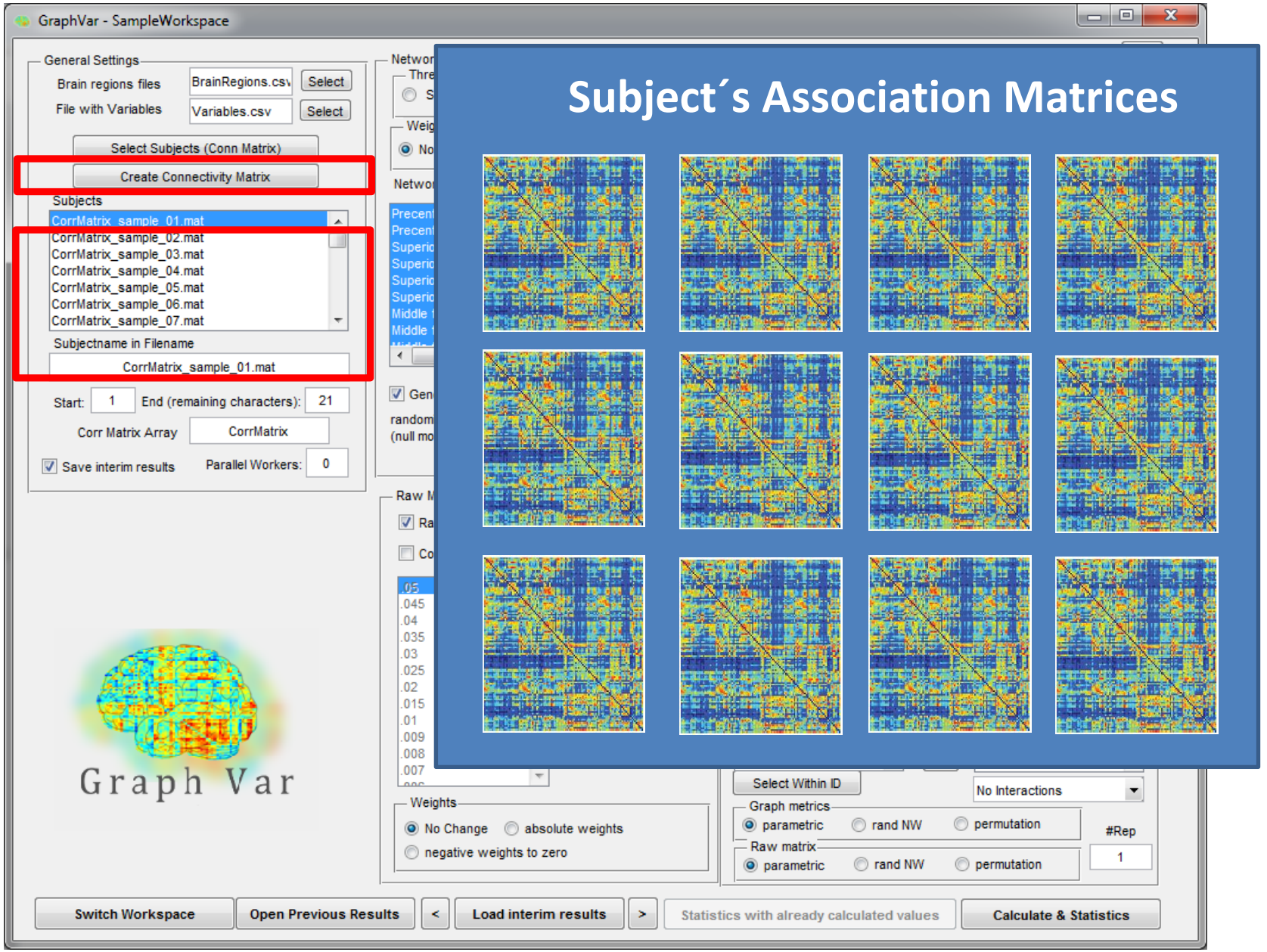
Calculate & Statistics

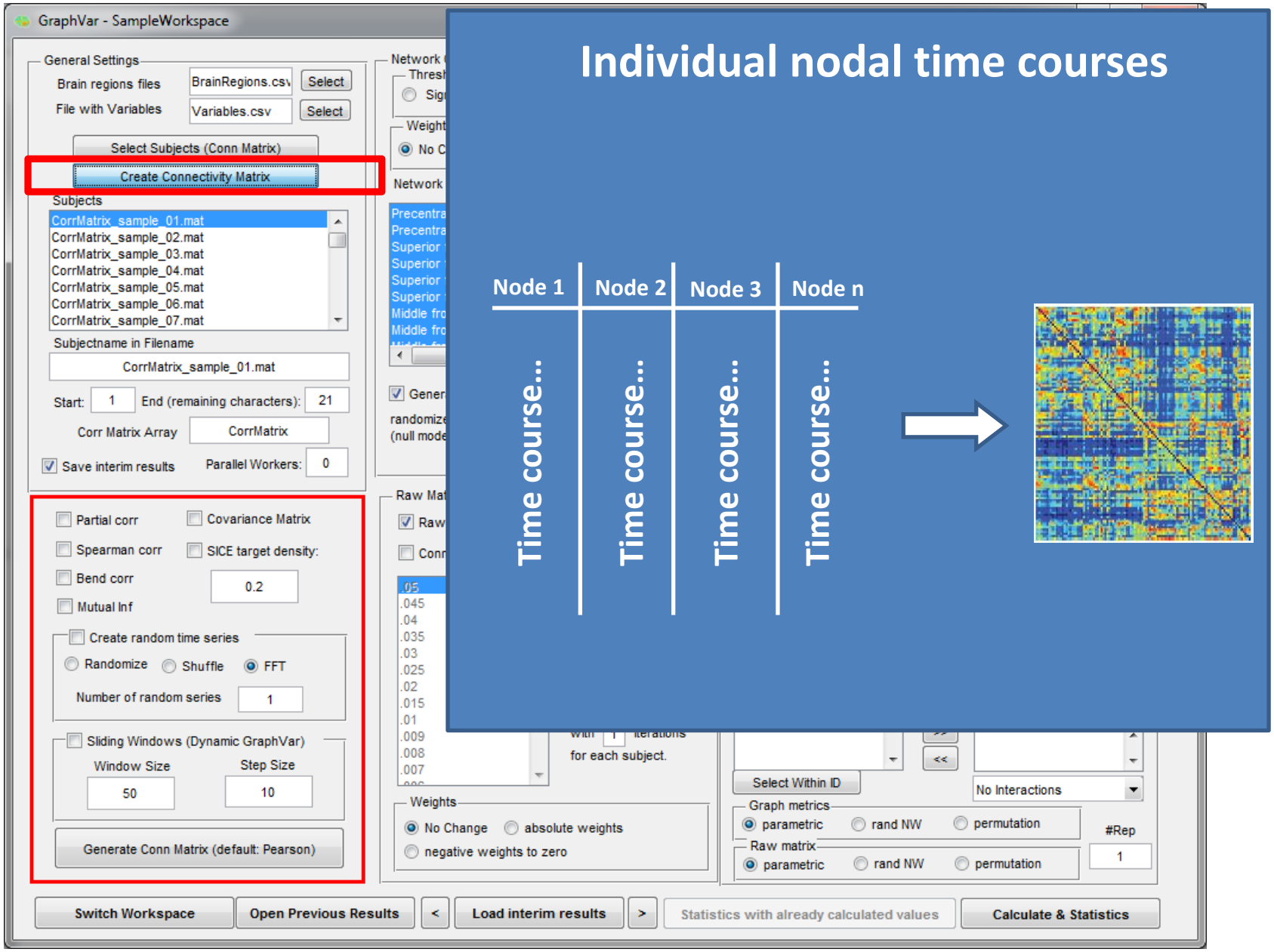
Setup panel



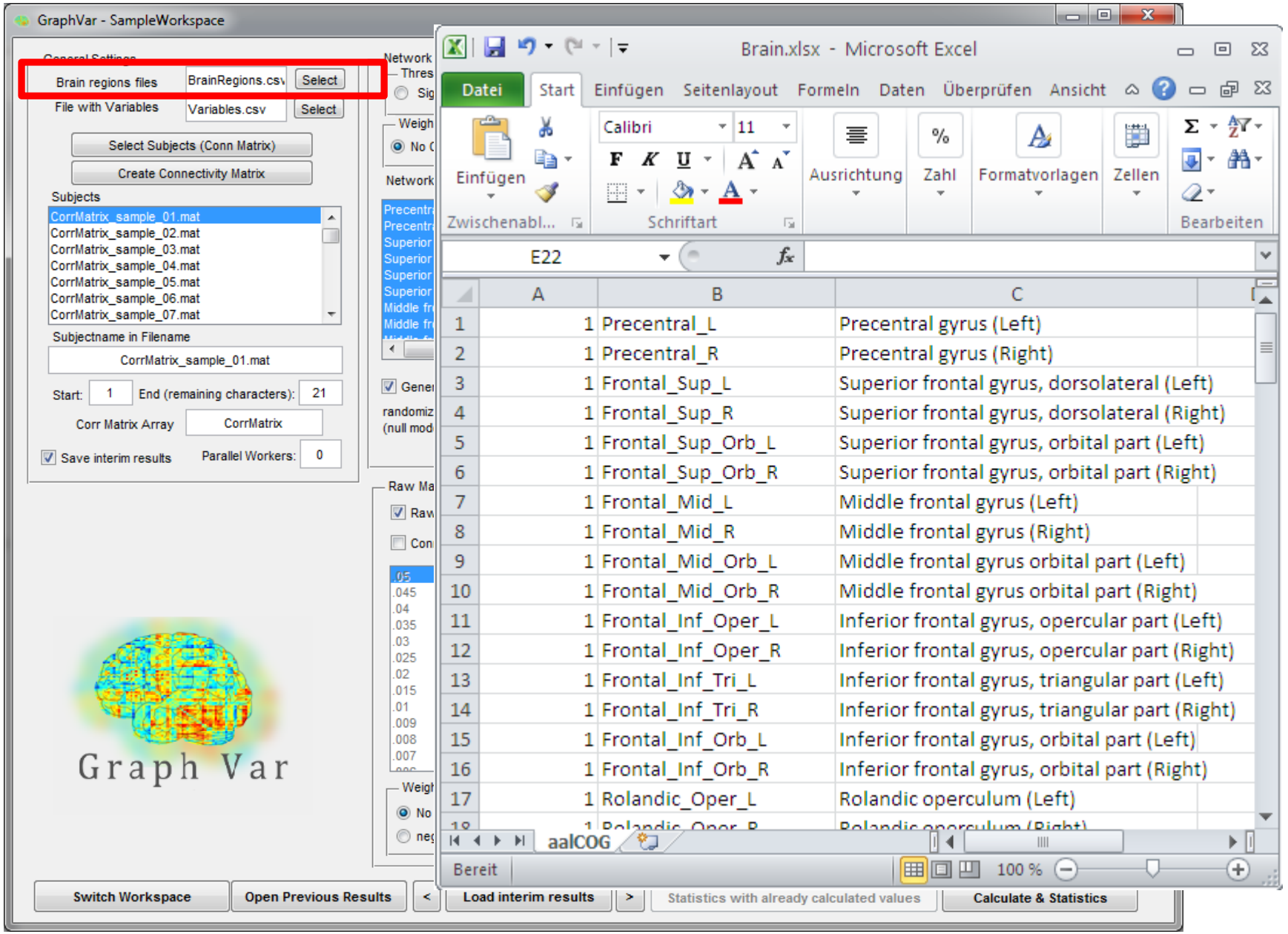
General settings



Load (existing) Connectivity Matrices



Generate Connectivity Matrices


GraphVar - SampleWorkspace
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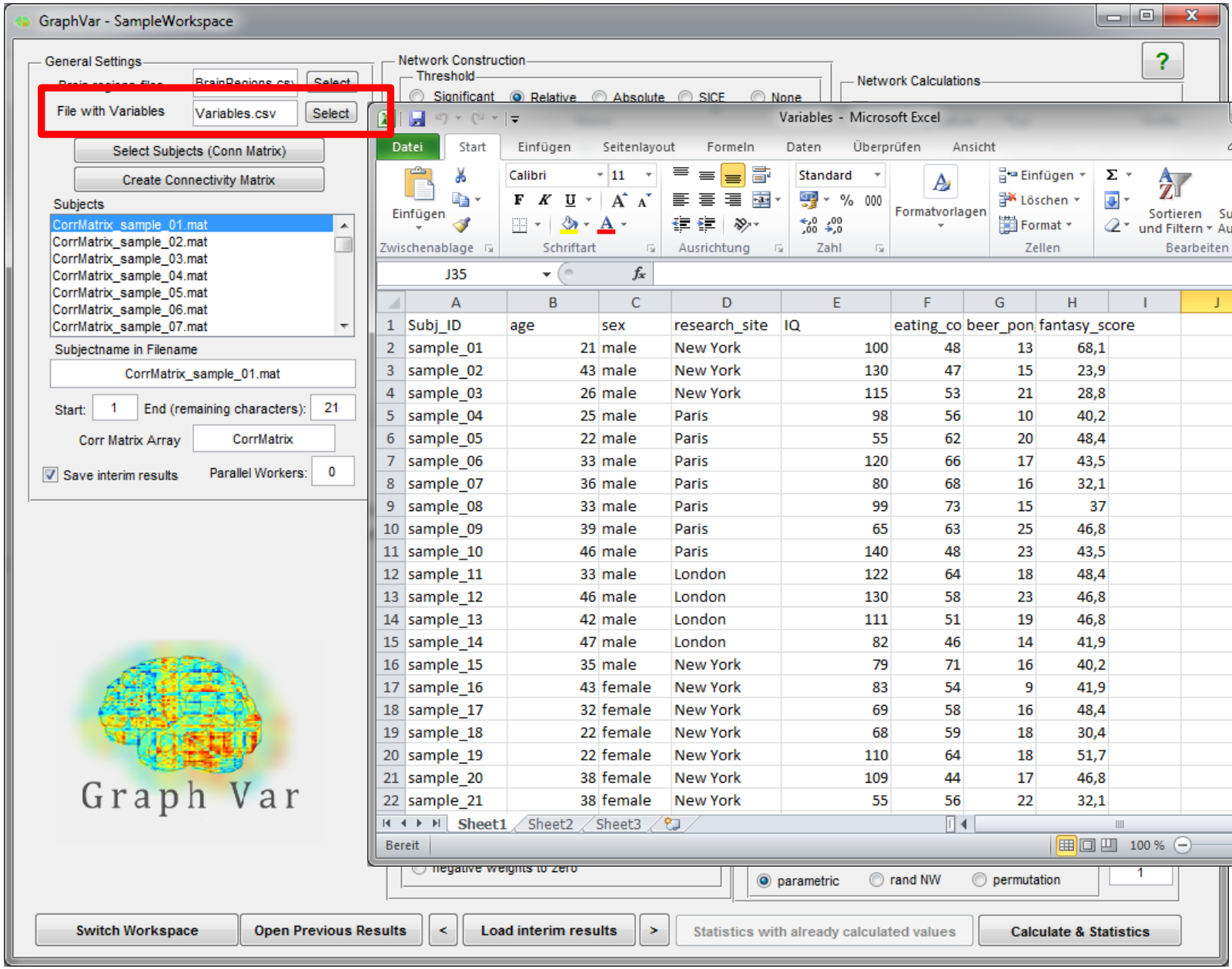
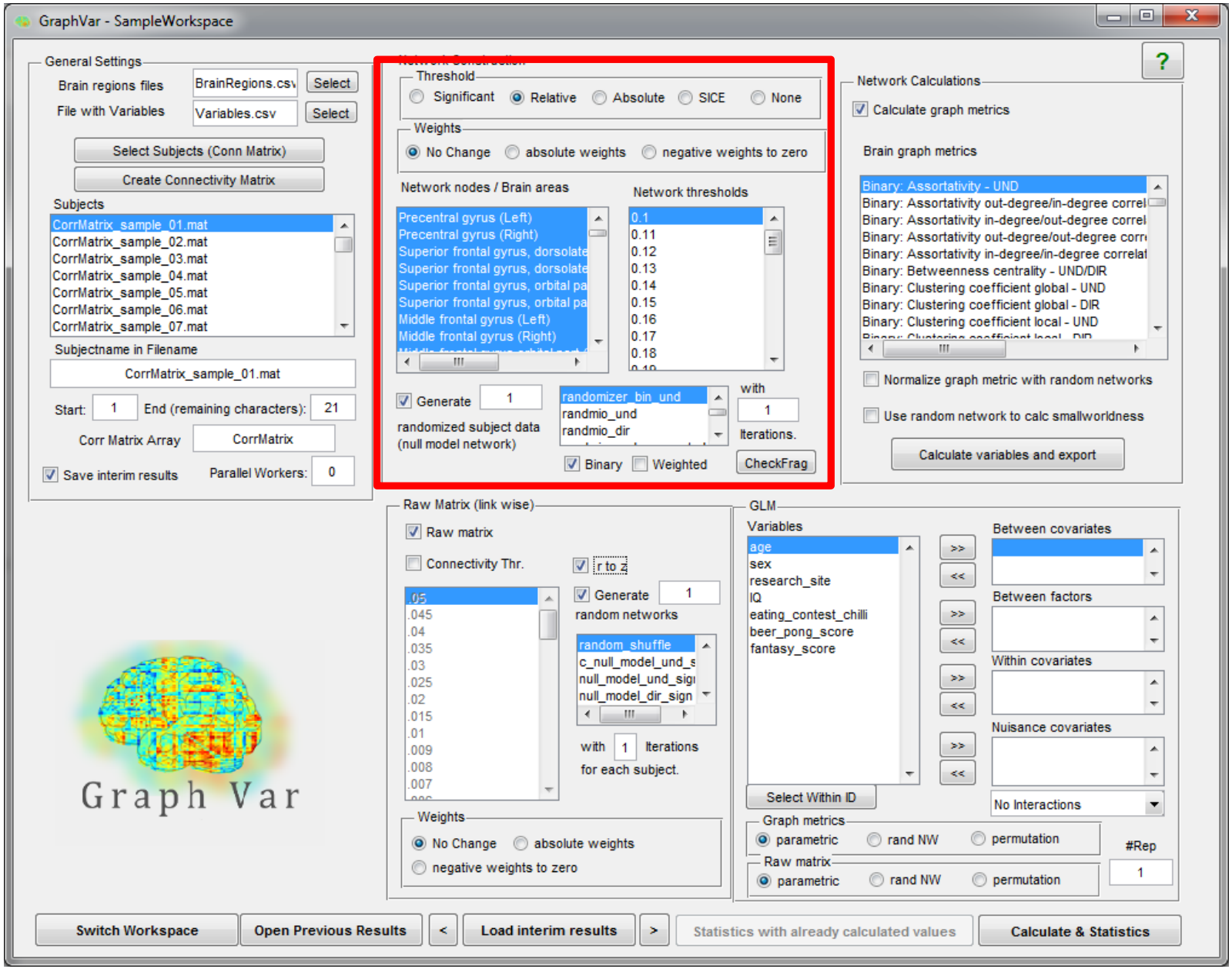
CorrMatrix
Save interim results
Parallel Workers: 0
Graph Var
Switch Workspace
Open Previous Results
Load interim results
Statistics with already calculated values
Calculate & Statistics
Brain.xlsx - Microsoft Excel
Datei
Start
Einfügen
Seitenlayout
Formeln
Daten
Überprüfen
Ansicht
Einfügen
Calibri
11
Ausrichtung
Zahl
Formatvorlagen
Zellen
Bearbeiten
Zwischenabl...
Schriftart
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)
aalCOG
Bereit
100 %

Label nodes

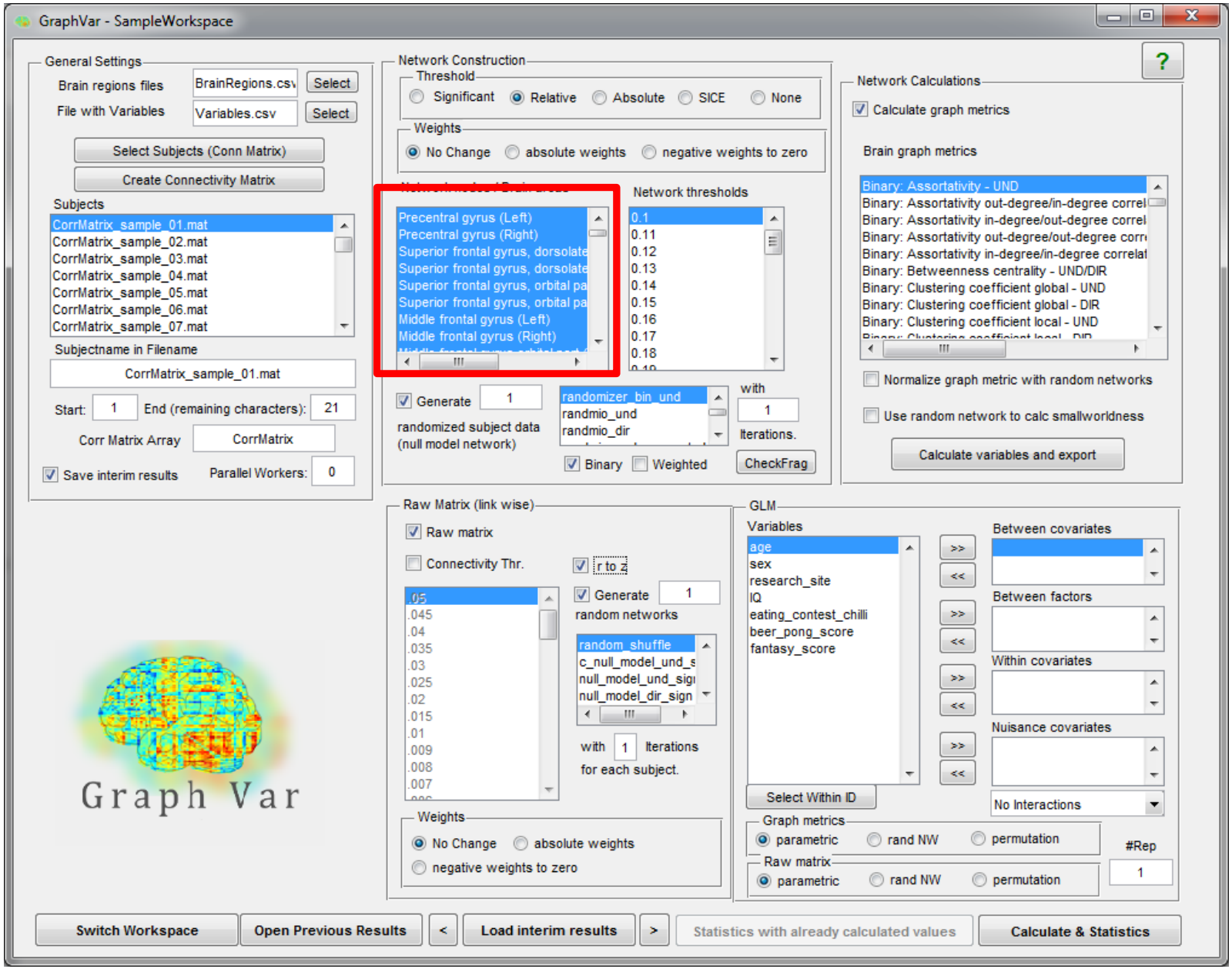


	A	B	C	D	E	F	G	H
1	Subj_ID	age	sex	research_site	IQ	eating_co	beer_pon	fantasy_score
2	sample_01	21	male	New York	100	48	13	68,1
3	sample_02	43	male	New York	130	47	15	23,9
4	sample_03	26	male	New York	115	53	21	28,8
5	sample_04	25	male	Paris	98	56	10	40,2
6	sample_05	22	male	Paris	55	62	20	48,4
7	sample_06	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

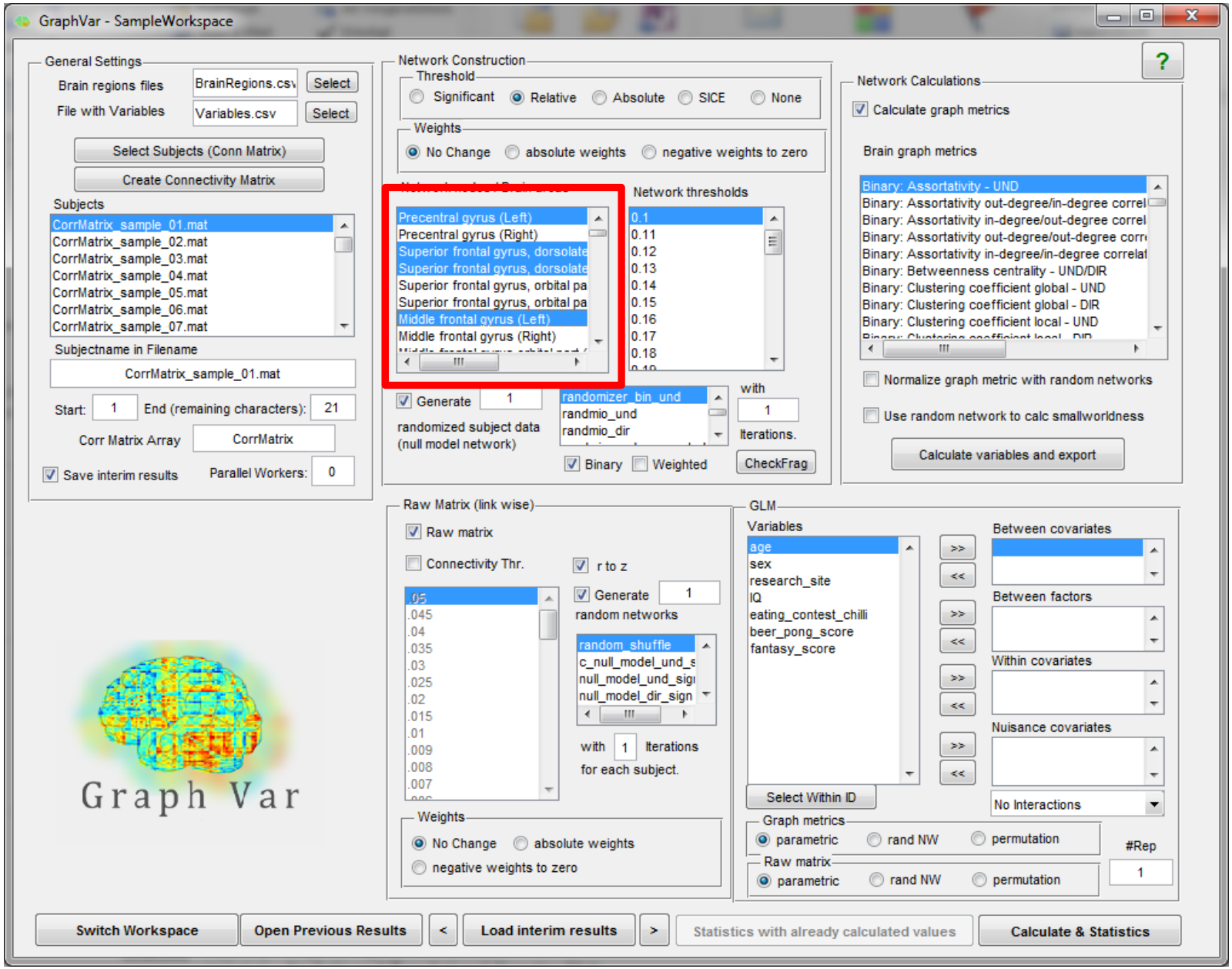
Variable Selection



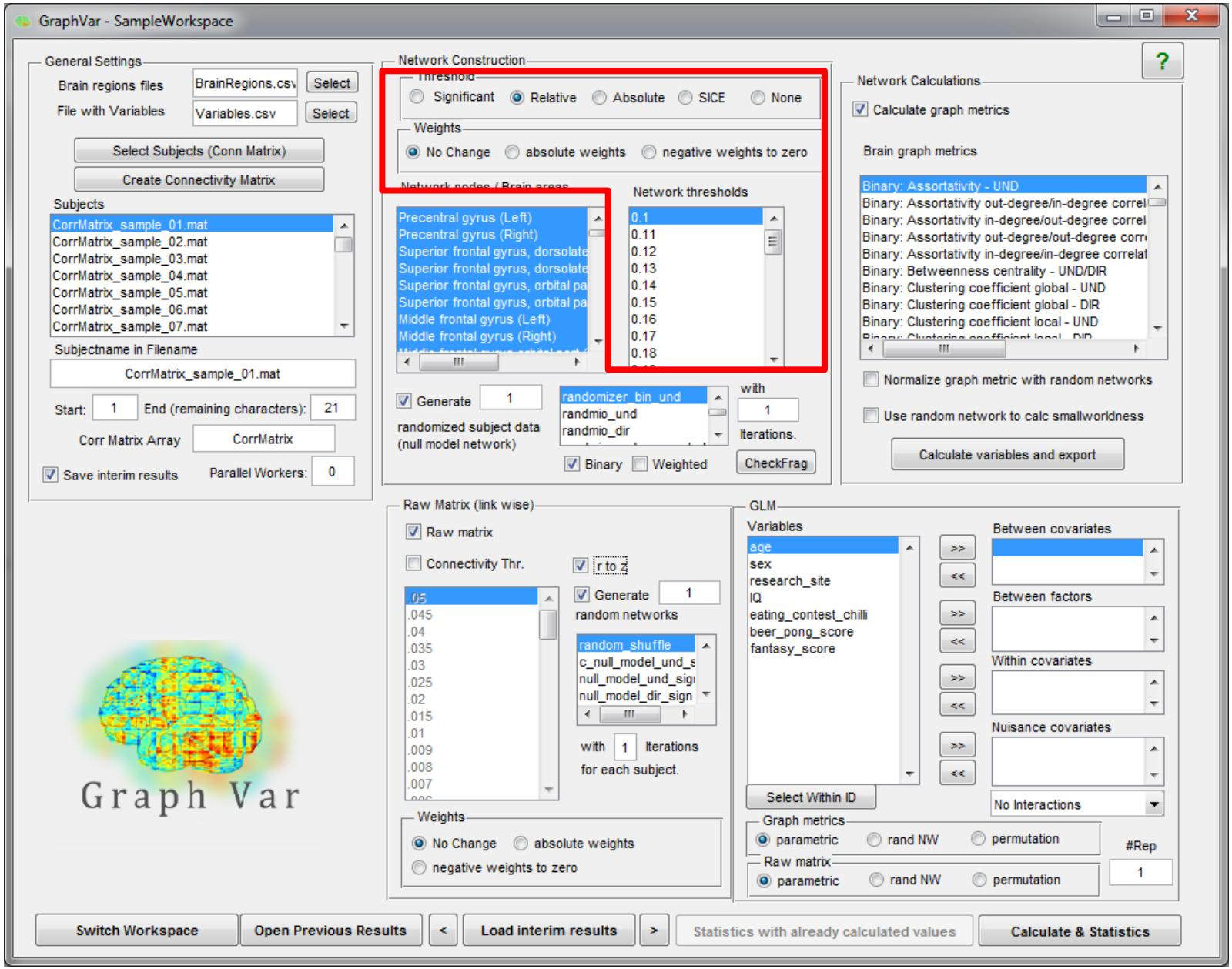
Network construction



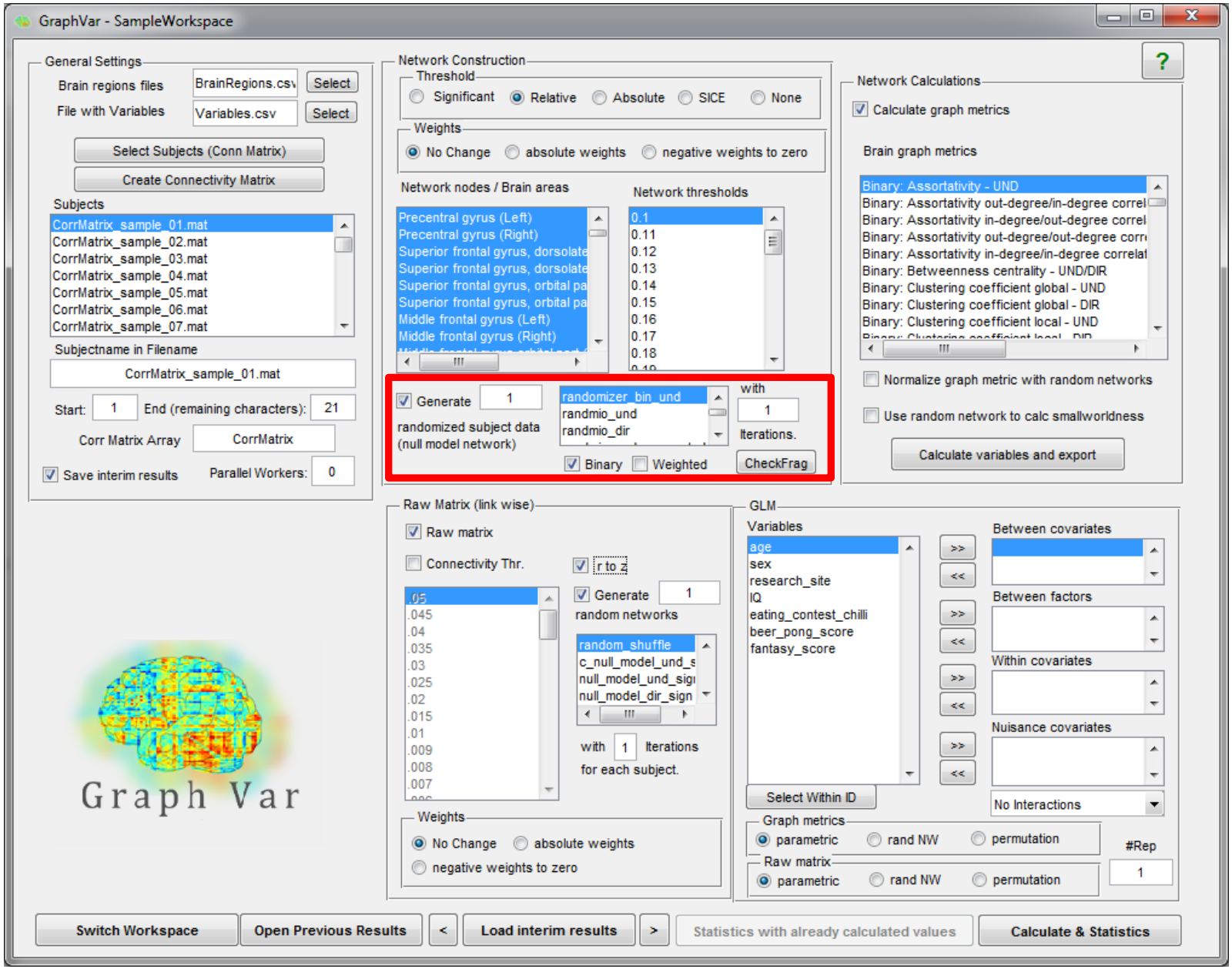
Network nodes



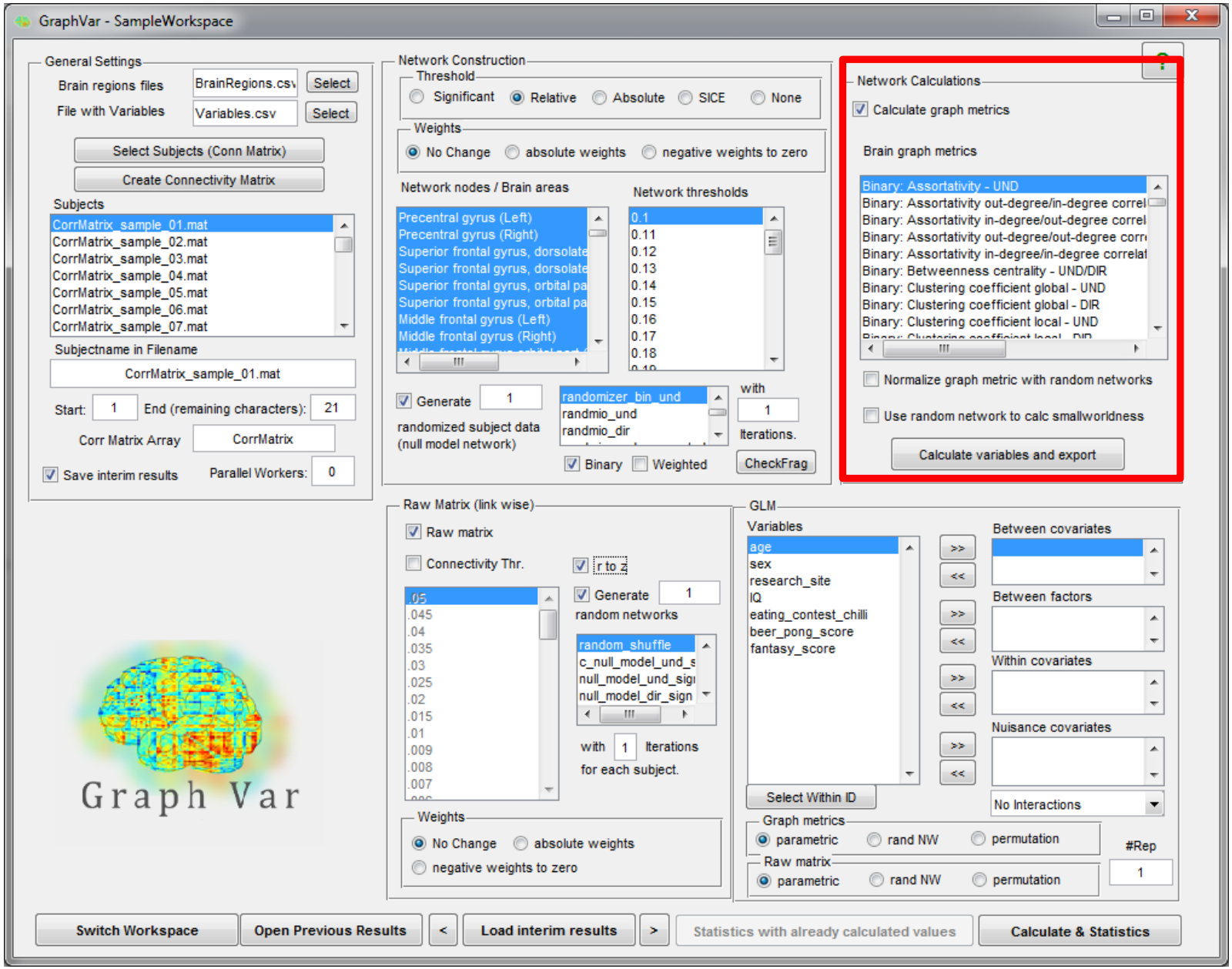
Redefine Network (Subnetwork analyses)



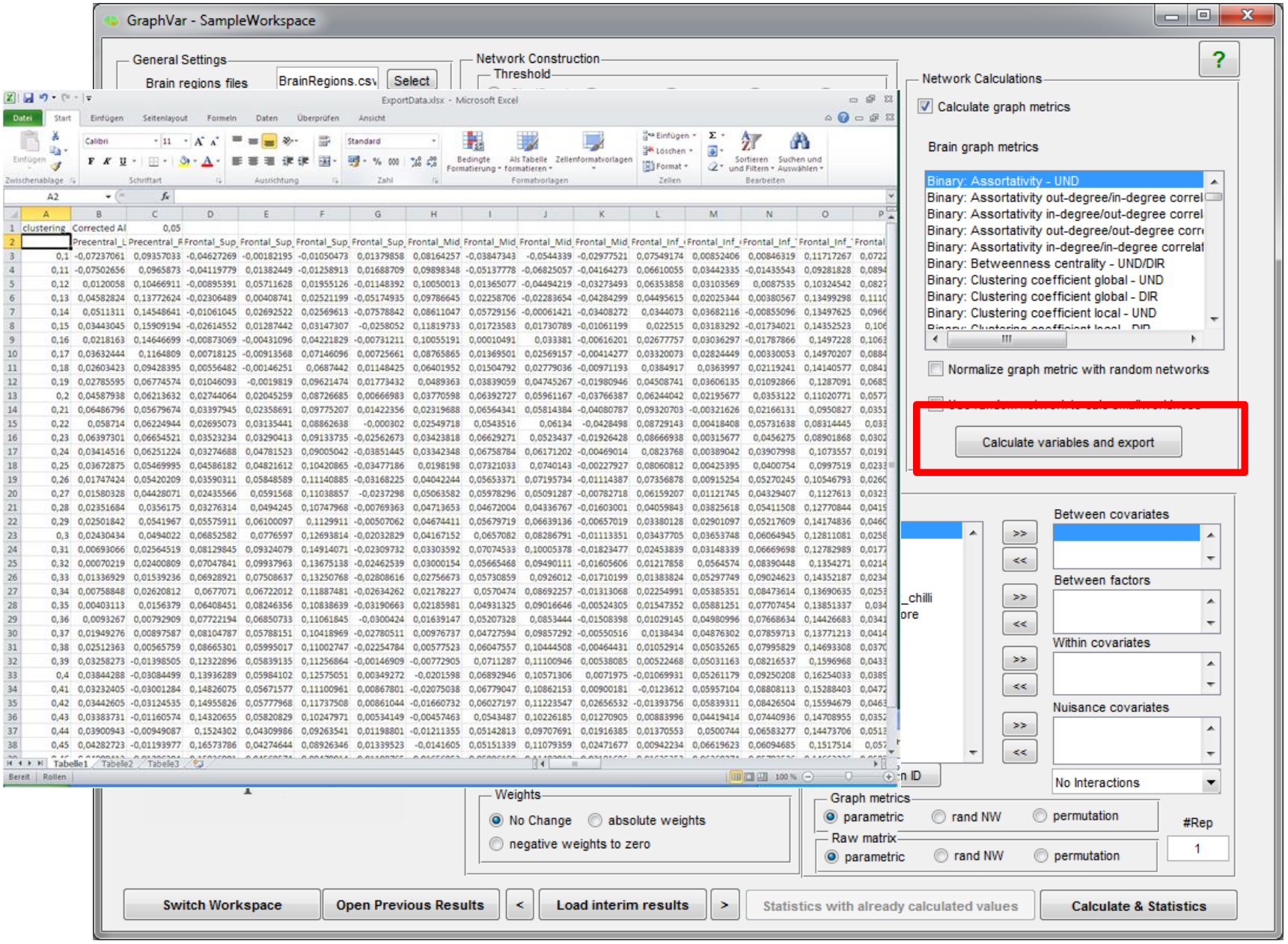
Network thresholds



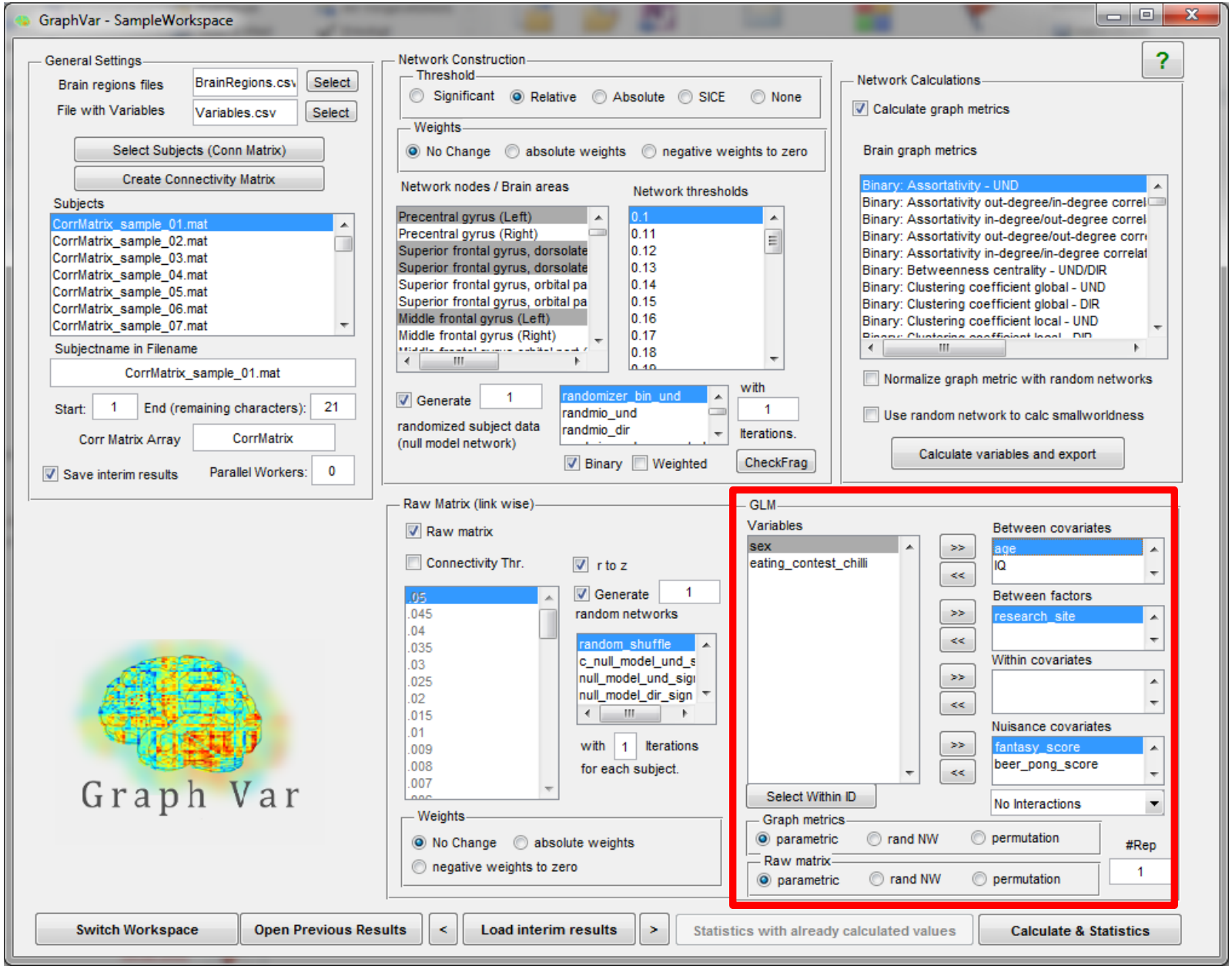
Subject specific null model networks



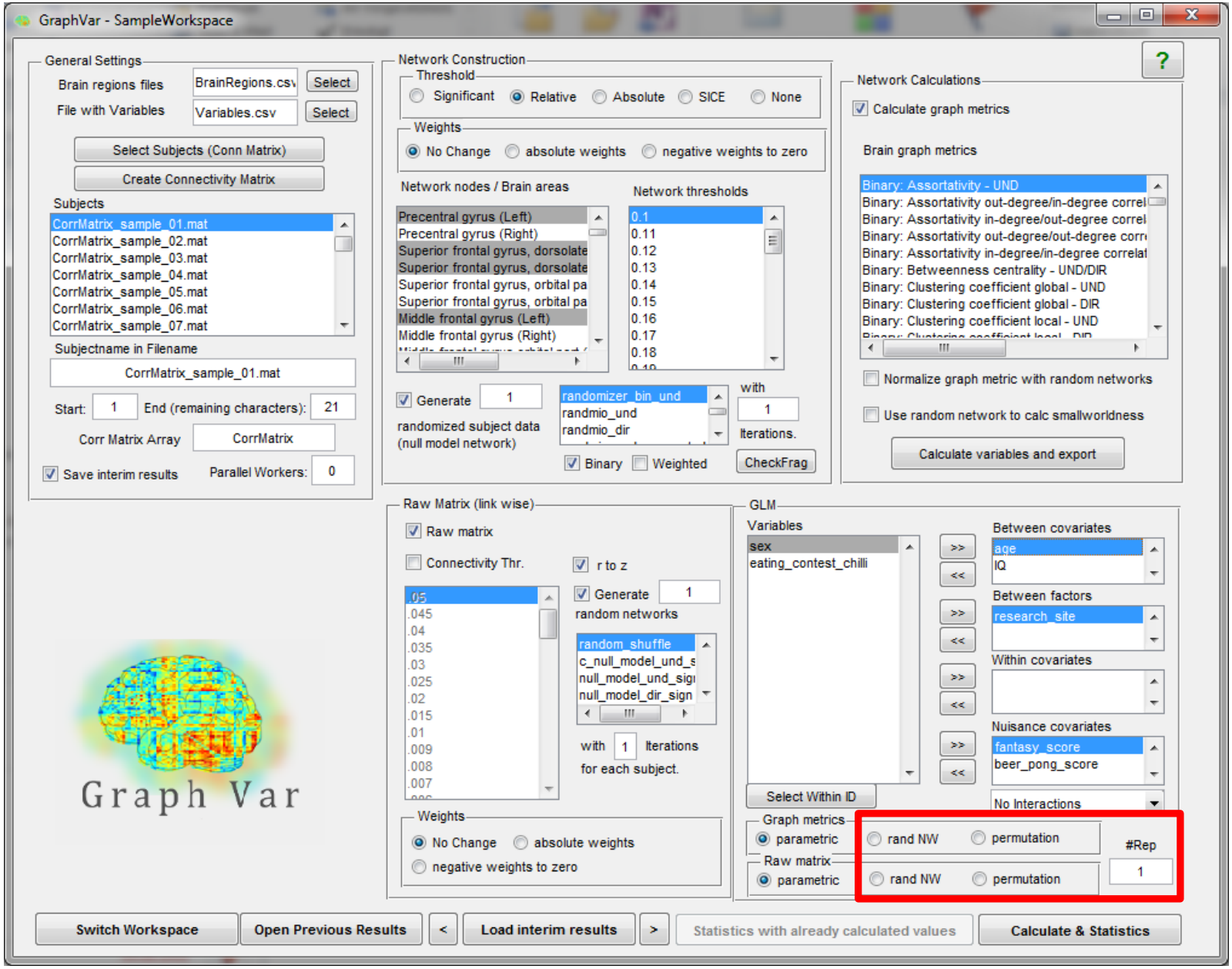
Network topological measures



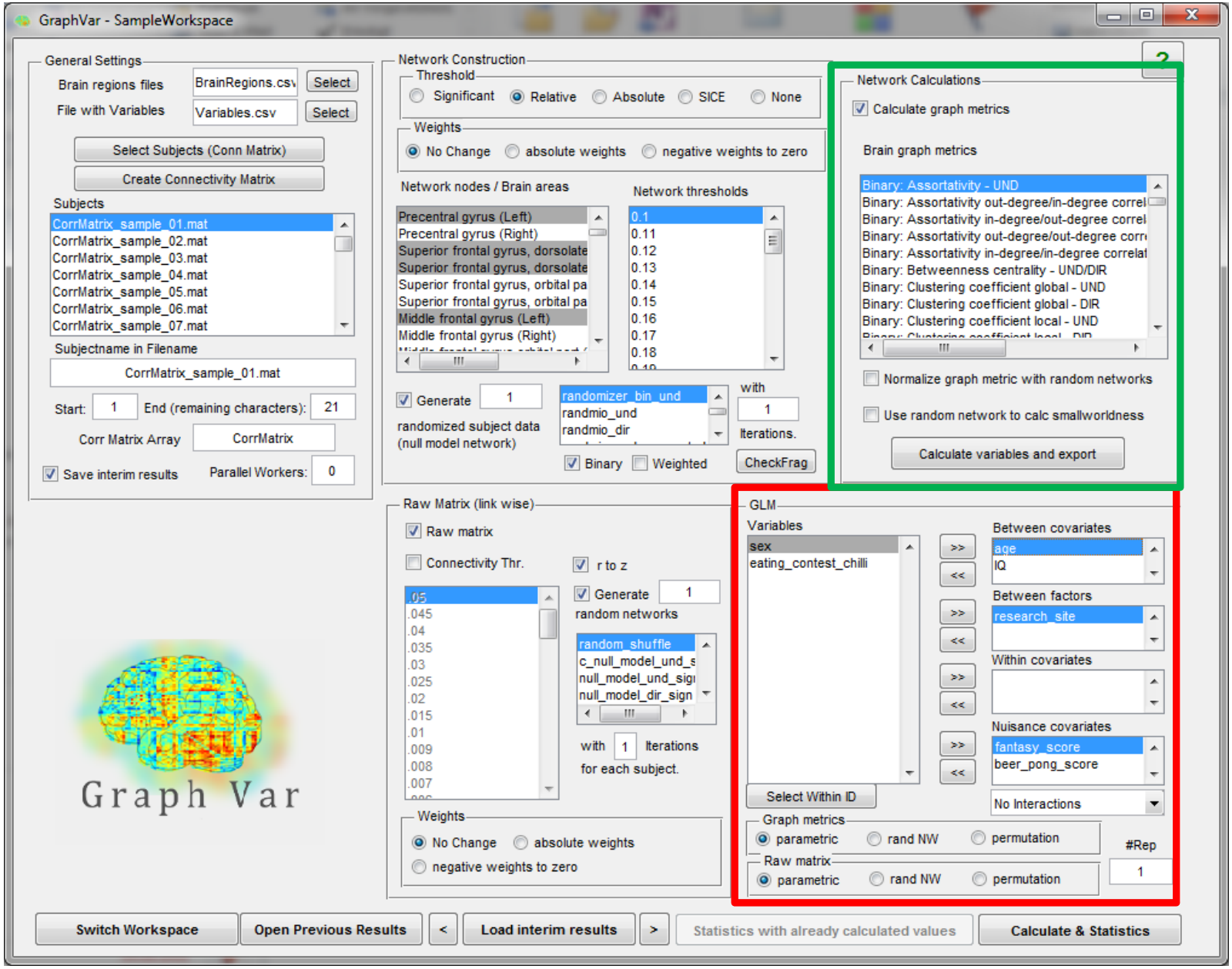
Export network topological measures



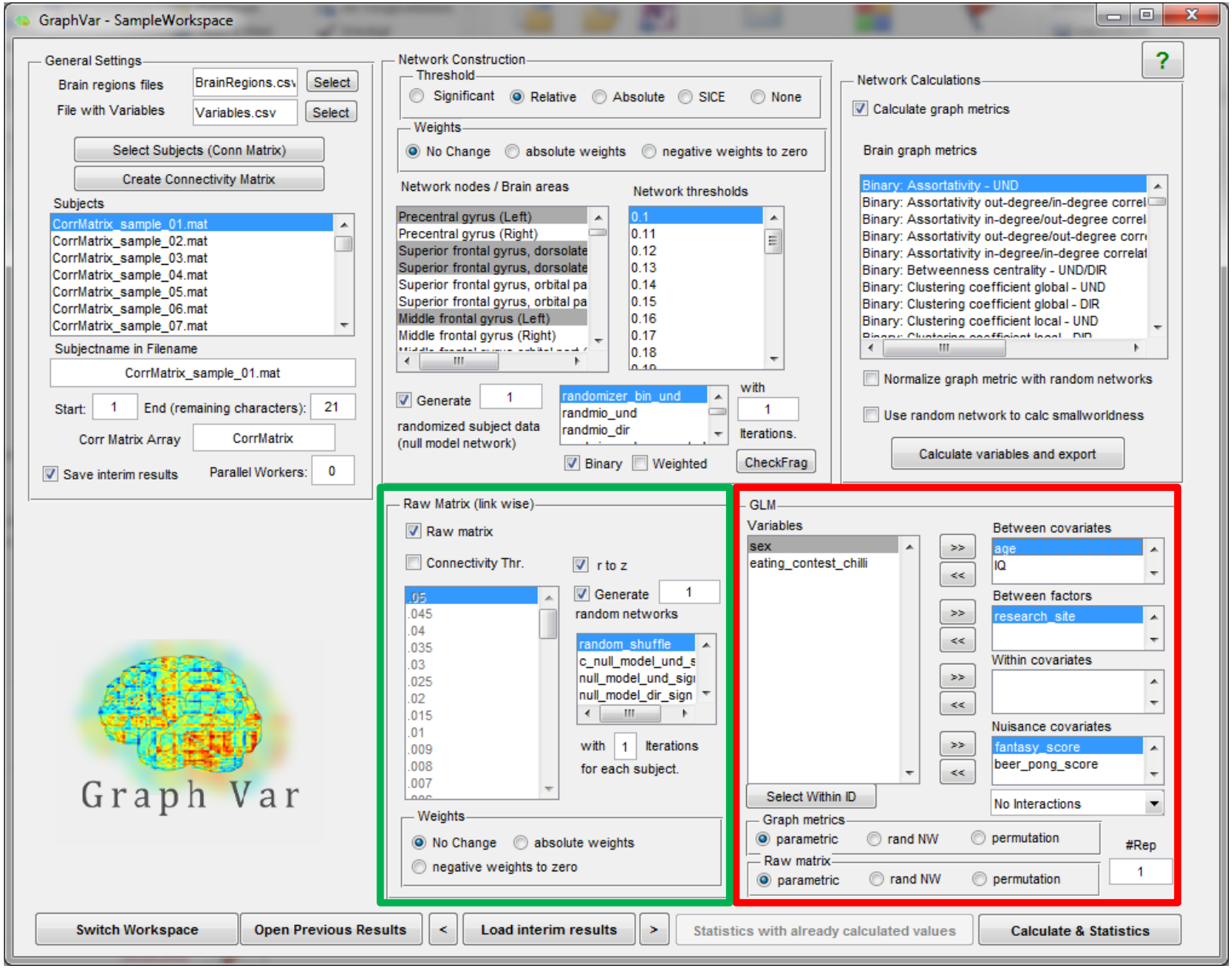
Statistical analyses (GLM)



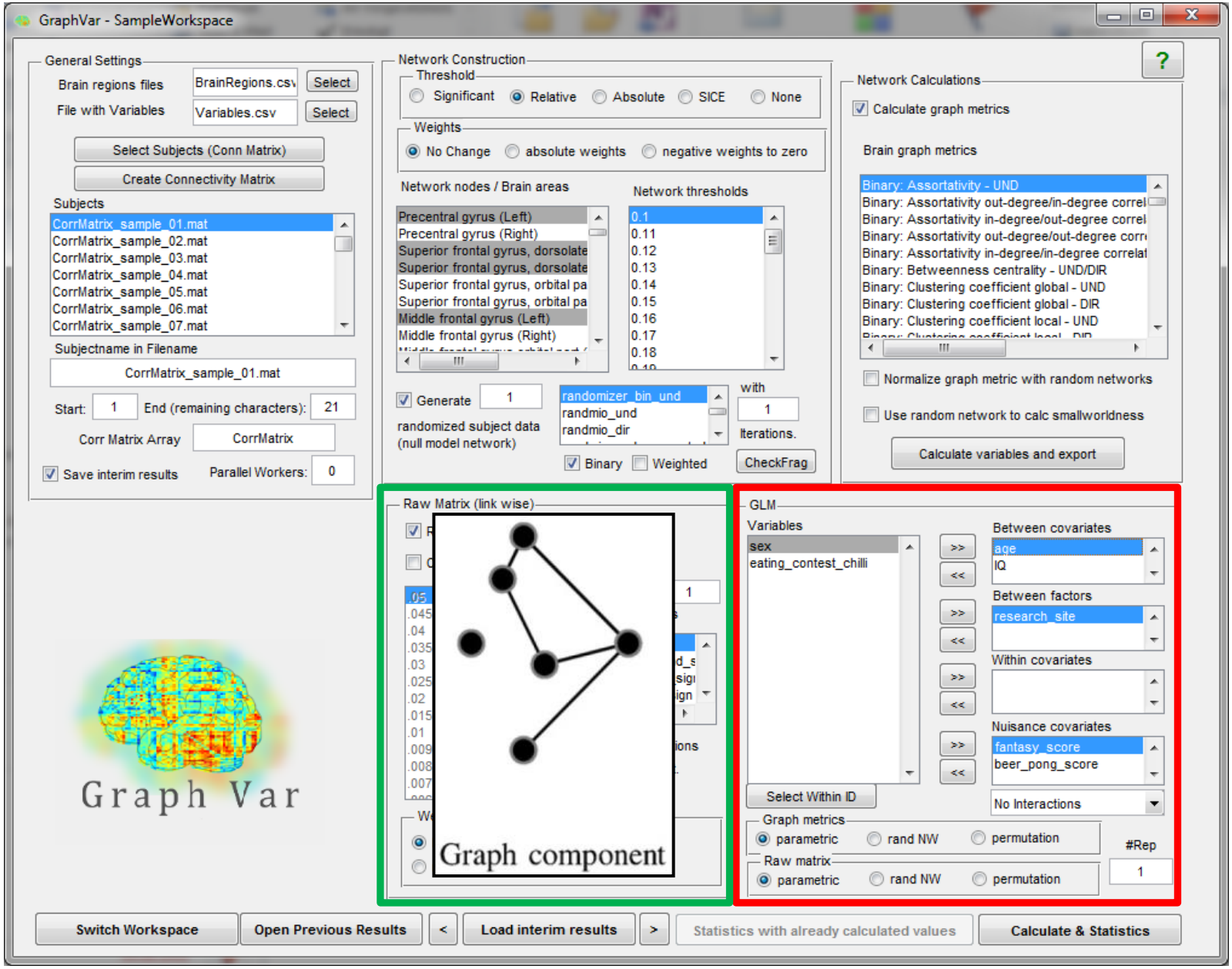
Non-parametric testing



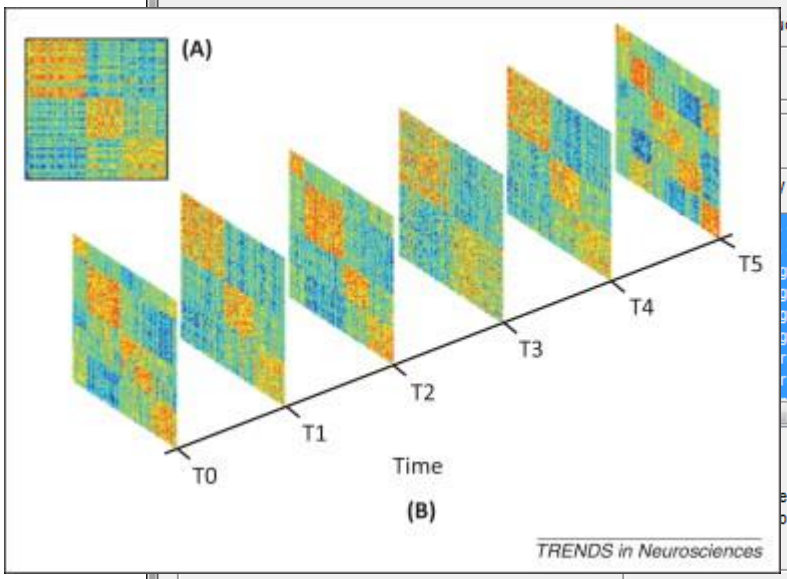
Statistical analyses of graph measures



Statistics on the raw conn matrices



Network-Based-Statistics



GraphVar - SampleWorkspace

Relative Absolute SICE None

absolute weights negative weights to zero

Brain areas

Network thresholds

Network Calculations

Calculate graph metrics

Brain graph metrics

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
Binary: Community structure Newman - modularity

Normalize graph metric with random networks

Use random network to calc smallworldness

Calculate variables and export

Partial corr Covariance Matrix

Spearman corr SICE target density: 0.2

Bend corr

Mutual Inf

Create random time series

Randomize Shuffle FFT

Number of random series 1

Sliding Windows (Dynamic GraphVar)

Window Size 20

Step Size 10

Raw Matrix (link wise)

Raw matrix

Connectivity Thr. r to z

.05 .045 .04 .035 .03 .025 .02 .015 .01 .009 .008 .007

Weights

No Change absolute weights

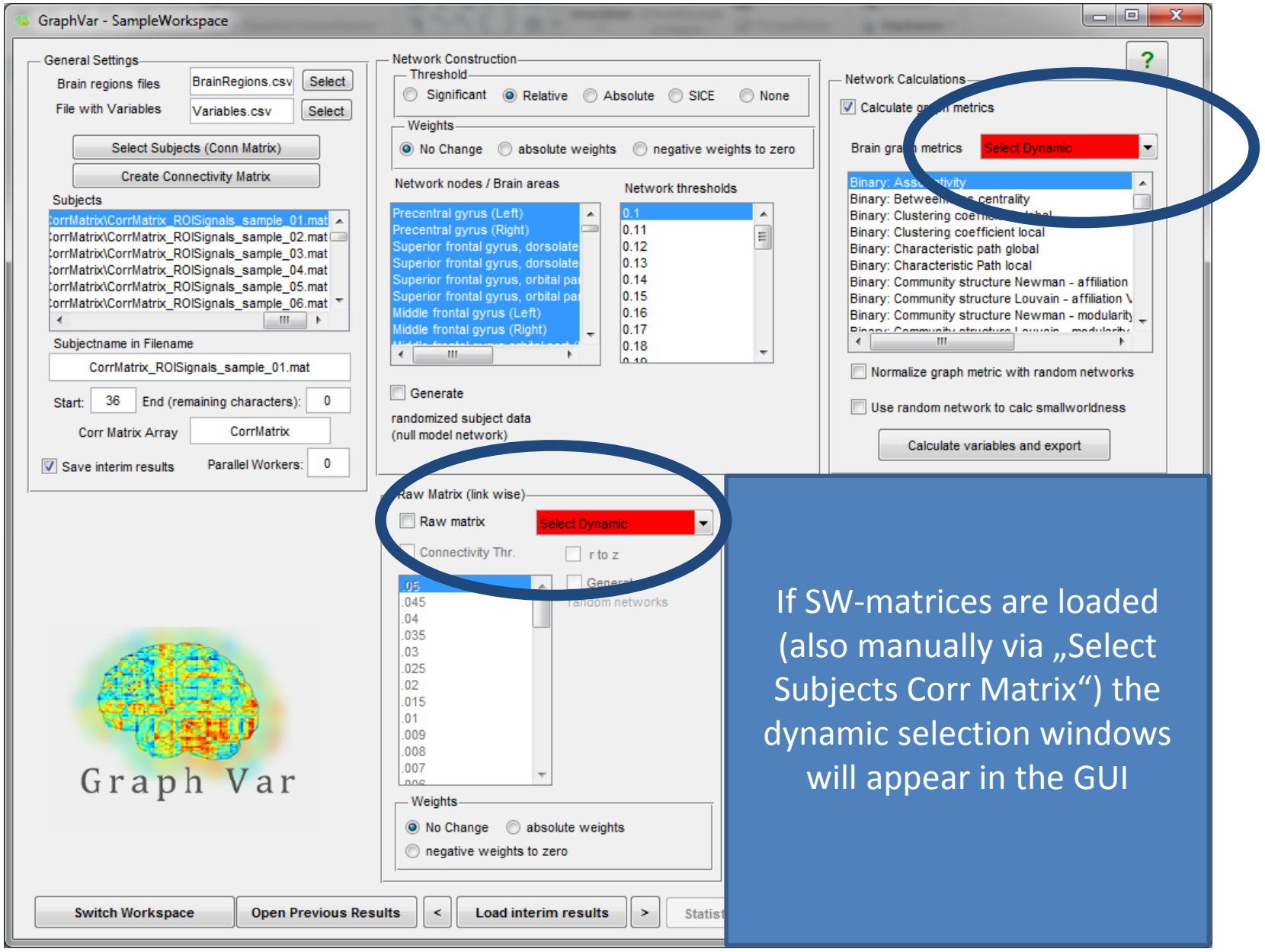
negative weights to zero

Switch Workspace | Open Previous Results | < | Load interim results

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

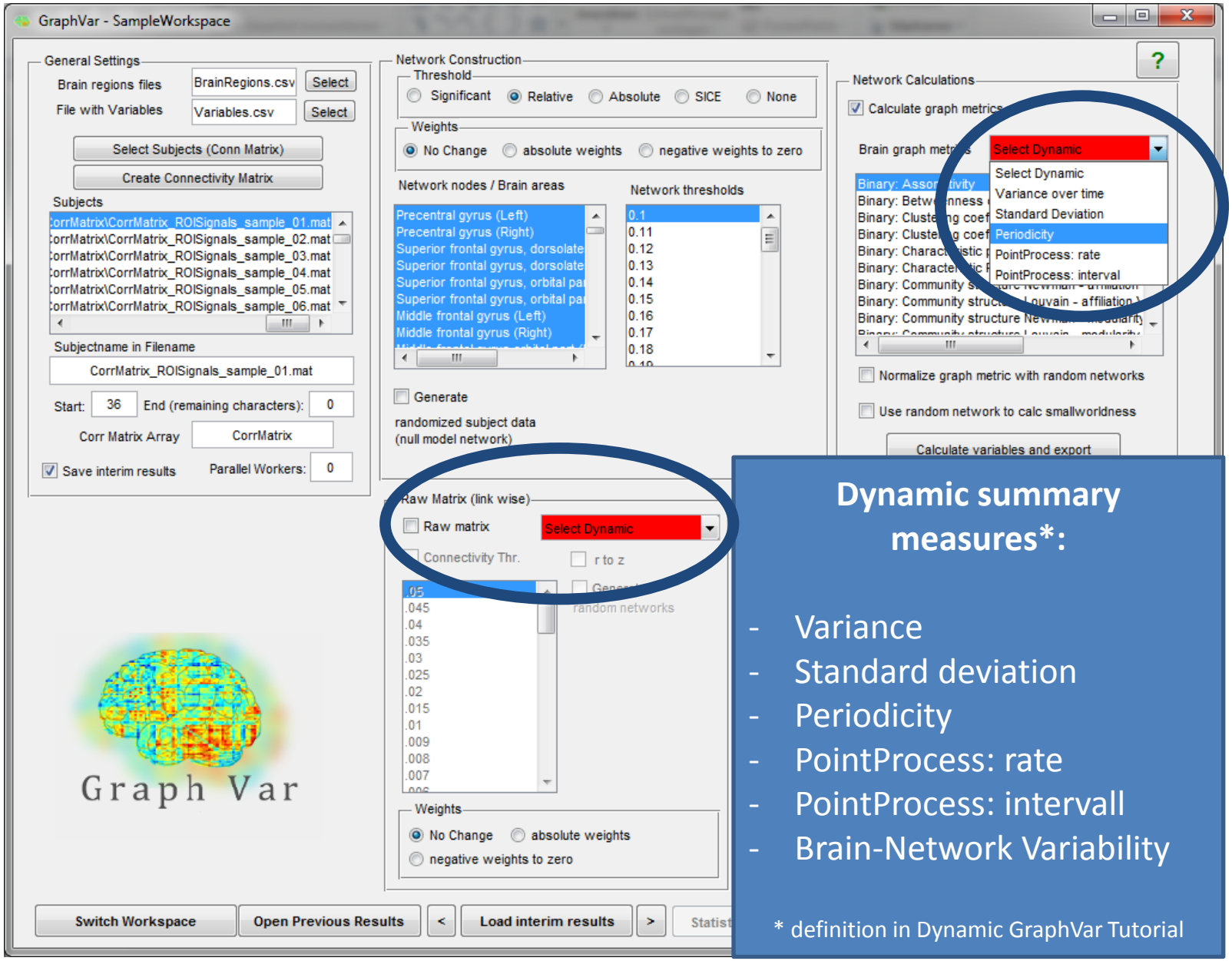
- Pearson corr
- Partial corr
- Covariance
- Mutual inf
- etc.....

Create Connectivity matrix -> **sliding windows**



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)

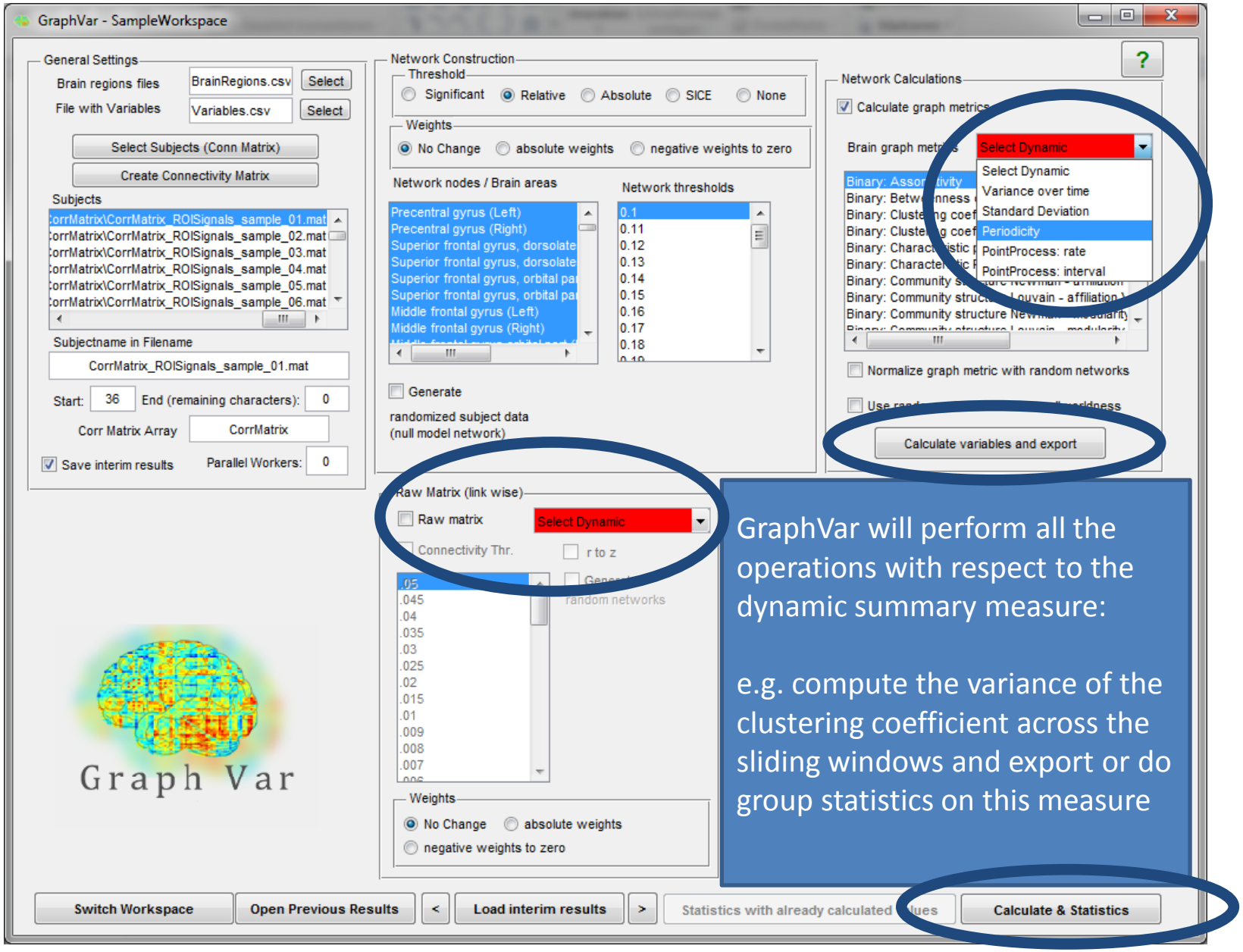


Dynamic summary measures*:

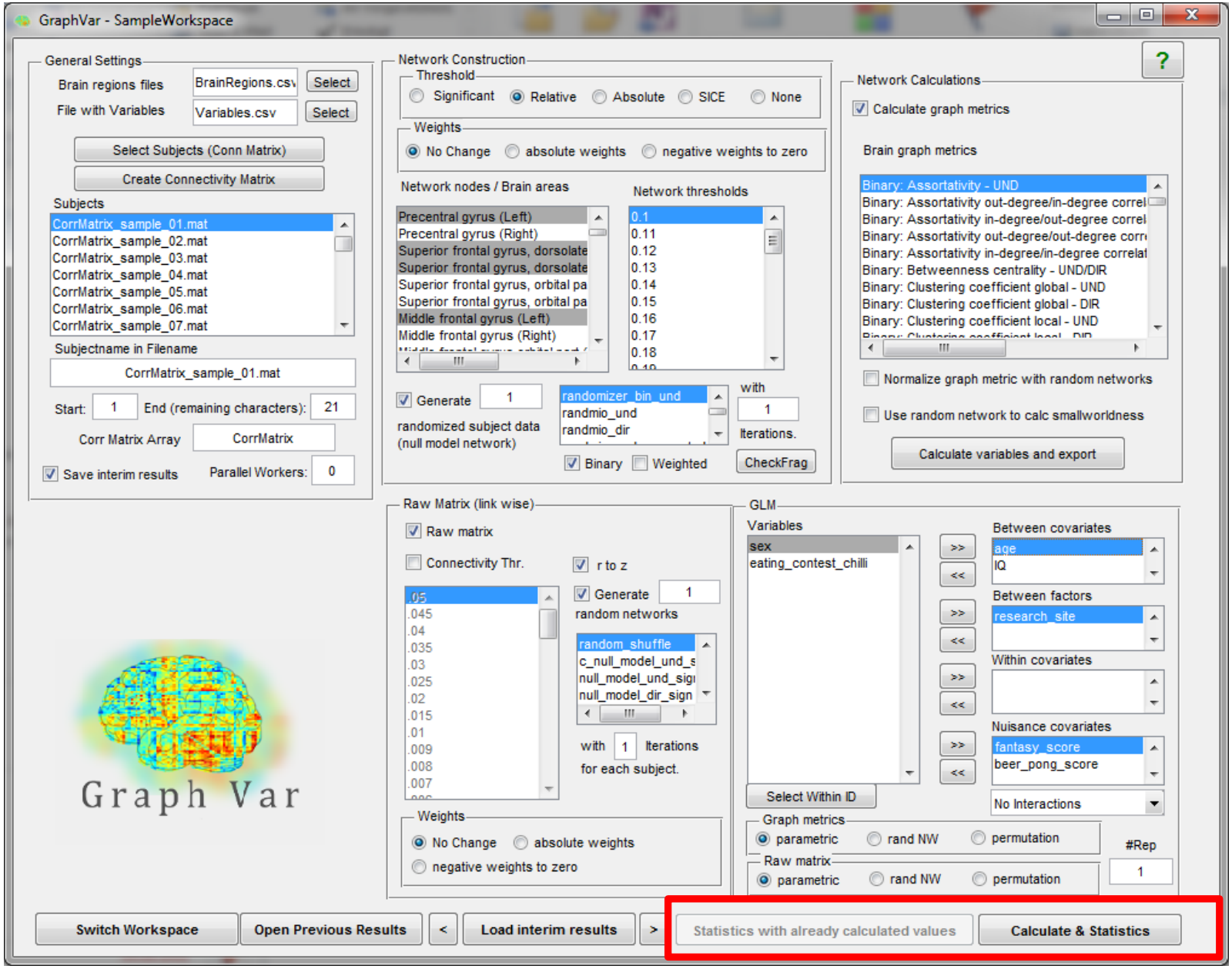
- Variance
- Standard deviation
- Periodicity
- PointProcess: rate
- PointProcess: intervall
- Brain-Network Variability

* definition in Dynamic GraphVar Tutorial

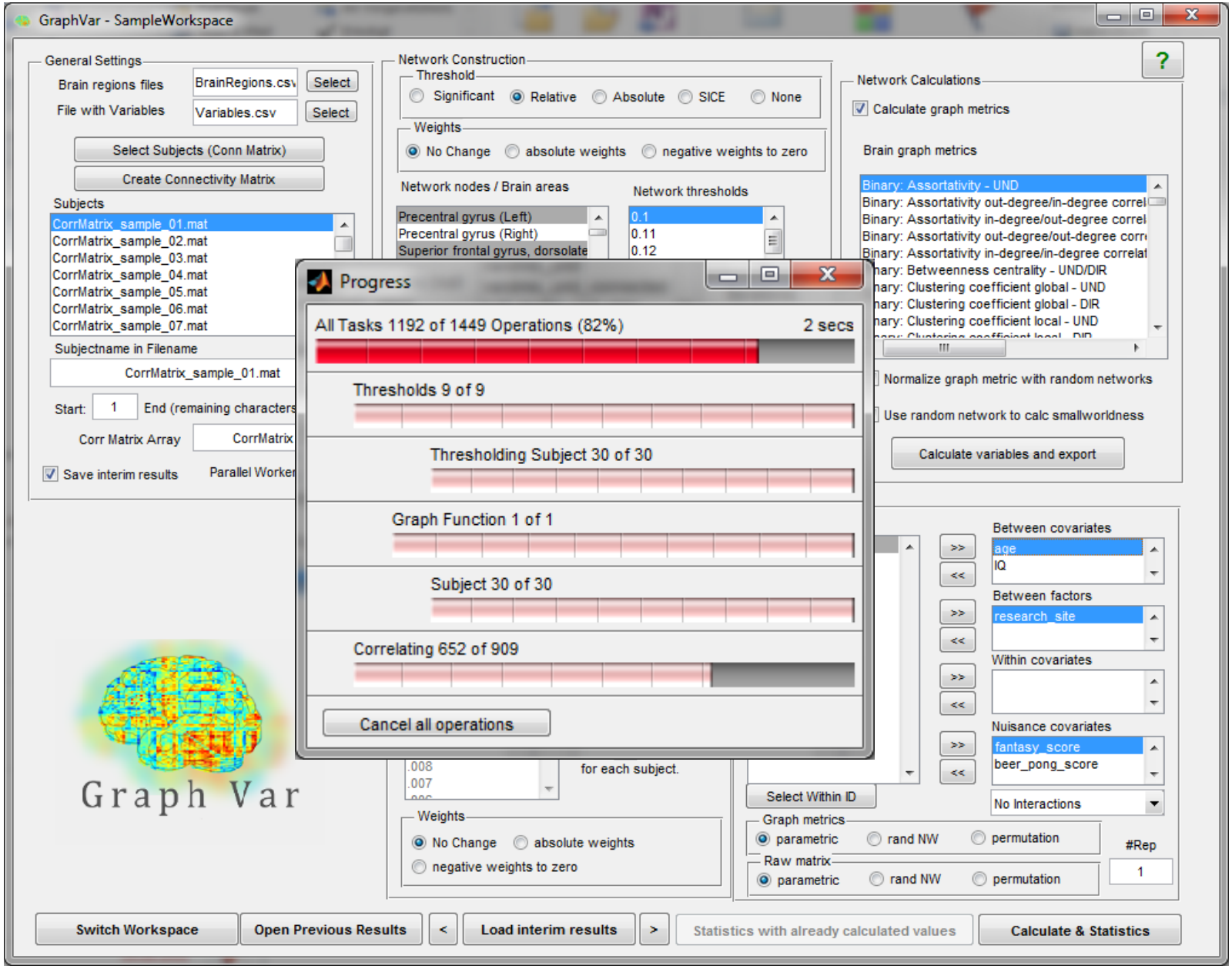
Select dynamic summary measure (graph metrics/raw matrix)



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, 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
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 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
Normalize graph metric with random networks
Use random network to calc smallworldness
Calculate variables and export
Raw Matrix (link wise)
Raw matrix
Connectivity Thr.
.05
.045
.04
.035
.03
.025
.02
.015
.01
.009
.008
.007
r to z
Generate
1
random networks
random_shuffle
c_null_model_und_s
null_model_und_sig
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
Select Within ID
Between covariates
age
IQ
Between factors
research_site
Within covariates
Nuisance covariates
fantasy_score
beer_pong_score
No Interactions
Graph metrics
parametric
rand NW
permutation
Raw matrix
parametric
rand NW
permutation
#Rep
1
Graph Var
Switch Workspace
Open Previous Results
<
Load interim results
>
Statistics with already calculated values
Calculate & Statistics

Ready to go!


GraphVar - SampleWorkspace
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BrainRegions.csv
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File with Variables
Variables.csv
Select
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CorrMatrix_sample_06.mat
CorrMatrix_sample_07.mat
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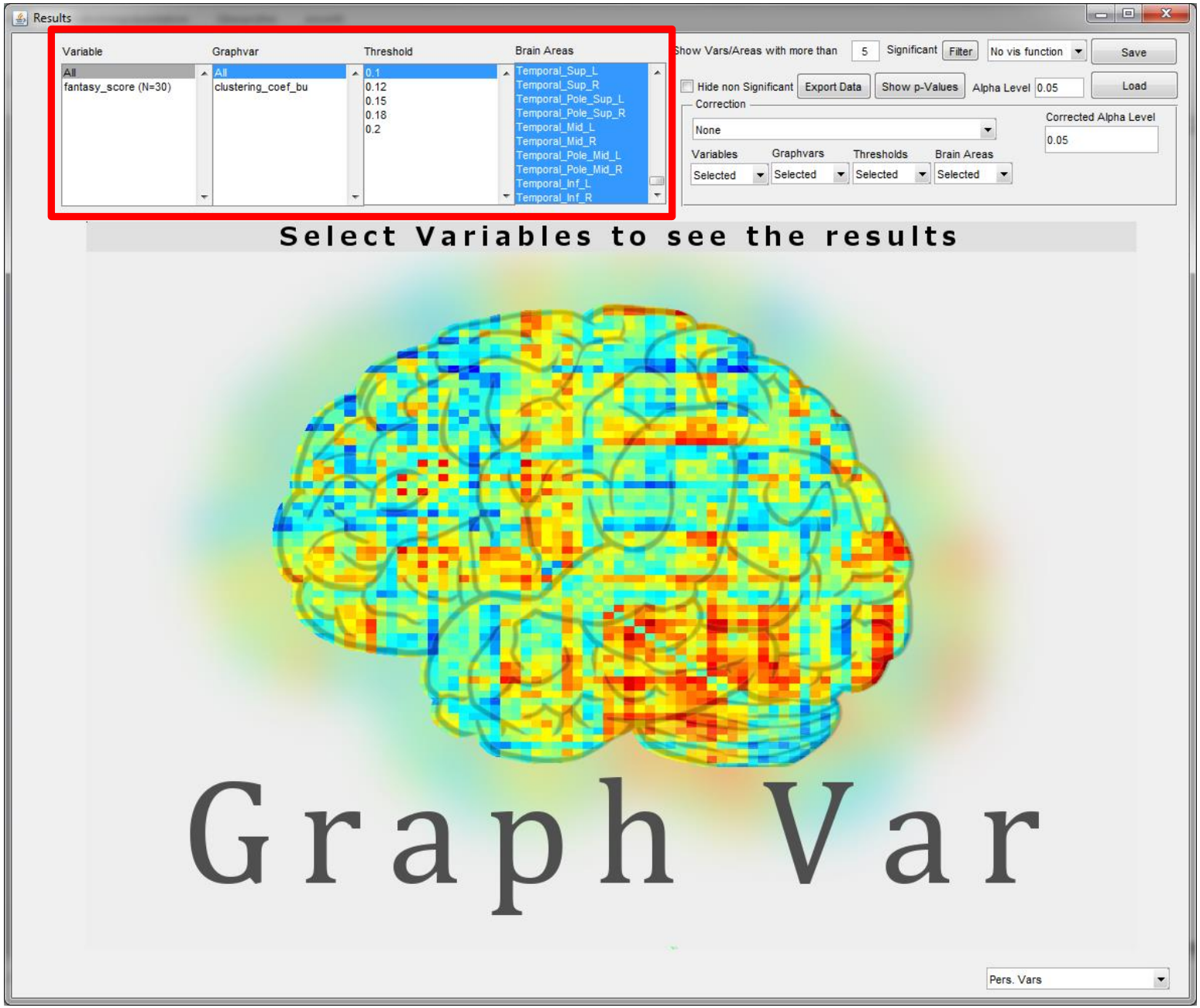
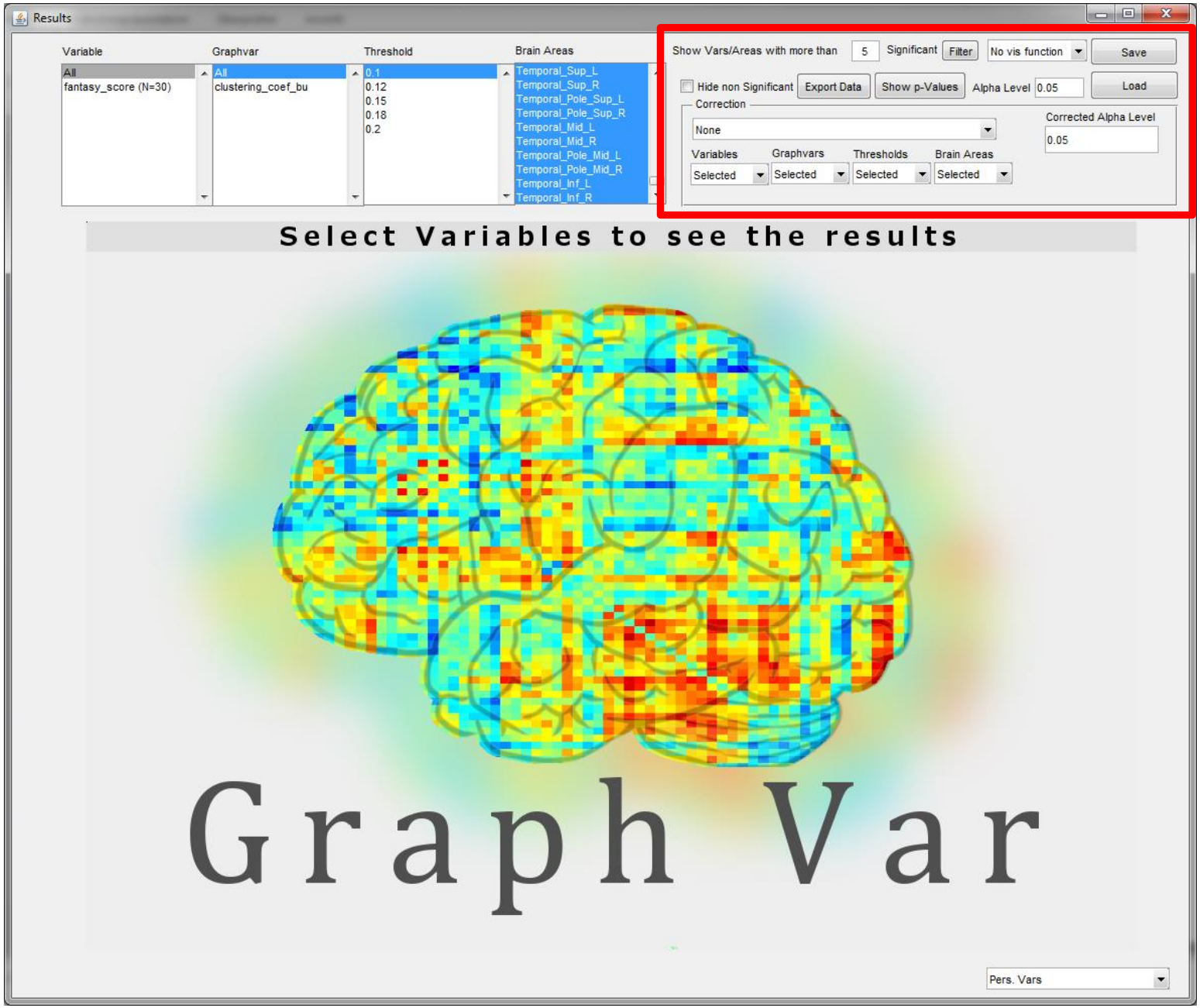
nary: Betweenness centrality - UND/DIR
nary: Clustering coefficient global - UND
nary: Clustering coefficient global - DIR
nary: Clustering coefficient local - UND
Normalize graph metric with random networks
Use random network to calc smallworldness
Calculate variables and export
Progress
All Tasks 1192 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
Between covariates
age
IQ
Between factors
research_site
Within covariates
Nuisance covariates
fantasy_score
beer_pong_score
.008
.007
for each subject.
Select Within ID
No Interactions
Weights
No Change
absolute weights
negative weights to zero
Graph metrics
parametric
rand NW
permutation
Raw matrix
parametric
rand NW
permutation
#Rep
1
Graph Var
Switch Workspace
Open Previous Results
<
Load interim results
>
Statistics with already calculated values
Calculate & Statistics

Status bar

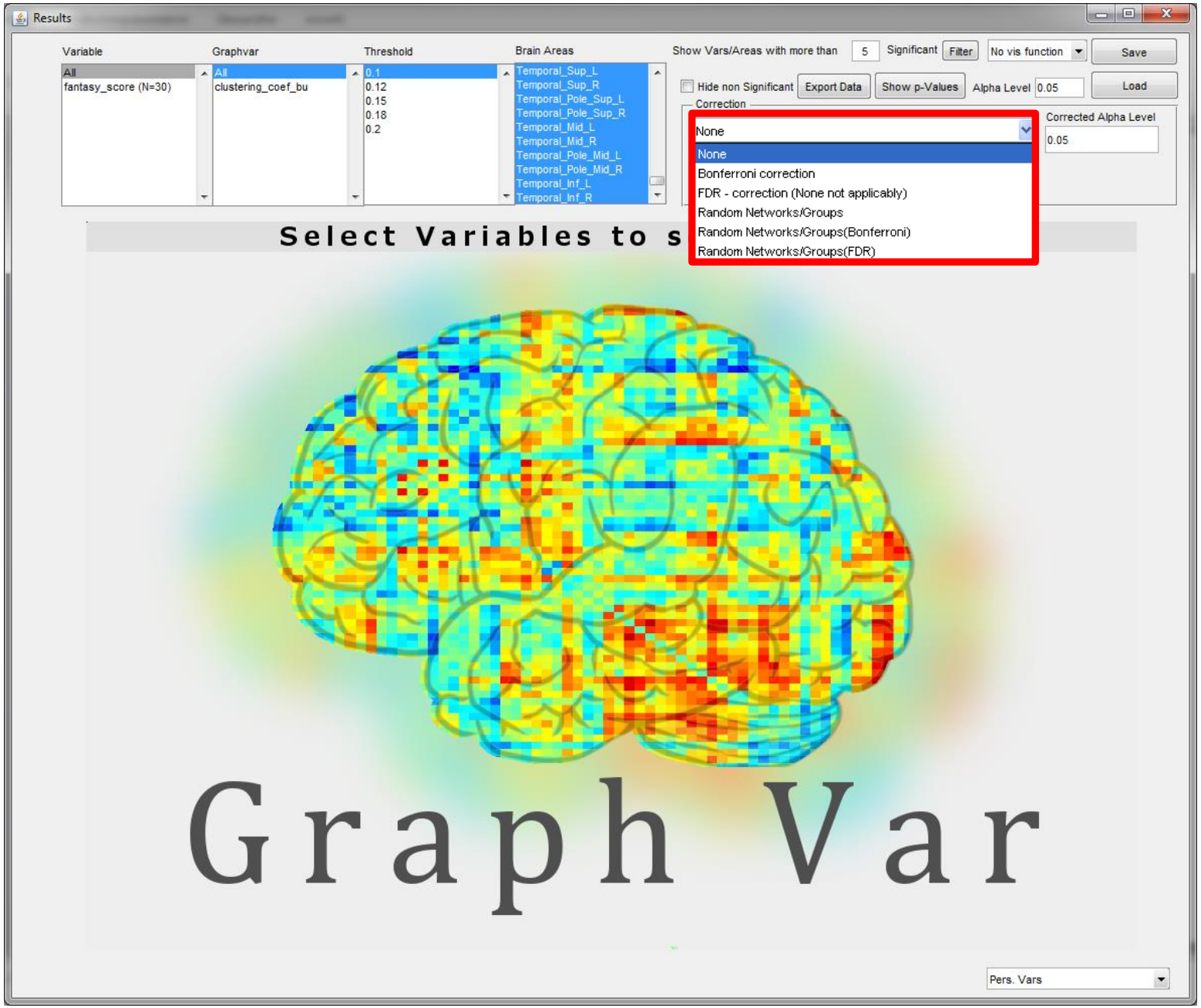
The Results Viewer GUI



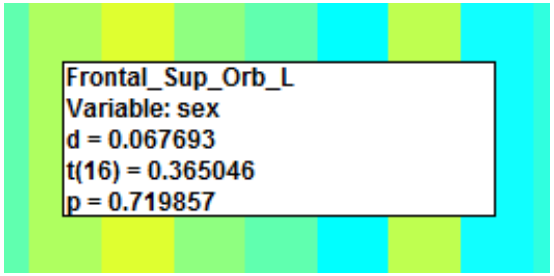
Results selection box

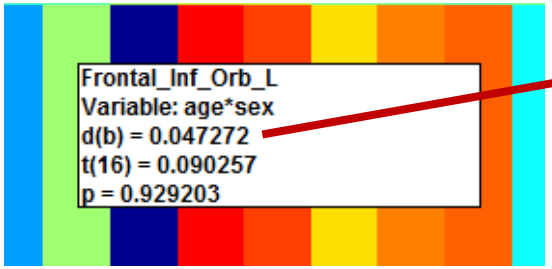


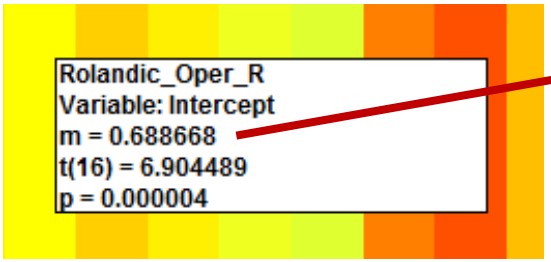
General functions panel



Correction for multiple comparisons







d: Difference between Group Means

F(df1,df2): F-value

d(b): Difference between Standardized Regression Weights

b: Standardized Regression Weight

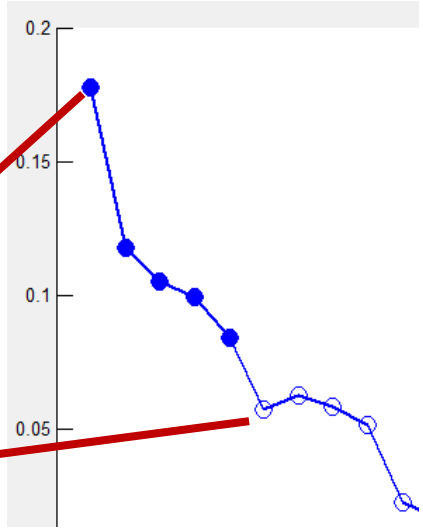
t(df): t-Value

p: p-Value

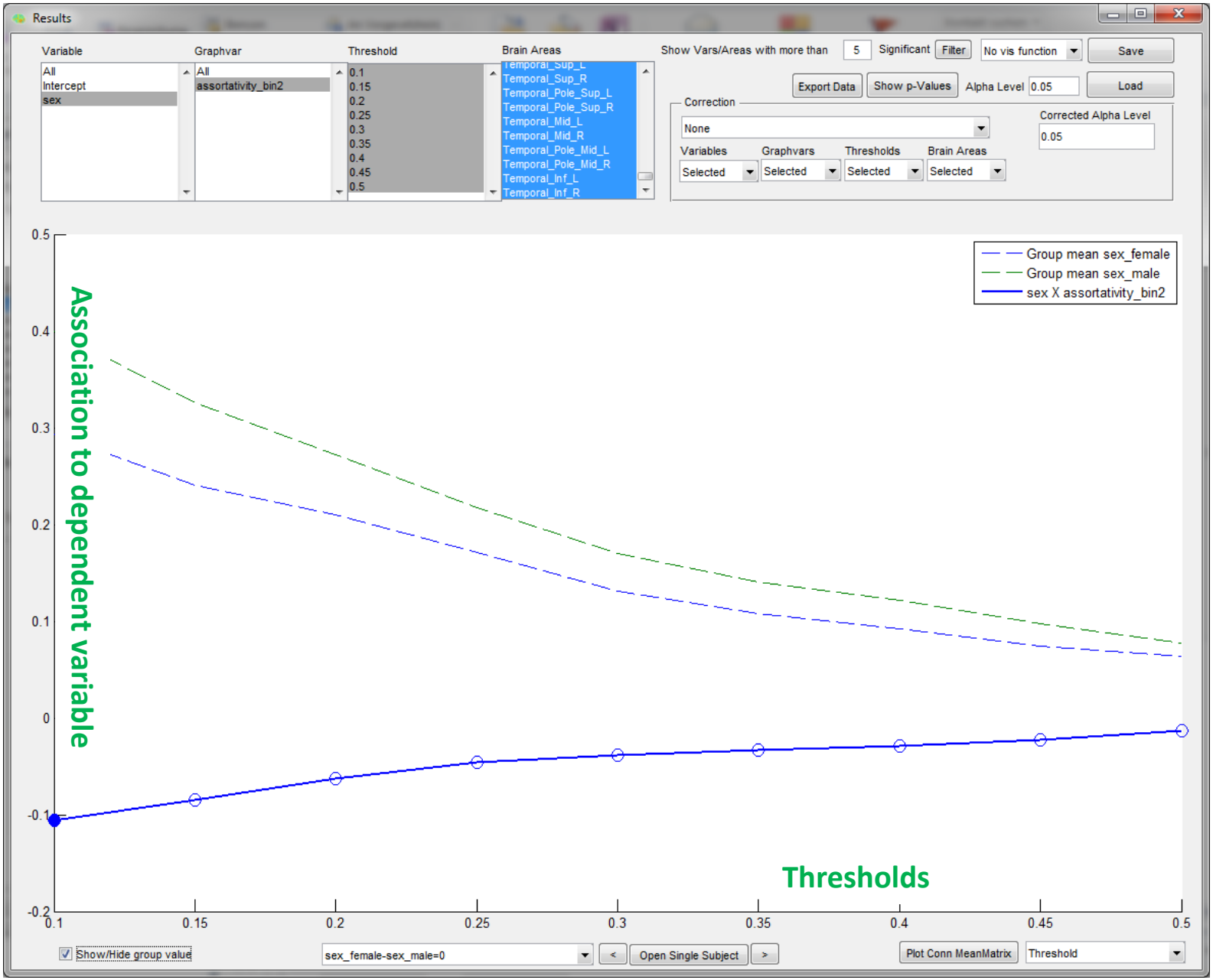
m: Mean

significant

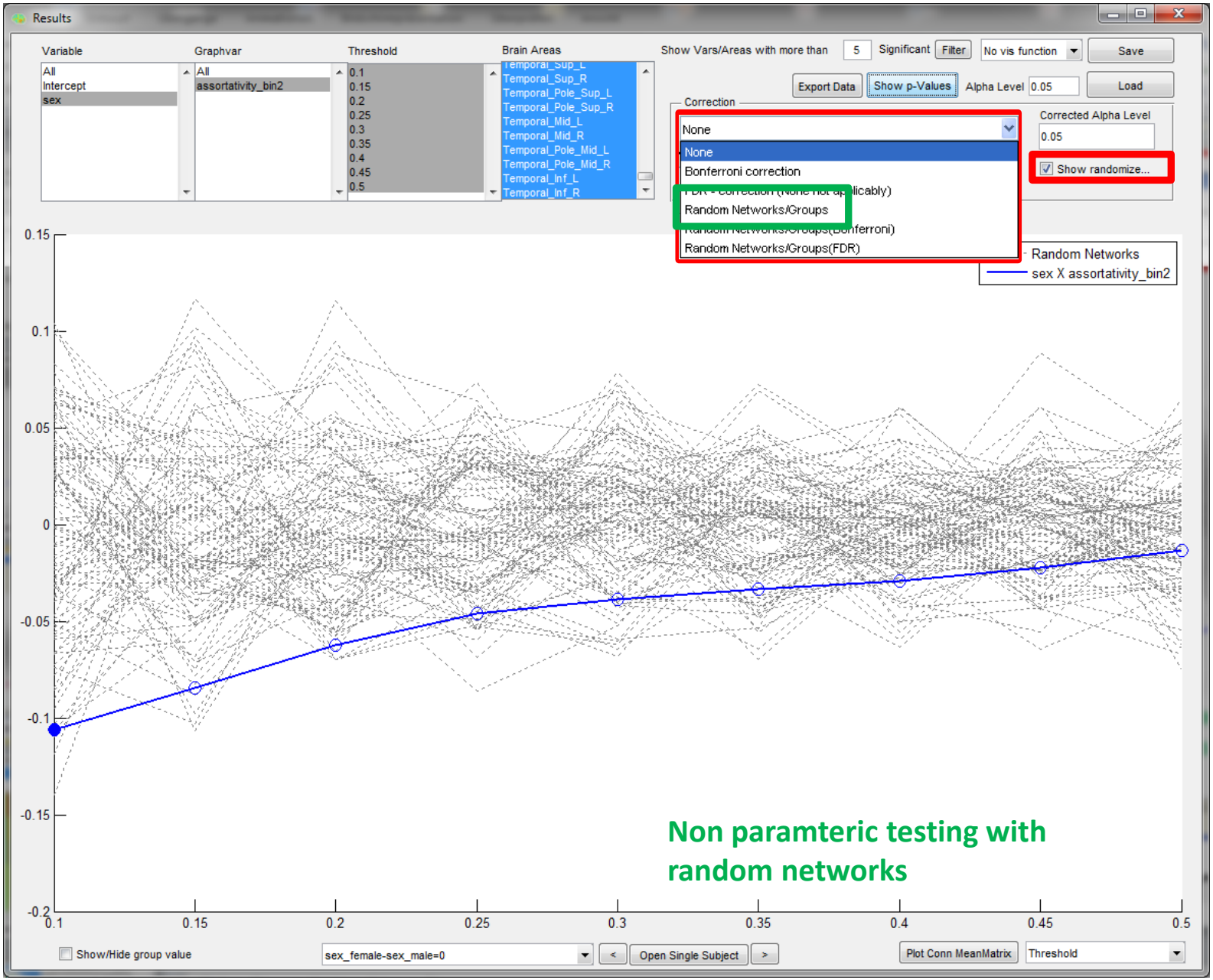
not-significant



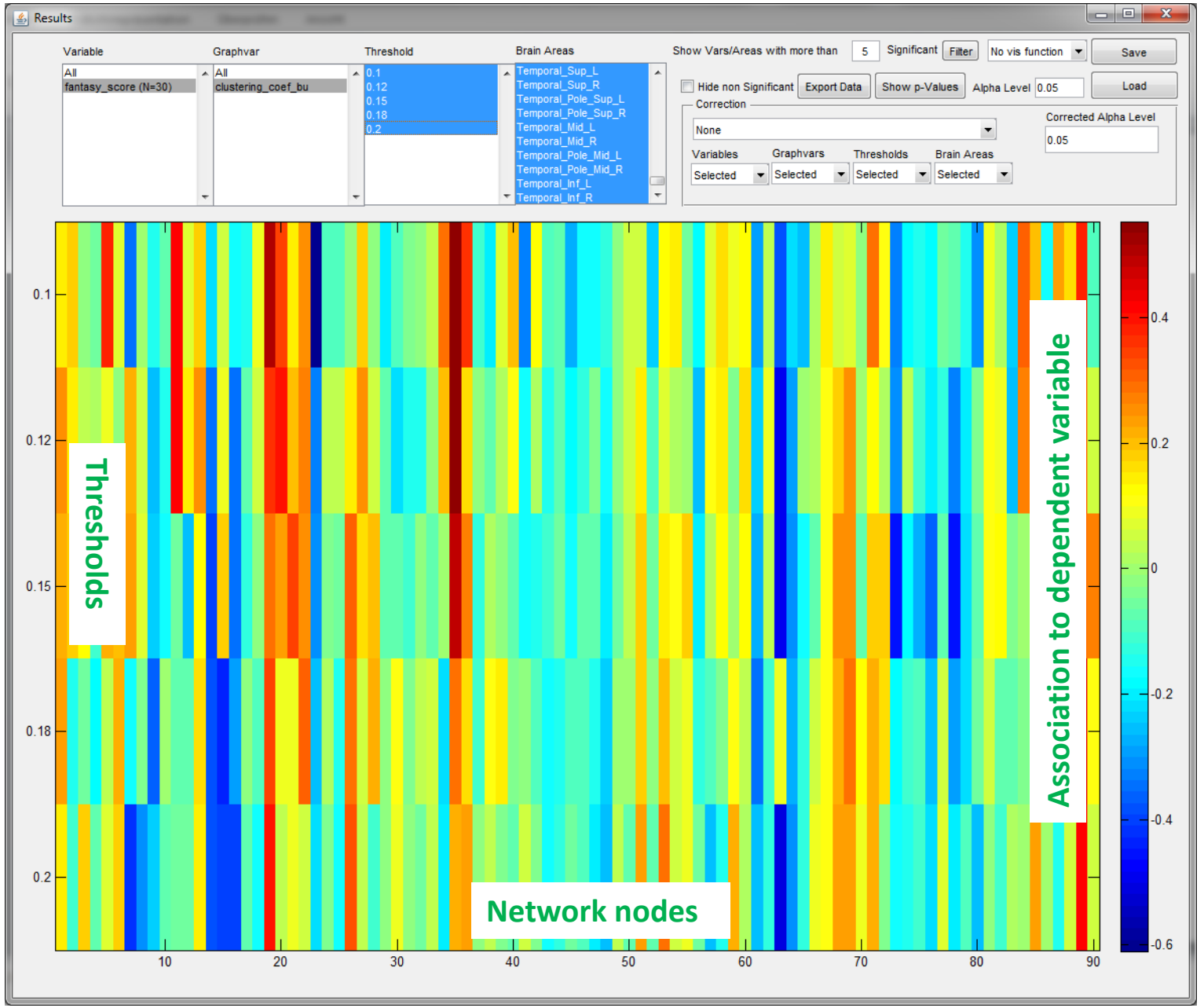
Interpreting GraphVar output



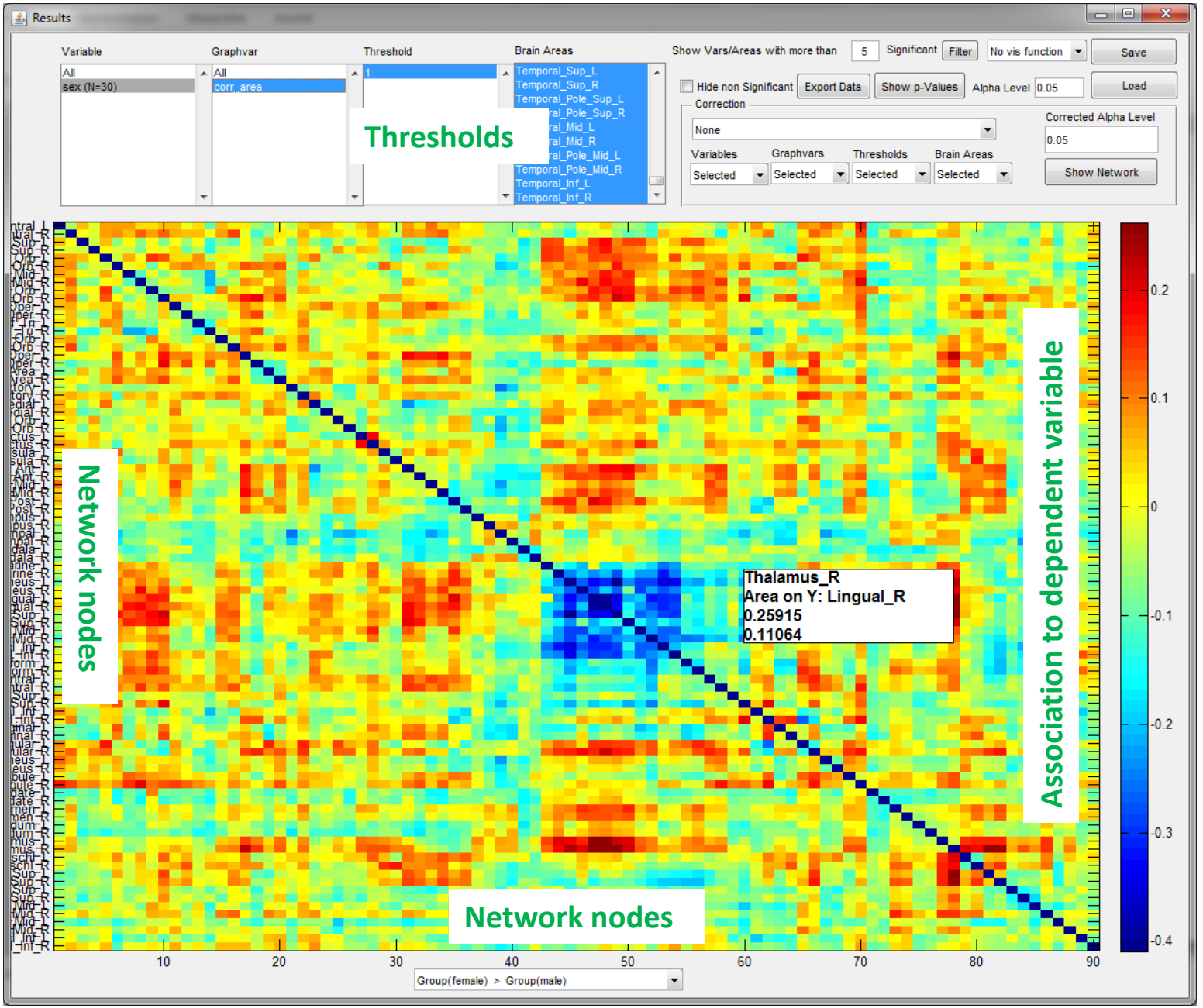
One dimensional graph metrics



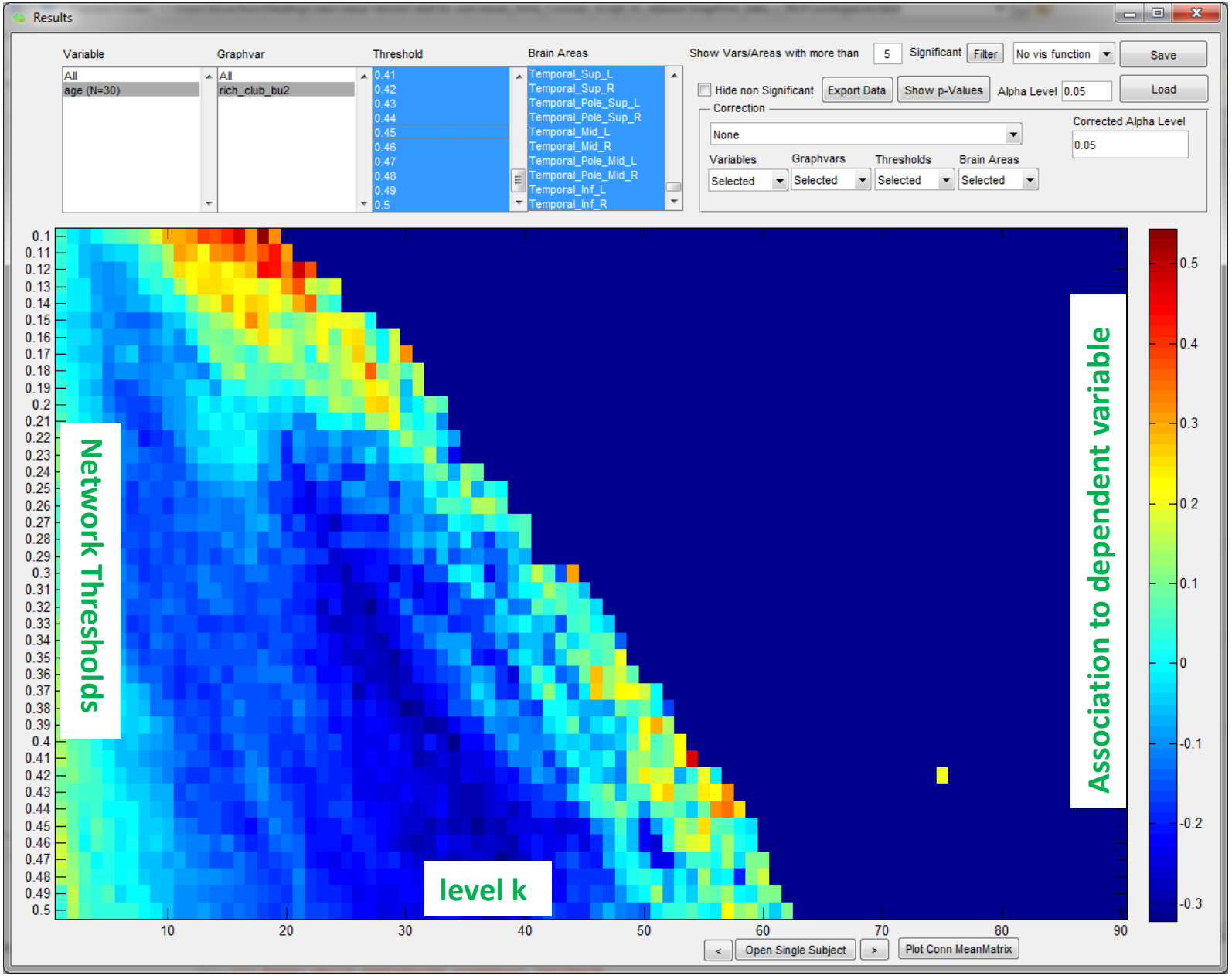
One dimensional graph metrics



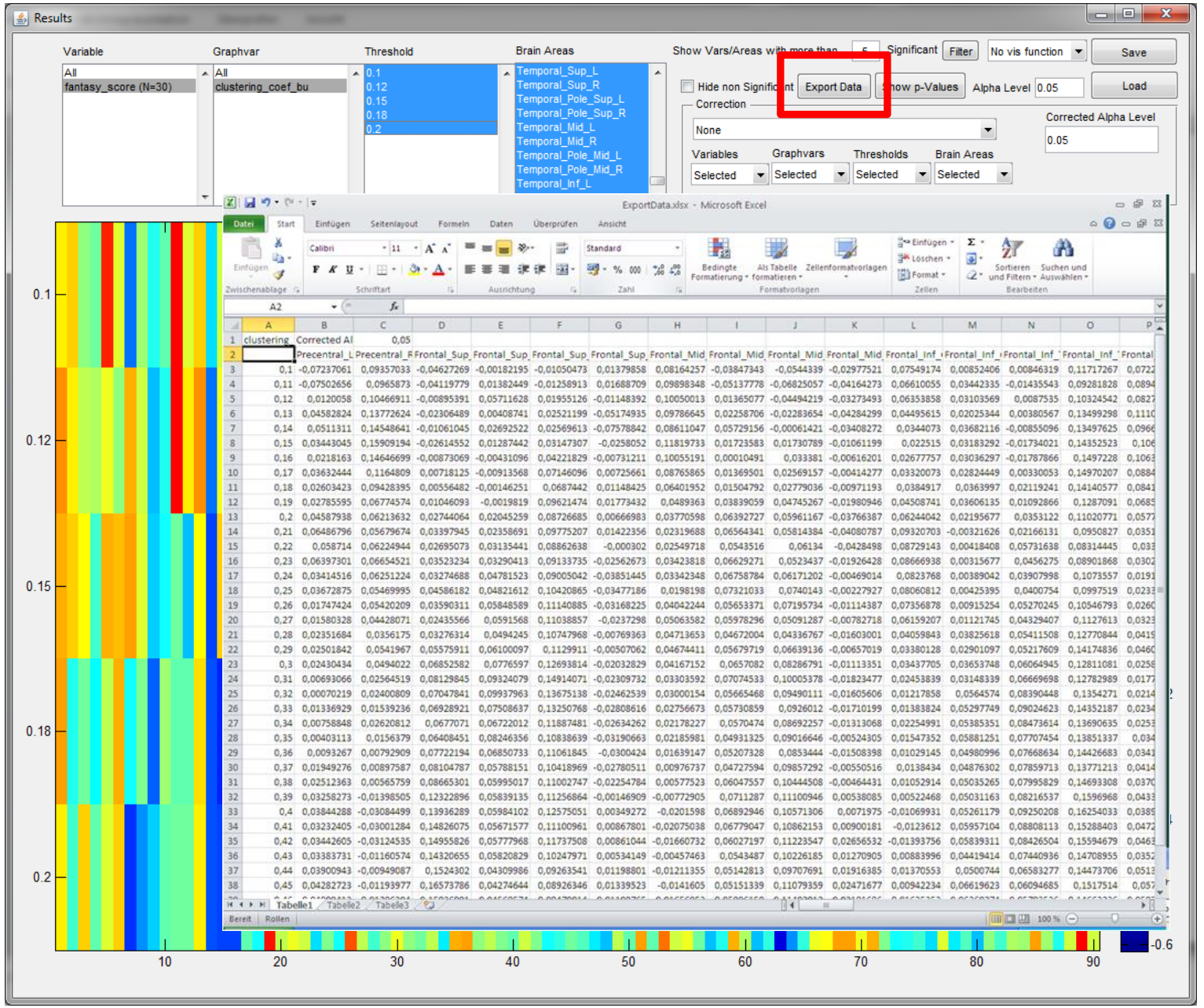
Two dimensional graph metrics



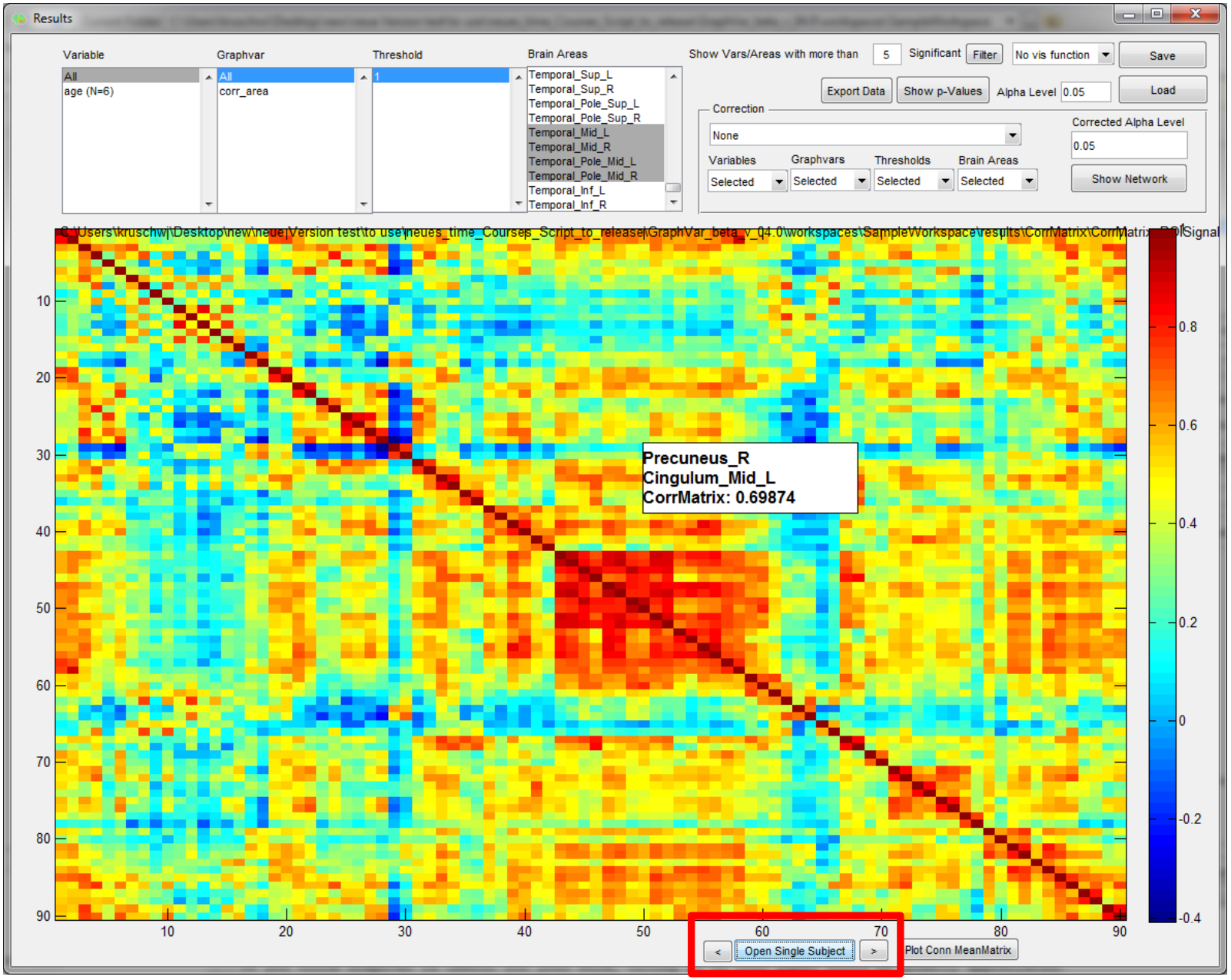
Three dimensional graph metrics



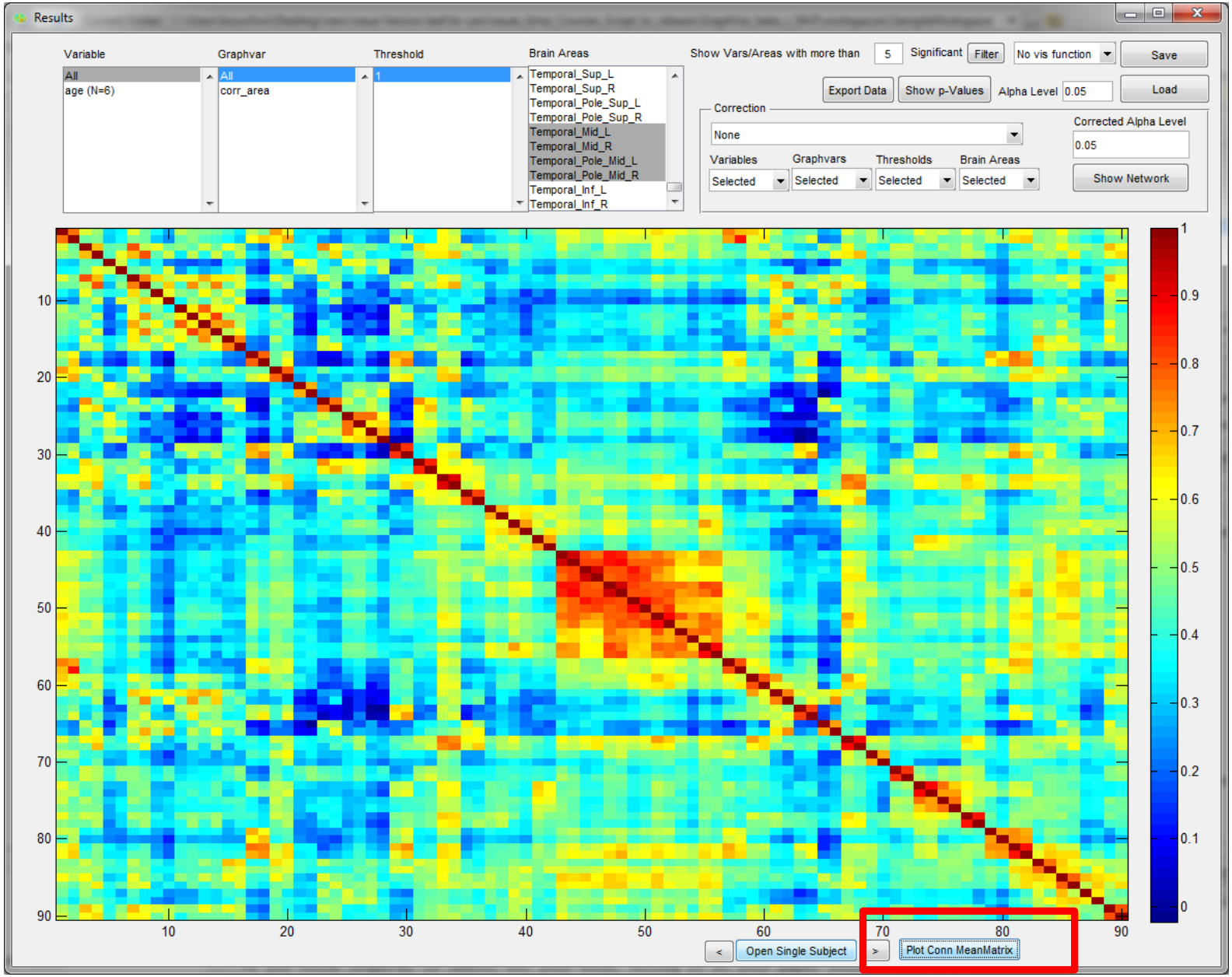
Associations to Rich club coefficients



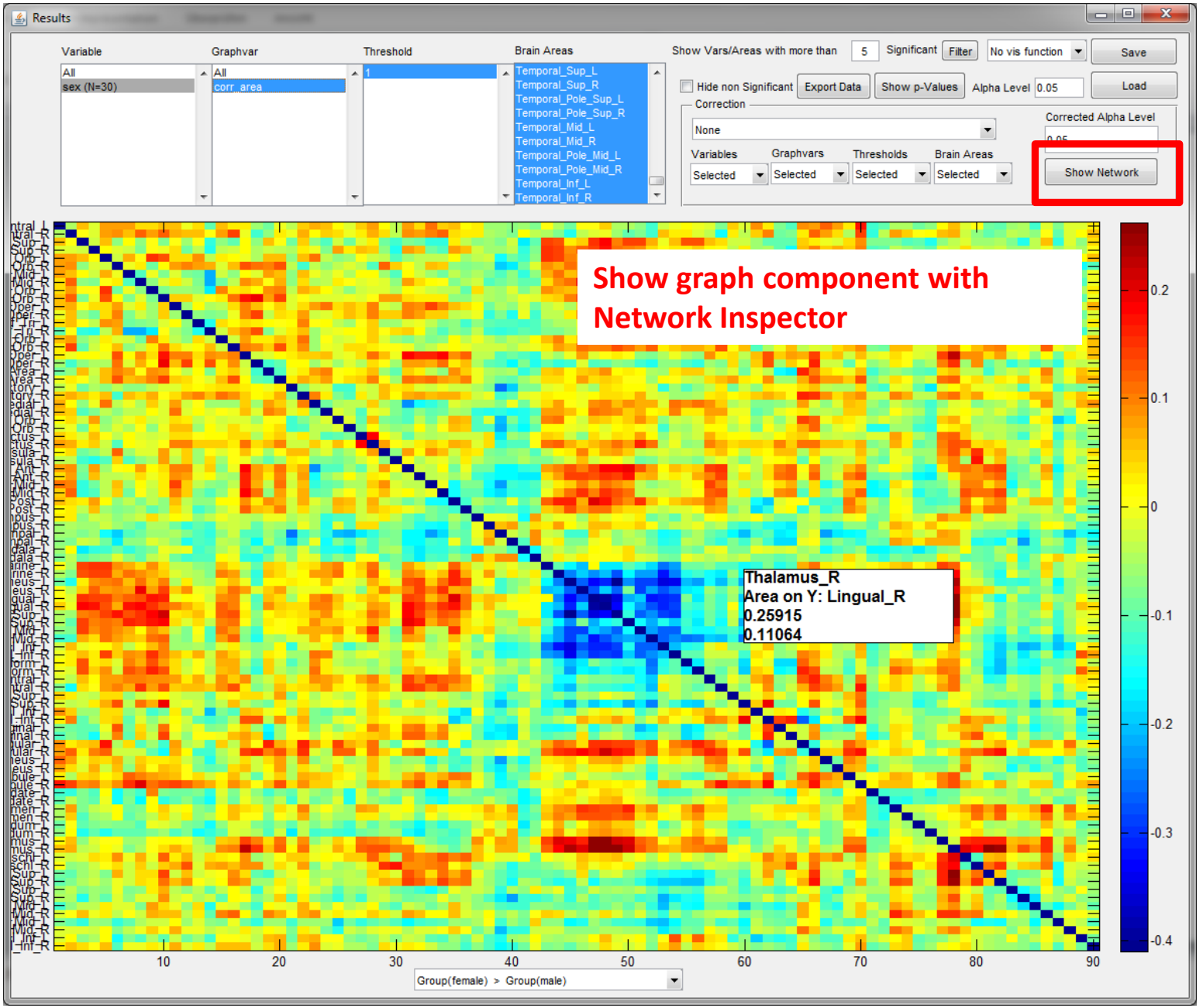
Export Results



Plot single subject association matrices

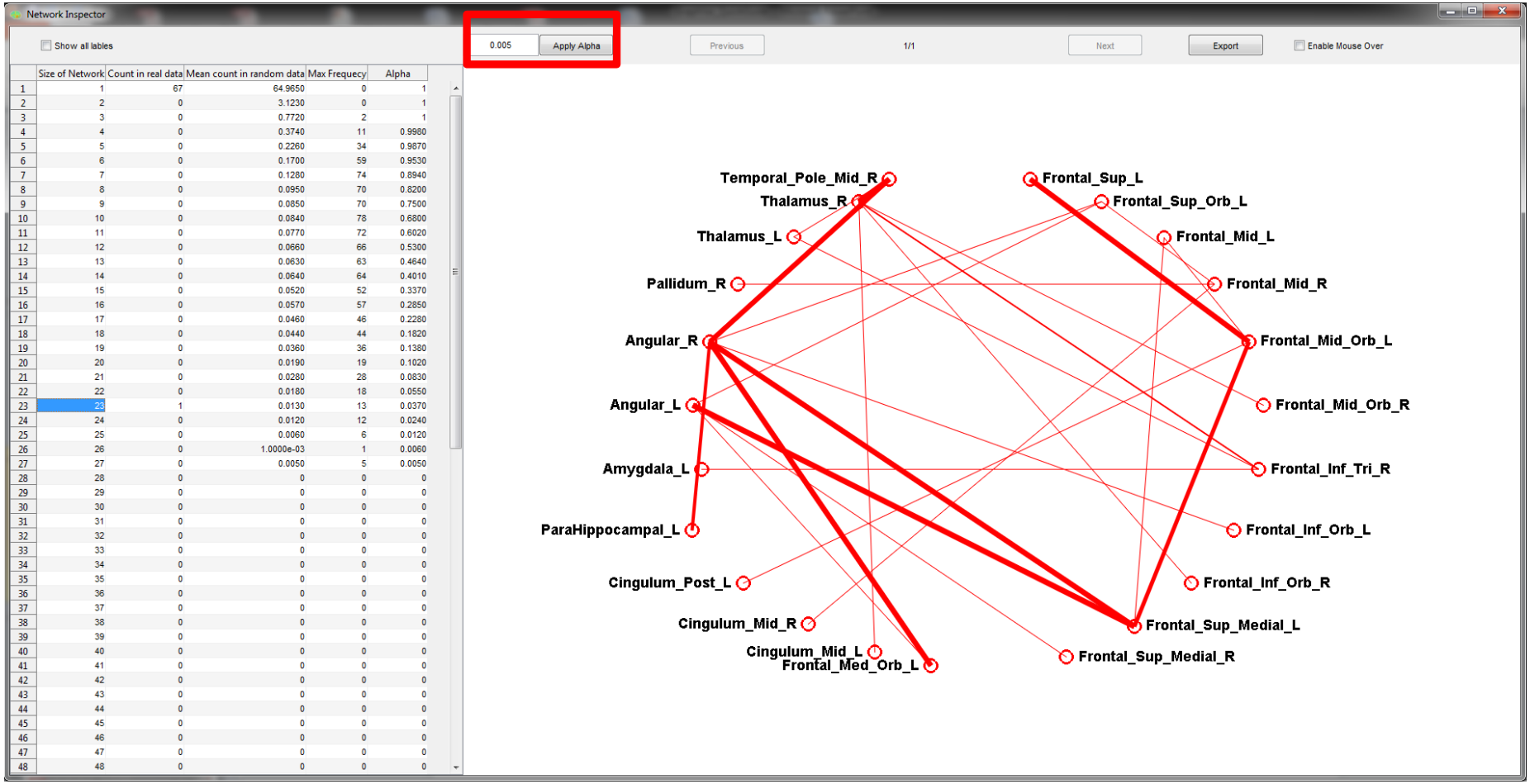


Plot mean connectivity matrix across subjects



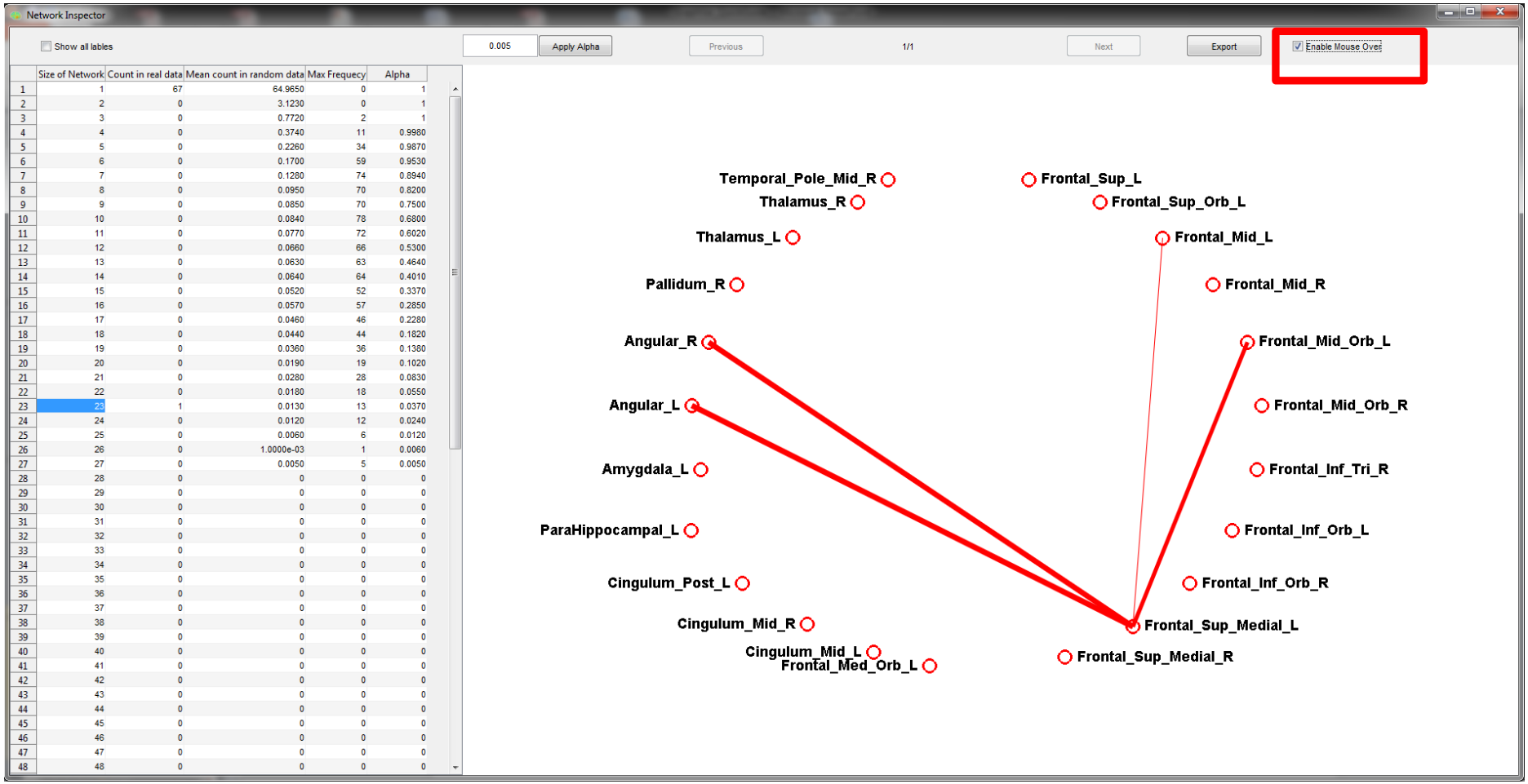
Identify Graph Components

Network Inspector GUI

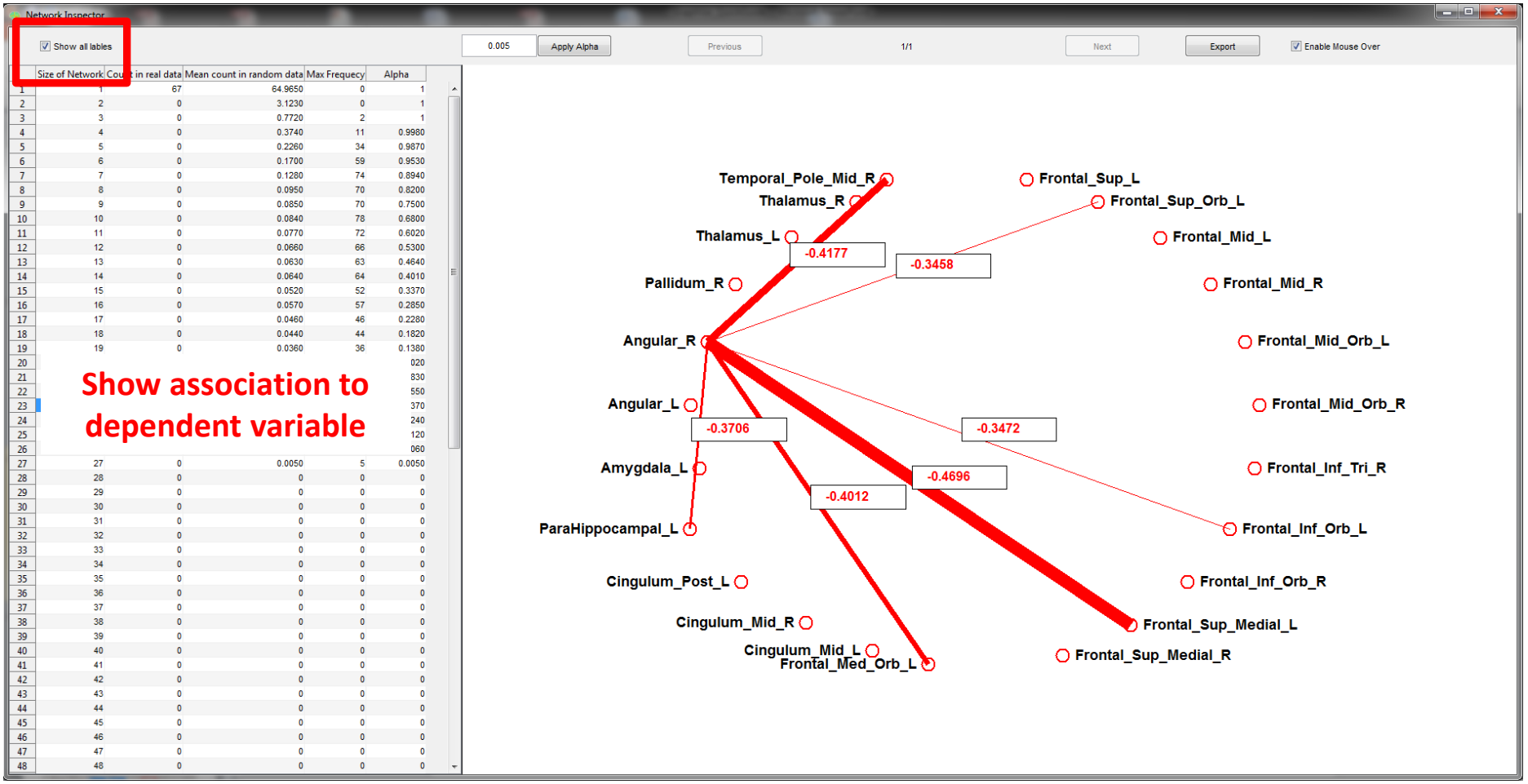


	Size of Network	Count in real data	Mean count in random data	Max Frequecy	Alpha
1	1	67	64.9650	0	1
2	2	0	3.1230	0	1
3	3	0	0.7720	2	1
4	4	0	0.3740	11	0.9980
5	5	0	0.2260	34	0.9870
6	6	0	0.1700	59	0.9530
7	7	0	0.1280	74	0.8940
8	8	0	0.0950	70	0.8200
9	9	0	0.0850	70	0.7500
10	10	0	0.0840	78	0.6800
11	11	0	0.0770	72	0.6020
12	12	0	0.0660	66	0.5300
13	13	0	0.0630	63	0.4640
14	14	0	0.0640	64	0.4010
15	15	0	0.0520	52	0.3370
16	16	0	0.0570	57	0.2850
17	17	0	0.0460	46	0.2280
18	18	0	0.0440	44	0.1820
19	19	0	0.0360	36	0.1380
20	20	0	0.0190	19	0.1020
21	21	0	0.0280	28	0.0830
22	22	0	0.0180	18	0.0550
23	23	1	0.0130	13	0.0370
24	24	0	0.0120	12	0.0240
25	25	0	0.0060	6	0.0120
26	26	0	1.0000e-03	1	0.0060
27	27	0	0.0050	5	0.0050
28	28	0	0	0	0
29	29	0	0	0	0
30	30	0	0	0	0
31	31	0	0	0	0
32	32	0	0	0	0
33	33	0	0	0	0
34	34	0	0	0	0
35	35	0	0	0	0
36	36	0	0	0	0
37	37	0	0	0	0
38	38	0	0	0	0
39	39	0	0	0	0
40	40	0	0	0	0
41	41	0	0	0	0
42	42	0	0	0	0
43	43	0	0	0	0
44	44	0	0	0	0
45	45	0	0	0	0
46	46	0	0	0	0
47	47	0	0	0	0
48	48	0	0	0	0

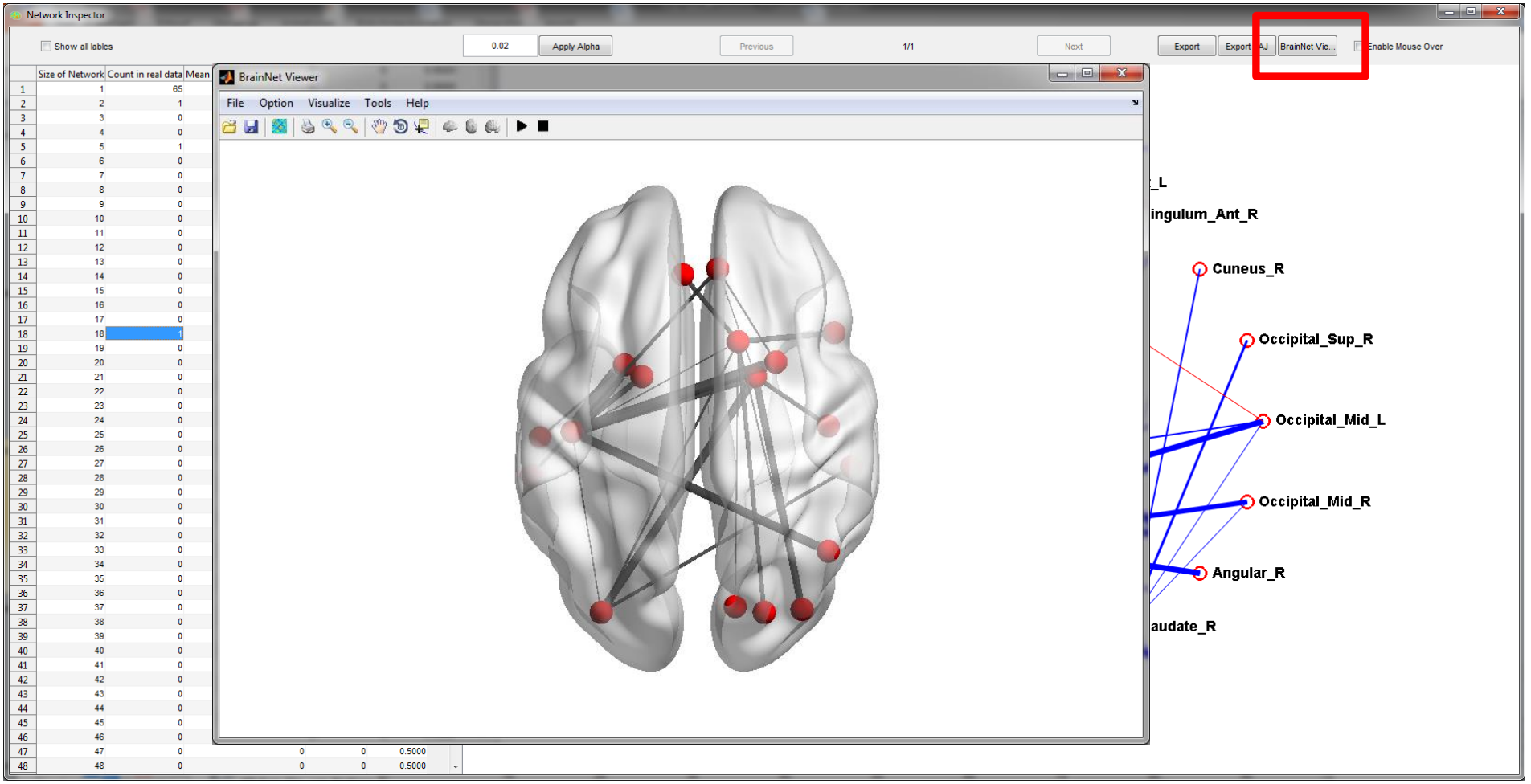
Identify Graph Components


Network Inspector
Show all lables
0.005
Apply Alpha
Previous
1/1
Next
Export
Enable Mouse Over
Size of Network
Count in real data
Mean count in random data
Max Frequecy
Alpha
Temporal_Pole_Mid_R
Thalamus_R
Thalamus_L
Pallidum_R
Angular_R
Angular_L
Amygdala_L
ParaHippocampal_L
Cingulum_Post_L
Cingulum_Mid_R
Cingulum_Mid_L
Frontal_Med_Orb_L
Frontal_Sup_L
Frontal_Sup_Orb_L
Frontal_Mid_L
Frontal_Mid_R
Frontal_Mid_Orb_L
Frontal_Mid_Orb_R
Frontal_Inf_Tri_R
Frontal_Inf_Orb_L
Frontal_Inf_Orb_R
Frontal_Sup_Medial_L
Frontal_Sup_Medial_R

Mouse over



Show association strenght



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

GraphVar -Team