

## Dynamic features (and others) tutorial

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: 12 End (remaining characters): 4

Corr Matrix Array: CorrMatrix

Save interim results Parallel Workers: 0

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

Network Construction

Threshold:  Significant  Relative  Absolute  SICE  None

Weights:  No Change  absolute weights  negative weights to zero

Network nodes / Brain areas	Network thresholds
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

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
- Binary: Community structure Louvain - modularity

Weights:  No Change  absolute weights  negative weights to zero

Test against shuffled data Number of repetitions: 1

Test against random networks (graph metrics)

Test against random networks (raw matrix)

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

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

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

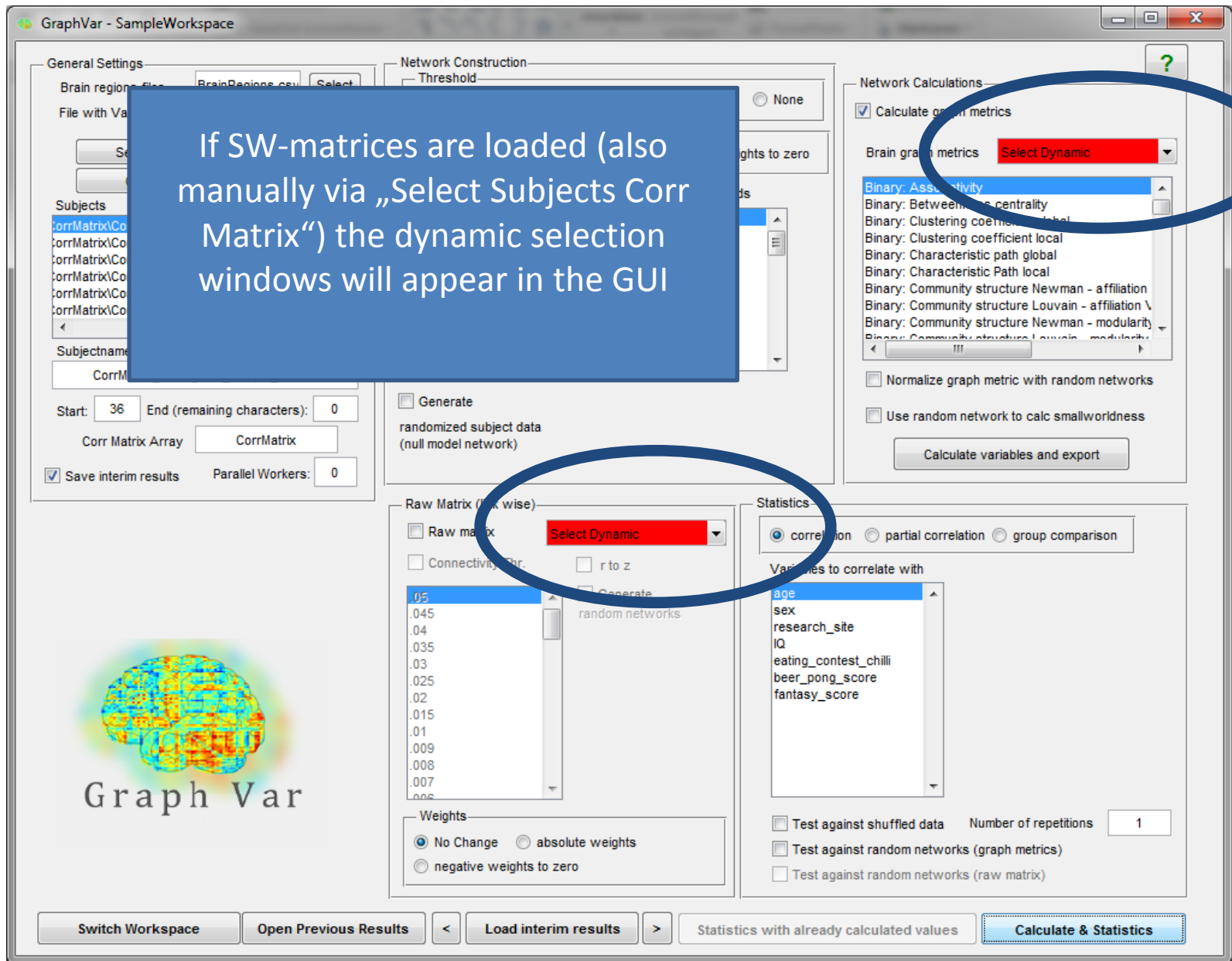
Create Connectivity matrix -> **sliding windows**

The screenshot displays the GraphVar software interface with several panels:

- General Settings:** Includes fields for 'Brain regions files' (BrainRegions.csv) and 'File with Variables' (Variables.csv). A 'Create Connectivity Matrix' button is highlighted with a blue circle.
- Subjects:** A list of subject files is shown, including 'CorrMatrix\CorrMatrix\_ROISignals\_sample\_01.mat' through 'sample\_06.mat'. This list is highlighted with a blue circle.
- Network Construction:** Features a 'Threshold' section with radio buttons for 'Significant', 'Relative' (selected), 'Absolute', 'SICE', and 'None'. It also includes 'Weights' and 'Network no.' options.
- Network Calculations:** Includes a checked 'Calculate graph metrics' option and a 'Calculate variables and export' button.
- Raw Matrix (link wise):** Contains a 'Raw matrix' section with a 'Select Dynamic' dropdown, a 'Connectivity Thr.' list (0.05 to 0.005), and 'Weights' options (No Change selected, absolute weights, negative weights to zero).
- Statistics:** Includes radio buttons for 'correlation' (selected), 'partial correlation', and 'group comparison'. A list of 'Variables to correlate with' includes 'age', 'sex', 'research\_site', 'IQ', 'eating\_contest\_chilli', 'beer\_pong\_score', and 'fantasy\_score'. It also has options for testing against shuffled data and random networks.

A blue text box is overlaid on the interface, containing the text: "SW Matrices are stored (as usual) in your workspace/results/CorrMatrix and are loaded automatically in the subject list".

GraphVar loads SW-matrices in the subject list



Select dynamic summary measure (graph metrics/raw matrix)

The screenshot shows the GraphVar software interface. A blue overlay box in the center contains the following text:

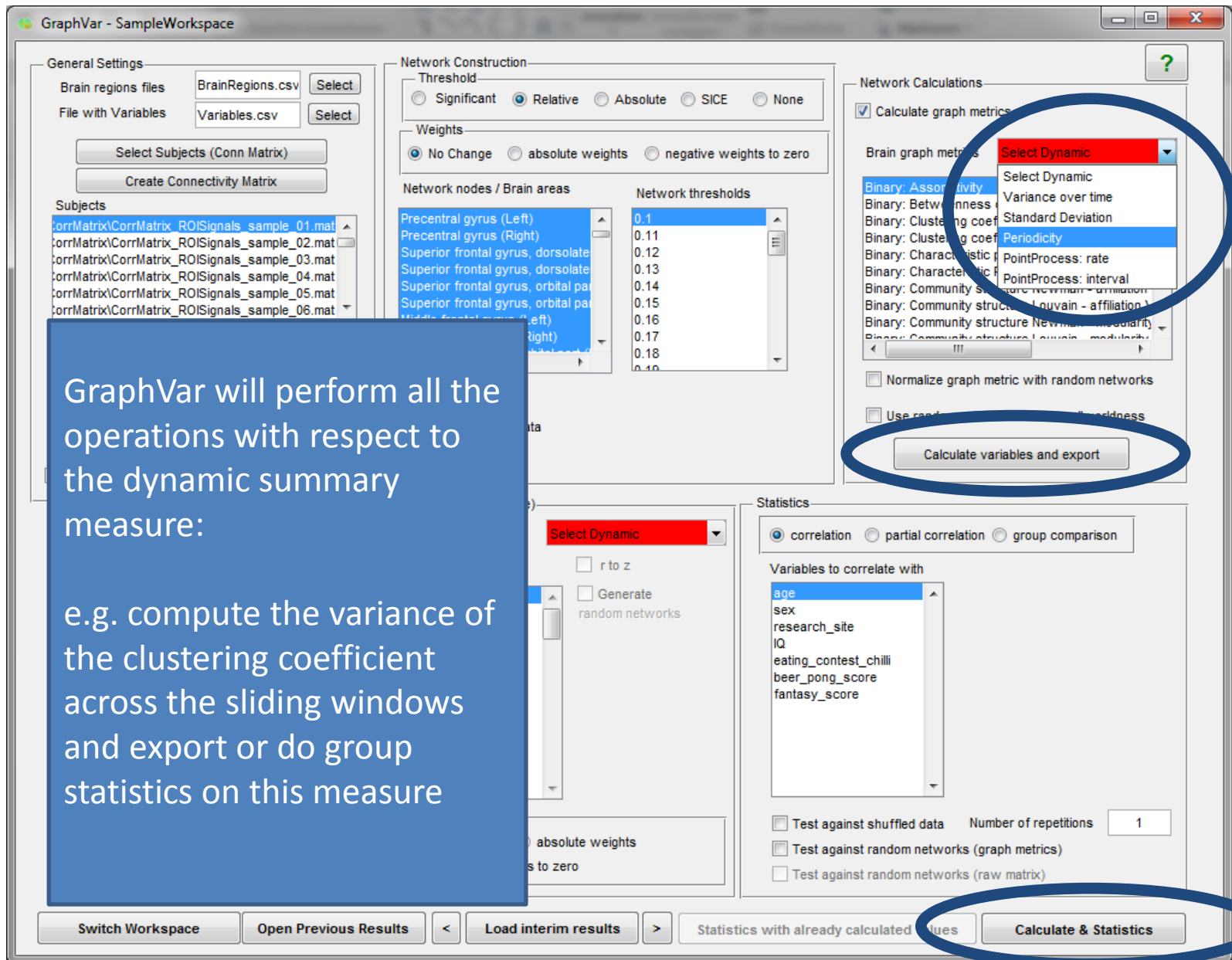
**Dynamic summary measures\*:**

- Variance
- Standard deviation
- Periodicity
- PointProcess: rate
- PointProcess: interval

\* definition at the end of document

The interface includes sections for General Settings, Network Construction, Network Calculations, and Statistics. The Network Calculations section has a dropdown menu for 'Brain graph metrics' with 'Select Dynamic' selected. The Statistics section has radio buttons for 'correlation', 'partial correlation', and 'group comparison', with 'correlation' selected. The 'Variables to correlate with' list includes 'age', 'sex', 'research\_site', 'IQ', 'eating\_contest\_chilli', 'beer\_pong\_score', and 'fantasy\_score'.

Select dynamic summary measure (graph metrics/raw matrix)



Select dynamic summary measure (graph metrics/raw matrix)

GraphVar - SampleWorkspace

General Settings

Brain

File w

Subject

CorrMat

CorrMat

CorrMat

CorrMat

CorrMat

CorrMat

Subject

Start:

Co

Save

Network Construction

Network Calculations

Calculate graph metrics

graph metrics

Select Dynamic

Select Dynamic

Variance over time

Standard Deviation

Periodicity

PointProcess: rate

PointProcess: interval

Community structure Newman - affiliation

Community structure Louvain - affiliation

Community structure Newman - modularity

Community structure Louvain - modularity

ELSEVIER

### NeuroImage

Volume 107, 15 February 2015, Pages 345–355

## Assessing dynamic brain graphs of time-varying connectivity in fMRI data: Application to healthy controls and patients with schizophrenia

Qingbao Yu<sup>a</sup>, Erik B. Erhardt<sup>b</sup>, Jing Sui<sup>a, c</sup>, Yuhui Du<sup>a, d</sup>, Hao He<sup>a, e</sup>, Devon Hjelm<sup>a, f</sup>, Mustafa S. Cetin<sup>a, f</sup>, Srinivas Rachakonda<sup>a</sup>, Robyn L. Miller<sup>a</sup>, Godfrey Pearson<sup>g, h, i</sup>, Vince D. Calhoun<sup>a, e, g, h</sup>

[Show more](#)

Weights

No Change  absolute weights  negative weights to zero

Test against shuffled data Number of repetitions 1

Test against random networks (graph metrics)

Test against random networks (raw matrix)

Switch Workspace

Open Previous Results

< Load interim results >

Statistics with already calculated values

**Calculate & Statistics**

A recent paper that showed differences in variance in Clustering Coefficient and Global Efficiency between schizophrenia patients and controls (here we got the idea from)

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):

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

Network Calculations  
 Calculate graph metrics  
 Brain graph metrics: Select Dynamic  
 Binary: Assortativity  
 Binary: Betweenness centrality  
 Binary: Clustering coefficient global  
 Binary: Clustering coefficient local

Apply these dynamic summary measures also to the raw matrices (in a way similar to the „DynamicBC“ toolbox)

DynamicBC Version 1.1(kruschwi)

Dynamic Brain Connectome Analysis Toolbox  
**DynamicBC**  
 Center for Cognition and Brain Disorders, Hangzhou Normal University

Dynamic FC  
 Dynamic EC

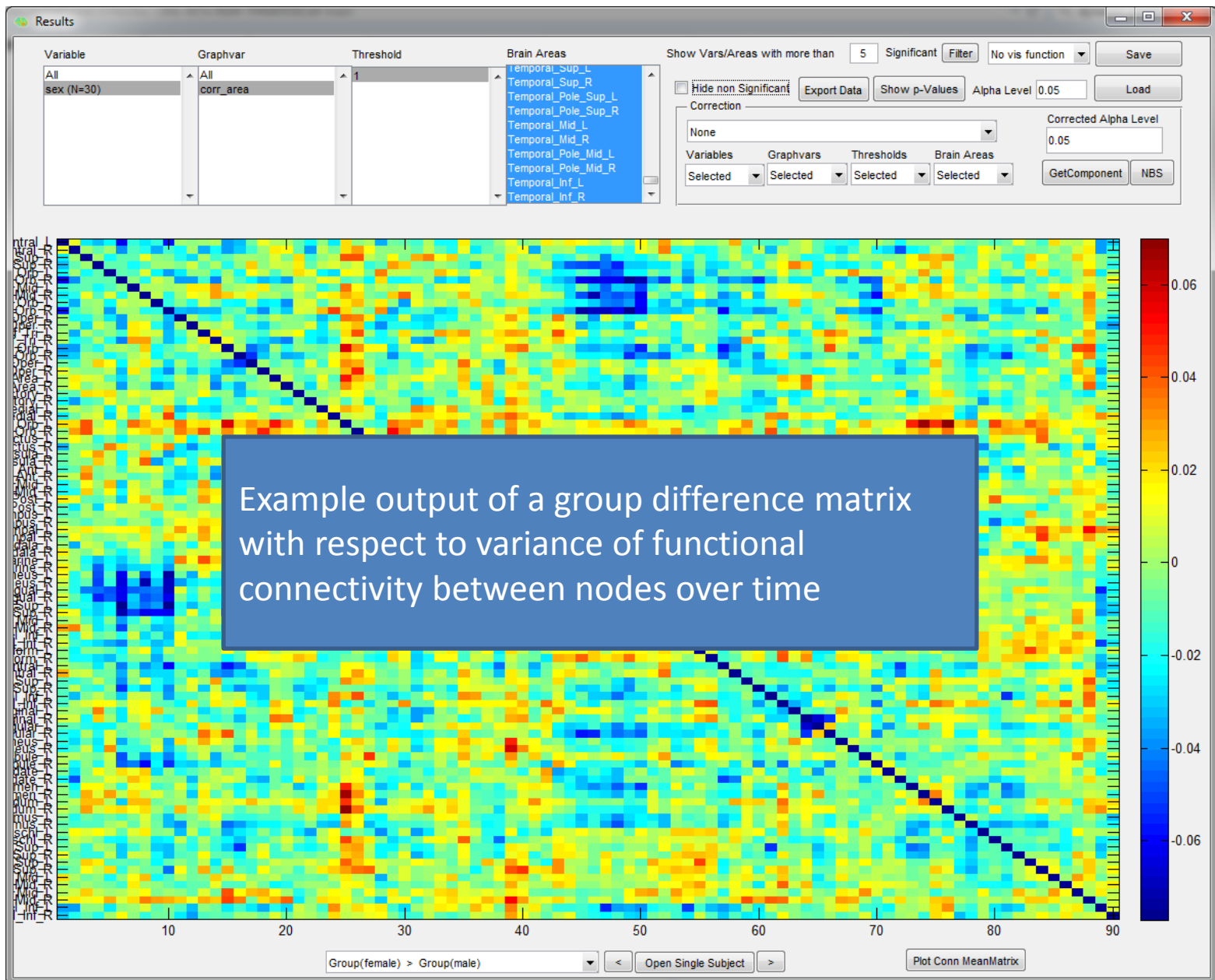
Matrix (link wise)  
 Raw matrix: Select Dynamic  
 Connectivity matrix: Select Dynamic  
 Variance over time  
 Standard Deviation  
 Periodicity  
 PointProcess: rate  
 PointProcess: interval

Statistics  
 correlation  partial correlation  group comparison  
 Variables to correlate with  
 Test against shuffled data: Number of repetitions: 1  
 Test against random networks (graph metrics)  
 Test against random networks (raw matrix)

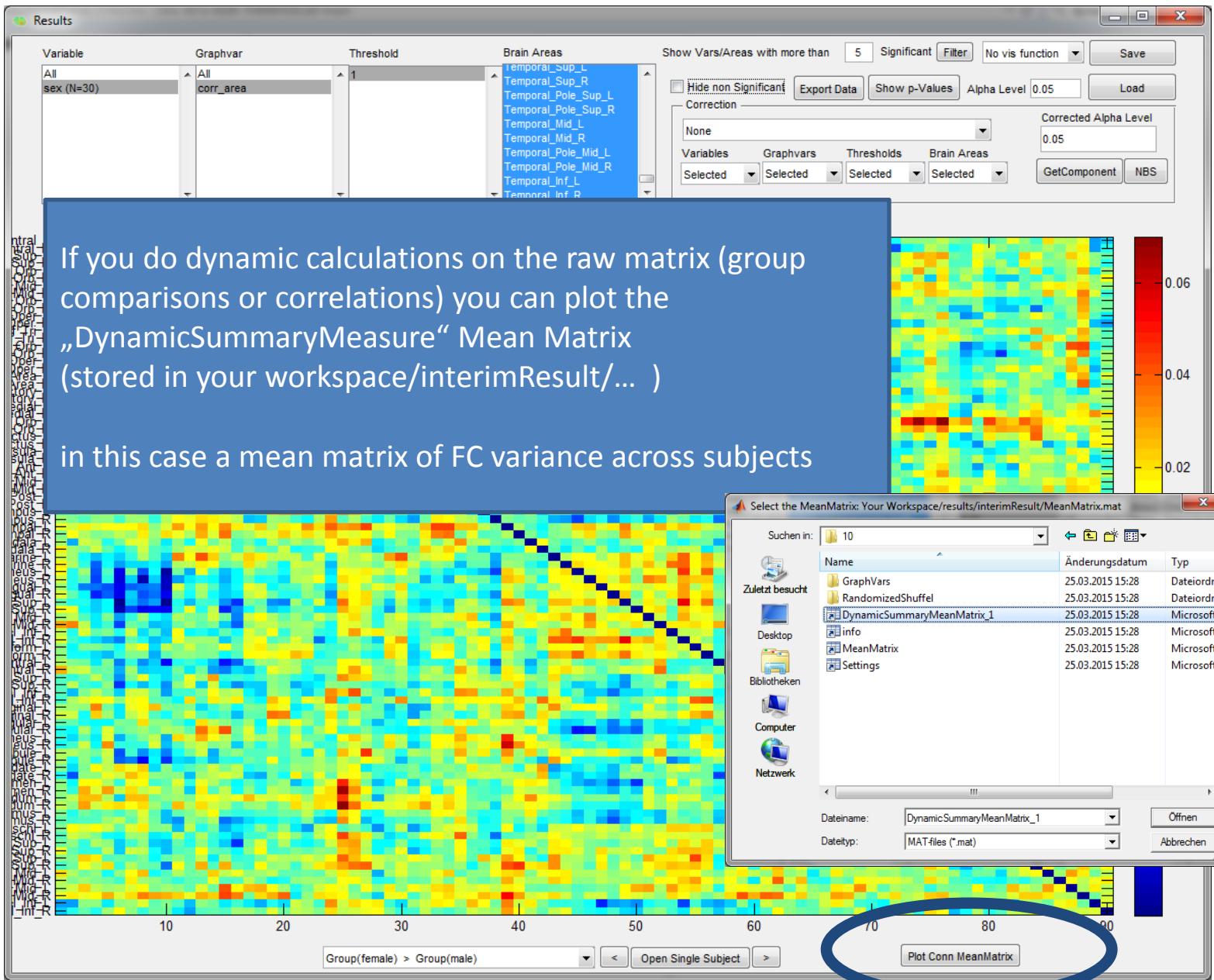
Switch Workspace Open Previous Results Load interim results Statistics with already calculated values Calculate & Statistics

Select dynamic summary measure (graph metrics/raw matrix)





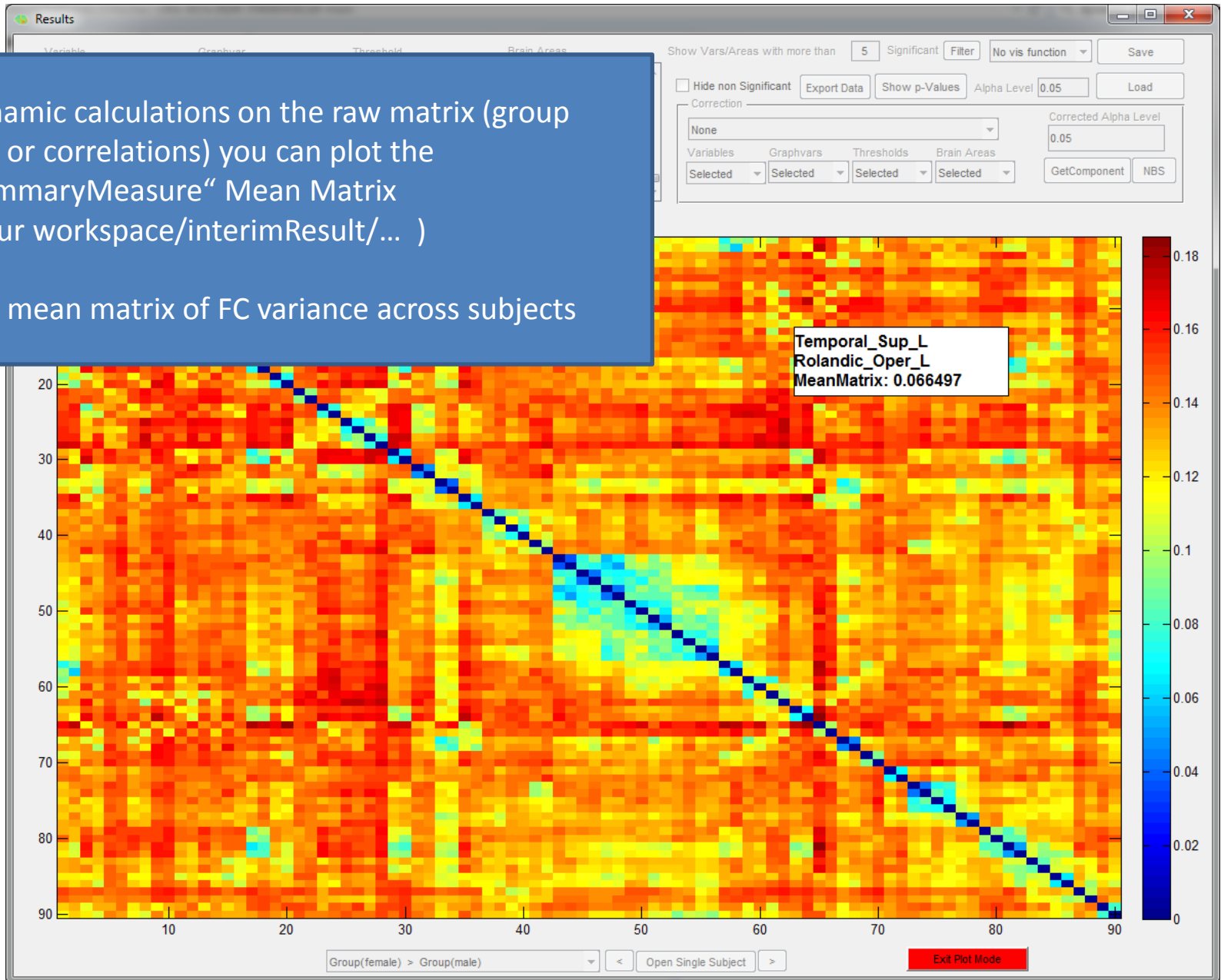
Example output of a variance FC group difference matrix



Example output of a FC variance group difference matrix

If you do dynamic calculations on the raw matrix (group comparisons or correlations) you can plot the „DynamicSummaryMeasure“ Mean Matrix (stored in your workspace/interimResult/... )

in this case a mean matrix of FC variance across subjects



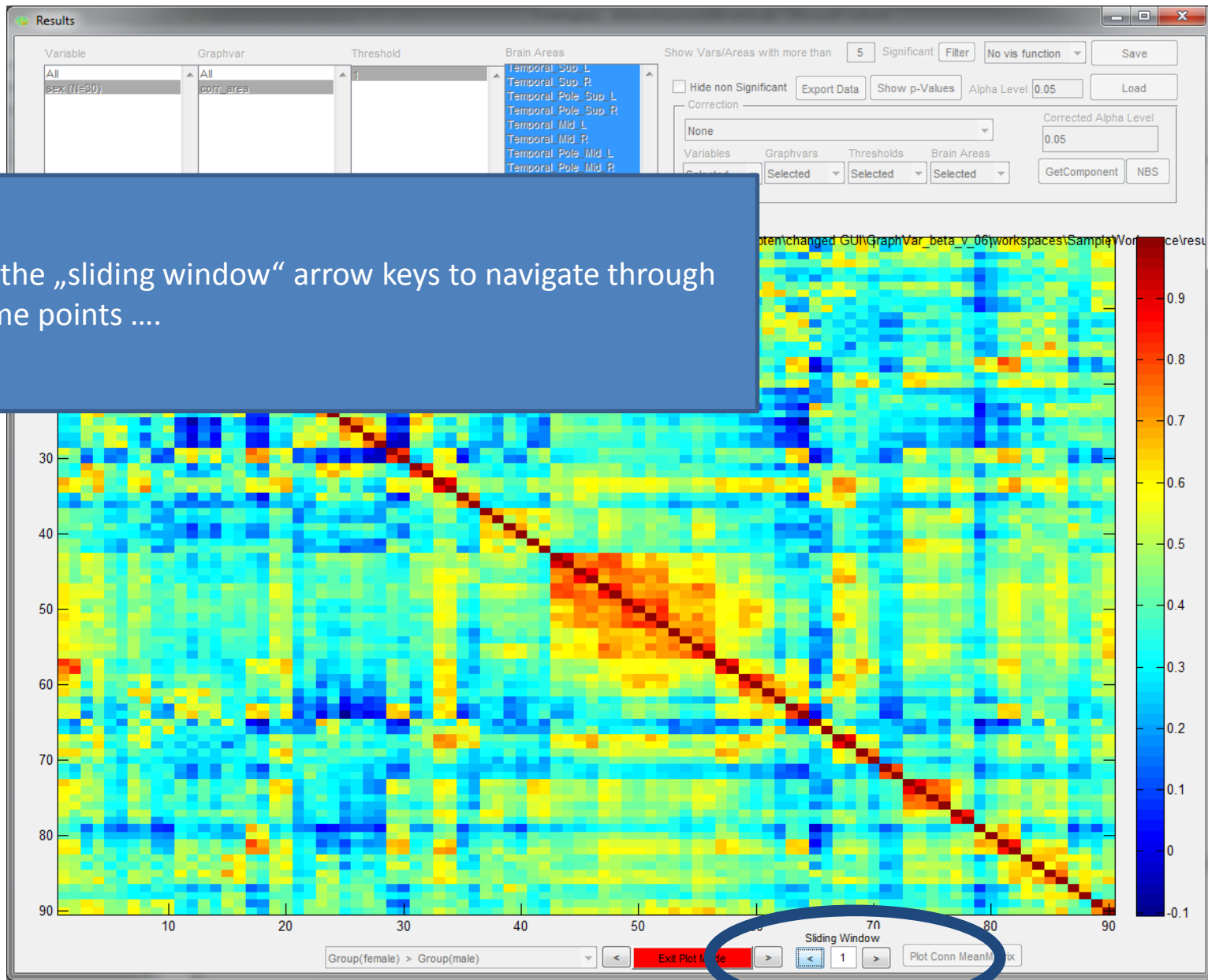
Plot dynamic summary mean matrix (here variance)

If you have conducted dynamic analyses on the raw matrix, you can plot the mean connectivity across all subjects for each sliding window

-> „Open Single Subject“ -> Dynamic Mean Matrix

The screenshot displays the GraphVar software interface. At the top right, there is a control panel with a dropdown menu set to 'None', a 'Corrected Alpha Level' input field set to '0.05', and buttons for 'GetComponent' and 'NBS'. Below this, a grey bar contains the text 'see the results'. The main area features a brain connectivity matrix plot with a color scale from blue to red. A dialog box titled 'Select a Variable:' is open, listing 'CorrMatrix', 'PValMatrix', 'BMatrix', and 'Dynamic Mean Matrix', with the latter selected. At the bottom, a navigation bar shows 'Group(female) > Group(male)', a set of navigation arrows, a button labeled 'Open Single Subject' (circled in blue), and a 'Plot Conn MeanMatrix' button.

Plot mean FC for each sliding window (across subjects)

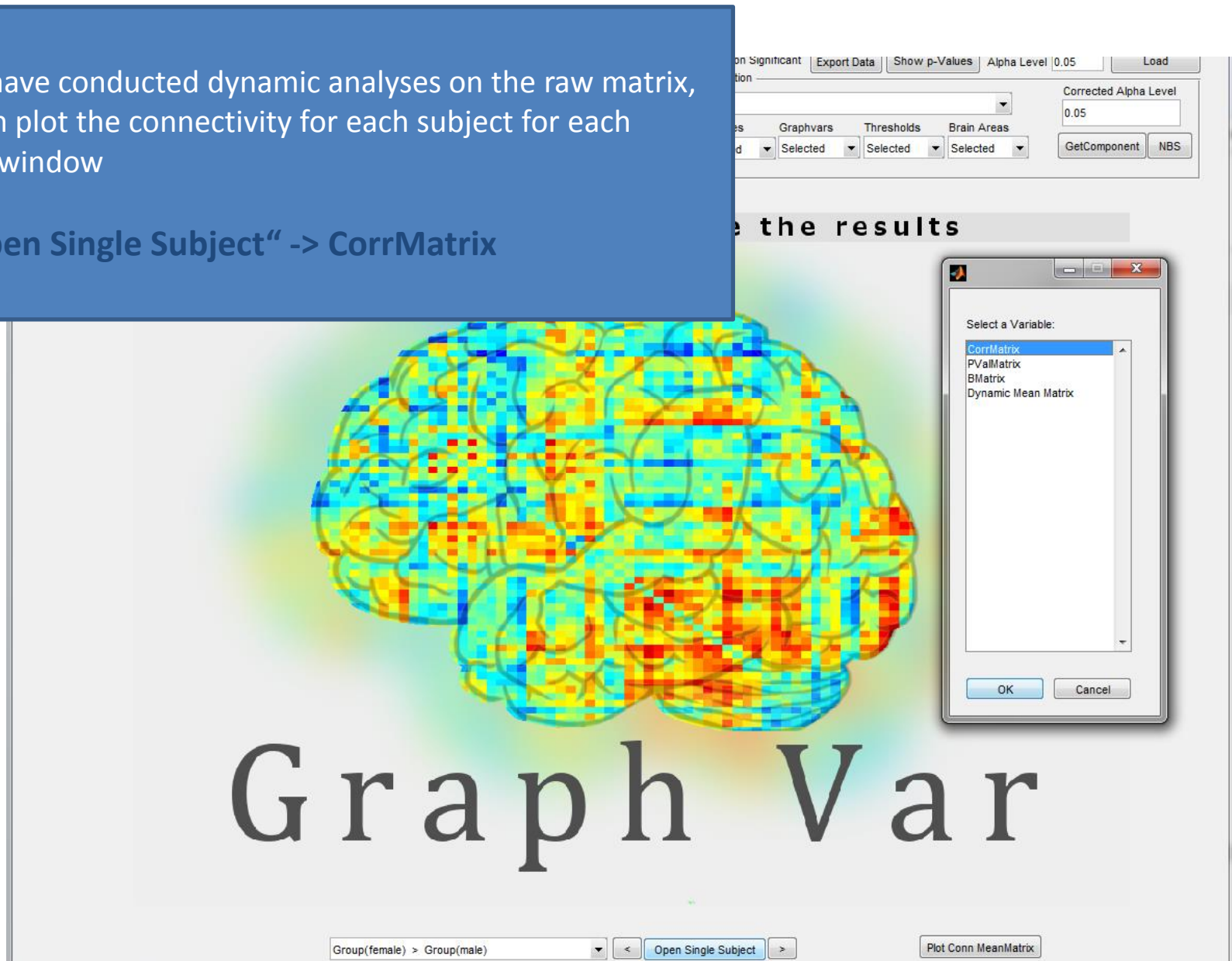


... use the „sliding window“ arrow keys to navigate through the time points ....

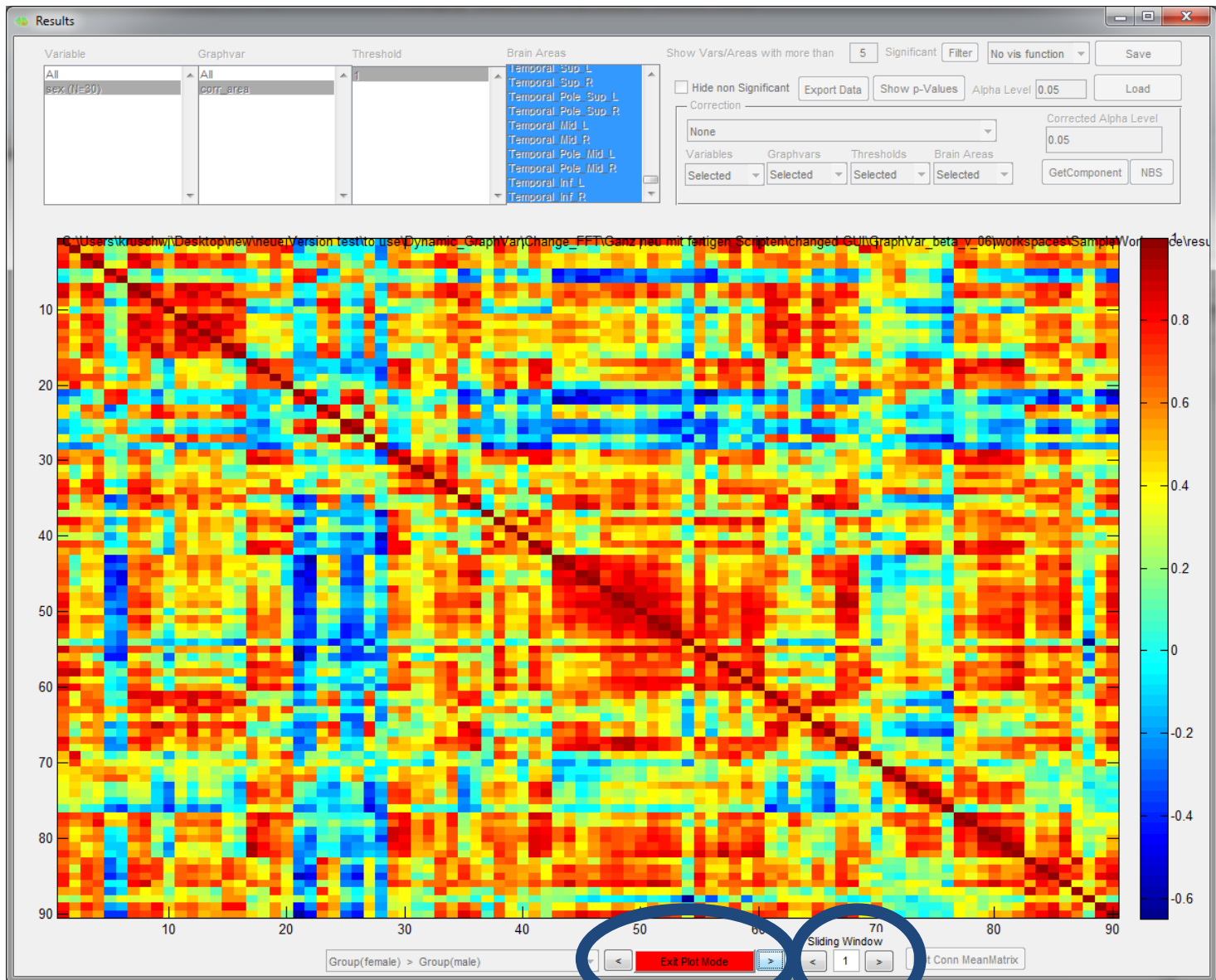
Plot mean FC for each sliding window (across subjects)

If you have conducted dynamic analyses on the raw matrix, you can plot the connectivity for each subject for each sliding window

-> „Open Single Subject“ -> CorrMatrix



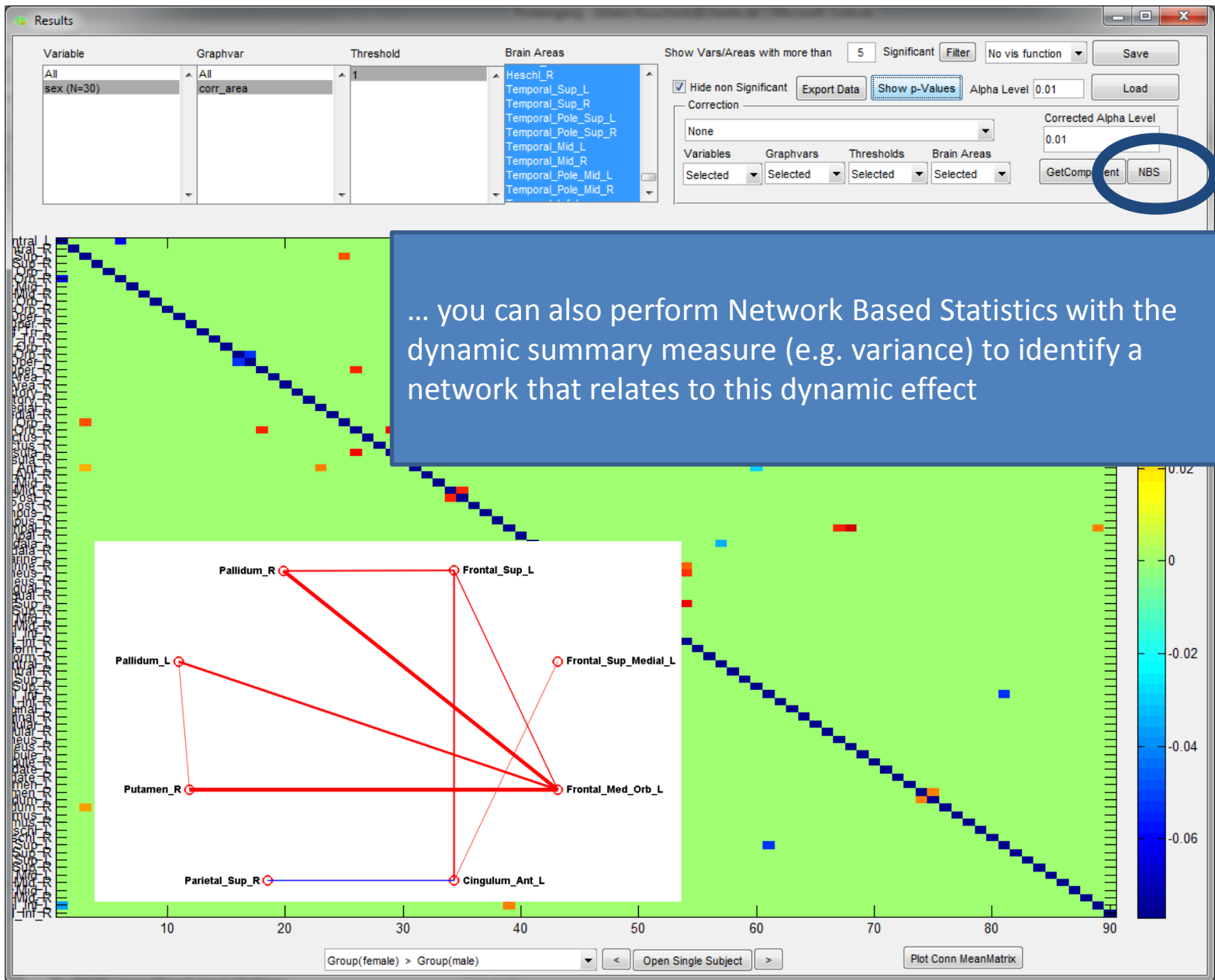
Plot sliding windows for single subjects



Select subject with arrows

Sliding Window

Plot mean FC for each sliding window (across subjects)



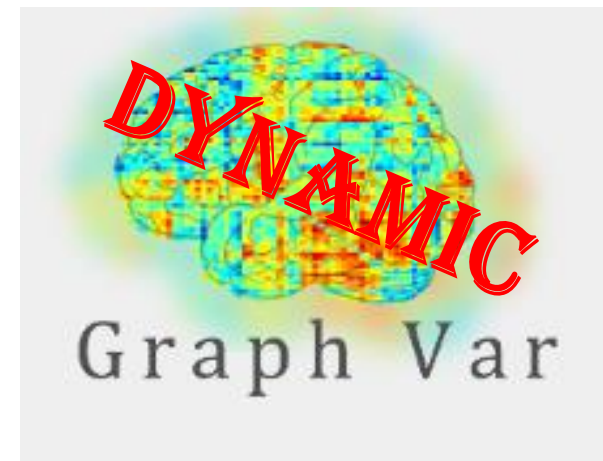
NBS with dynamic summary measures



## Variance:

$V = \text{var}(X)$  returns the variance of  $X$  for vectors. For matrices,  $\text{var}(X)$  is a row vector containing the variance of each column of  $X$ . For  $N$ -dimensional arrays,  $\text{var}$  operates along the first nonsingleton dimension of  $X$ . The result  $V$  is an unbiased estimator of the variance of the population from which  $X$  is drawn, as long as  $X$  consists of independent, identically distributed samples.

(Matlab definition)

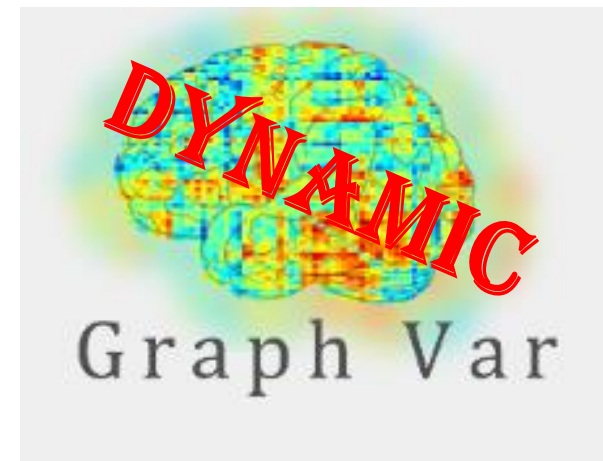


Dynamic summary measures

## Standard Deviation:

$s = \text{std}(X)$ , where  $X$  is a vector, returns the standard deviation. The result  $s$  is the square root of an unbiased estimator of the variance of the population from which  $X$  is drawn, as long as  $X$  consists of independent, identically distributed samples.

(Matlab definition)



Dynamic summary measures

## Periodicity:

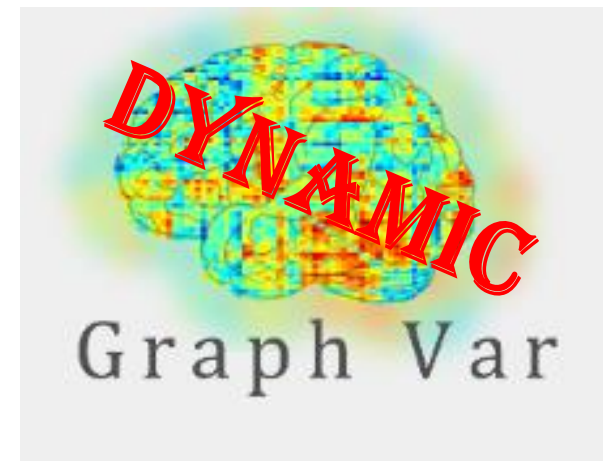
idea and function from [http://studyforrest.org/contest\\_findforrestnetworks.html](http://studyforrest.org/contest_findforrestnetworks.html)

*“Identifying task-related activity using periodic graph properties”*

Sat 01 November 2014 Lars Marstaller, Jeiran Choupan, Arend Hintze

-> Periodicity:

1. Optional: band pass filter of the time series of graph measures or connectivity measures of the raw matrix (by default this is not done; to change see script in src/ext/DynamicSummaryMeasures/periodicity)
2. project it into the frequency domain using a Fast Fourier transform.
3. Next, we count the number of peaks (defined as zero crossings of the first derivative) and calculate the maximum and the median of the power spectrum.
4. From these a final singular measure is derived, which is higher the more 'peaky' the power spectrum and hence the more periodic the changes in network properties
5. **(measure = maximum/[median\*peaks])**



Dynamic summary measures

## PointProcess – rate/interval:

idea from the paper: “*Enhanced repertoire of brain dynamical states during the psychedelic experience: Enhanced Repertoire of Brain Dynamical States*. Human Brain Mapping 35, 5442–5456. doi:10.1002/hbm.22562” by Tagliazucchi, E., Carhart-Harris, R., Leech, R., Nutt, D., Chialvo, D.R., 2014.

->the authors apply this to BOLD time series (in GraphVar “Raw matrix”) . We also offer to apply this method to “graph time series” (i.e., local efficiency at different time points). It is up to the community to determine if this approach may contribute to the evolving field of dynamic graph theory.

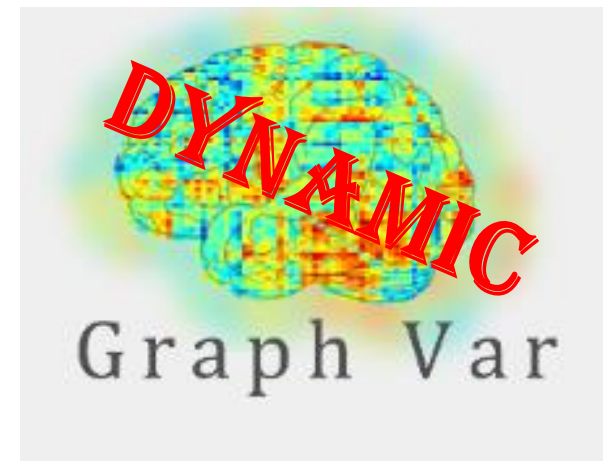
### -> Point Process – Rate/interval:

„ ... A recent series of studies demonstrated that the continuous BOLD signal can be transformed into a discrete point-process encoding the timings of the most functionally relevant events [Petridou et al., 2012, Davis et al., 2013; Tagliazucchi et al., a,b, 2012a]. In this approach, relevant events are defined by a threshold crossing (e.g. whenever the signal departs +1 SD from its mean value).

**Two interdependent observables are defined once the point-process is obtained: the rate (number of crossings divided by the series length) and inter-event intervals (average temporal separation between two consecutive points).**

On average, there is a clear inverse relationship between these two variables. Furthermore, the rate is expected to increase (or the interval to decrease) for a signal with a high contribution of fast frequencies.”

This approach is described as an efficient alternative to spectral analysis.



As default in GraphVar the critical threshold is set as mean + - 1 SD of the respective time series

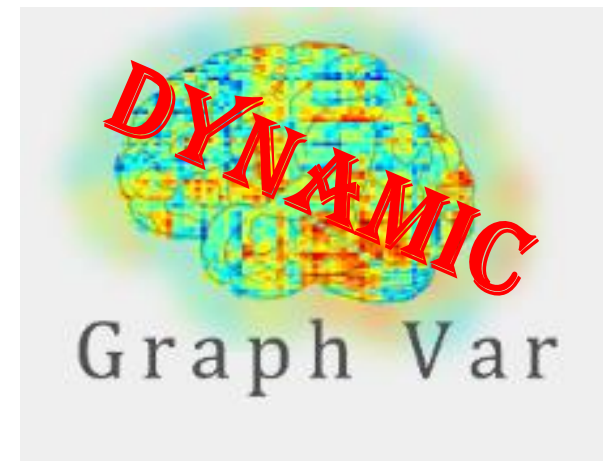
You can change this in the scripts:  
src/calc/pointprocess\_\*

## Dynamic summary measures

## Do it yourself:

As always you can include your own scripts for your costum analyses

1. Add your function name in the GUI
2. Add your function name in „CalcCorrMatrix“
3. Add your function name in „CalcVars“
4. -> make sure you find all the parts where „e.g. periodicity“ is mentioned in the scrips and copy the style of the reference functions. Also use the dimensions of the data as we suggest (the „multidimfunc“ will do the rest)



**If you have an awesome function that you would like to share with the community through GraphVar, we would be happy to receive the proper MATLAB code to include it in an upcoming version!**

Dynamic summary measures

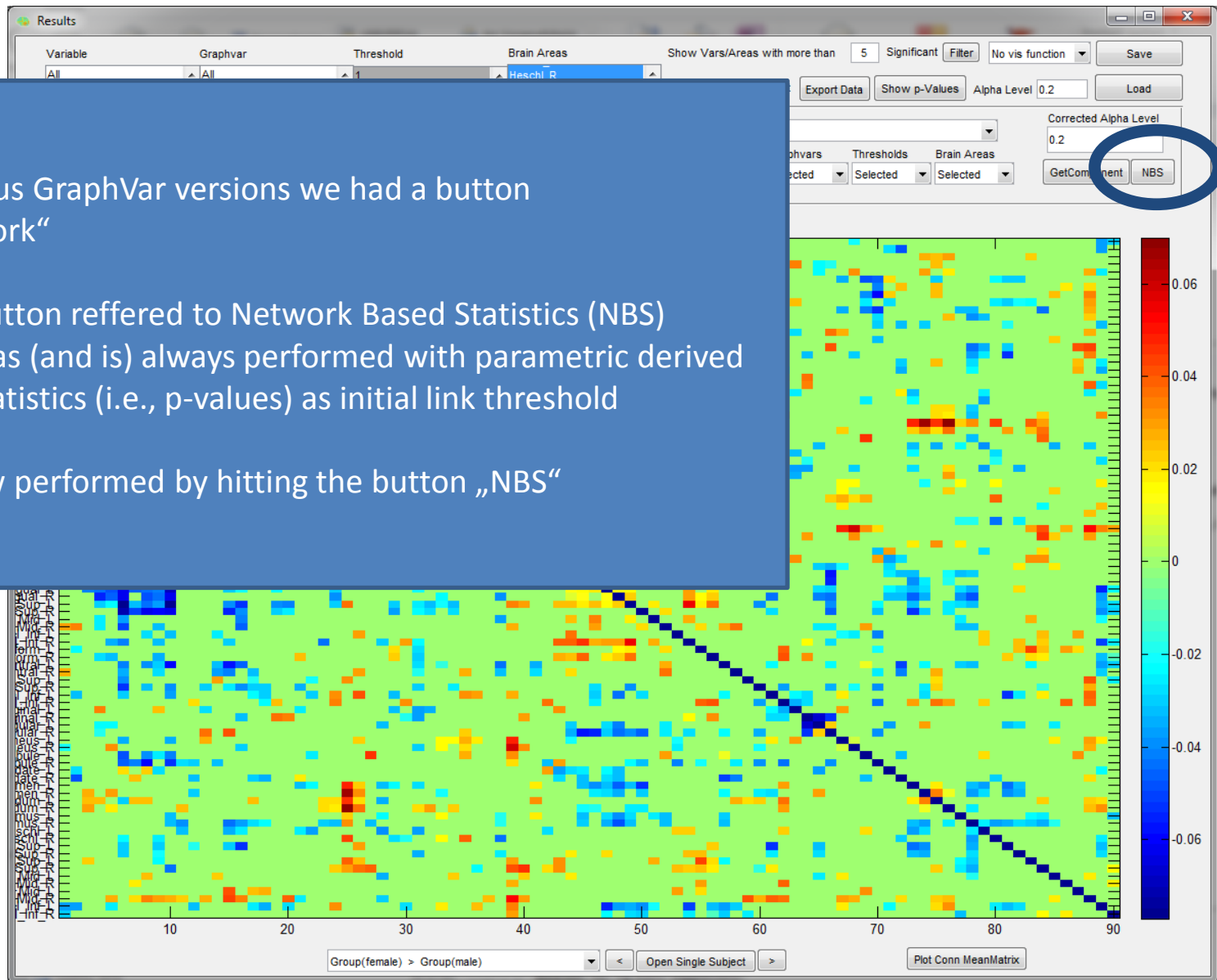
Additional „**GetComponent**“  
feature in beta 0.6

Dynamic summary measures

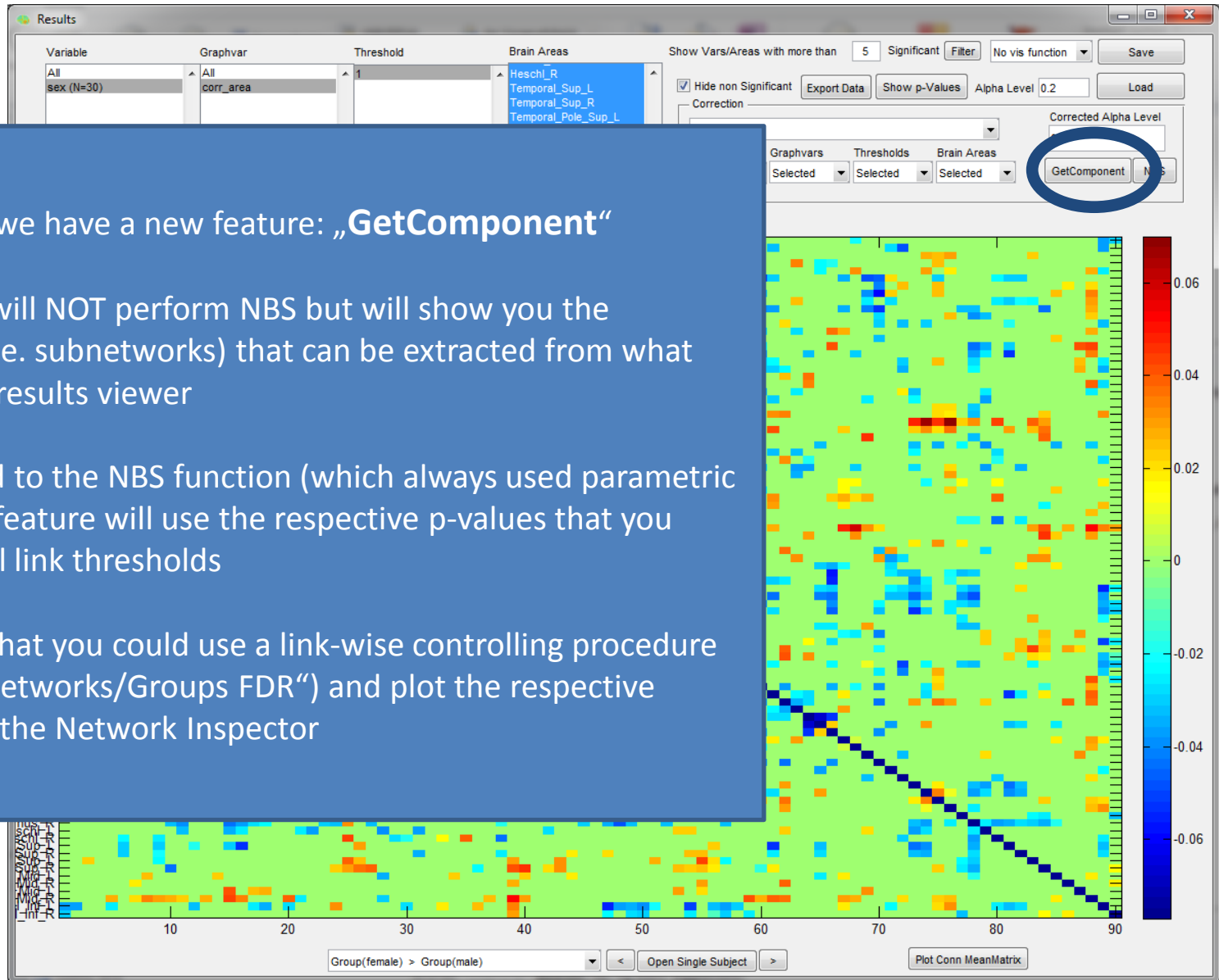
In the previous GraphVar versions we had a button „Show Network“

-> This old button referred to Network Based Statistics (NBS)  
... NBS was (and is) always performed with parametric derived test-statistics (i.e., p-values) as initial link threshold

-> NBS is now performed by hitting the button „NBS“



„GetComponent“ feature



In this version we have a new feature: „GetComponent“

-> this button will NOT perform NBS but will show you the components (i.e. subnetworks) that can be extracted from what you see in the results viewer

-> as compared to the NBS function (which always used parametric p-values), this feature will use the respective p-values that you select for initial link thresholds

-> this means that you could use a link-wise controlling procedure (e.g. random Networks/Groups FDR“) and plot the respective subnetwork in the Network Inspector

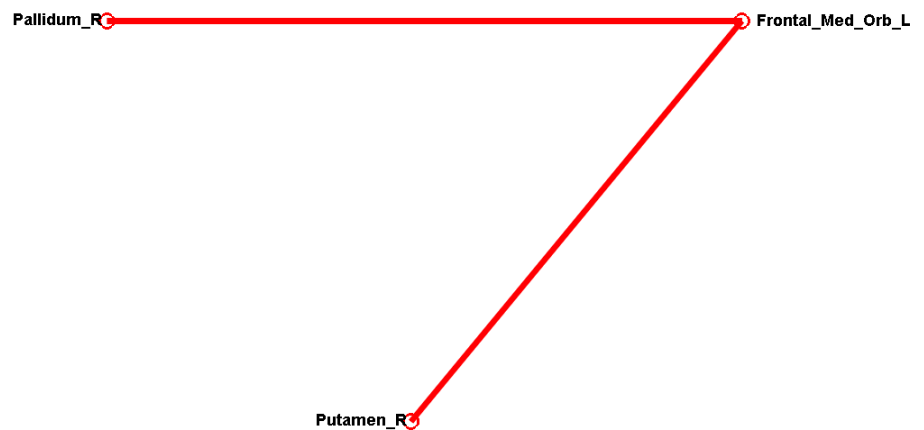
„GetComponent“ feature



-> for „GetComponent“ there is no column in the Network Inspector telling you the significance of this component as derived from comparison with random data (as this is only done in NBS)

-> however, if you have applied a proper link-wise controlling procedure (e.g. Bonferroni or FDR) you could interpret the subnetwork accordingly

	Size of Network	Count in real data
1	1	81
2	2	3
3	3	1
4	4	0
5	5	0
6	6	0
7	7	0
8	8	0
9	9	0
10	10	0
11	11	0
12	12	0
13	13	0
14	14	0
15	15	0



„GetComponent“ feature

*The  
End*