New Features and Tutorial

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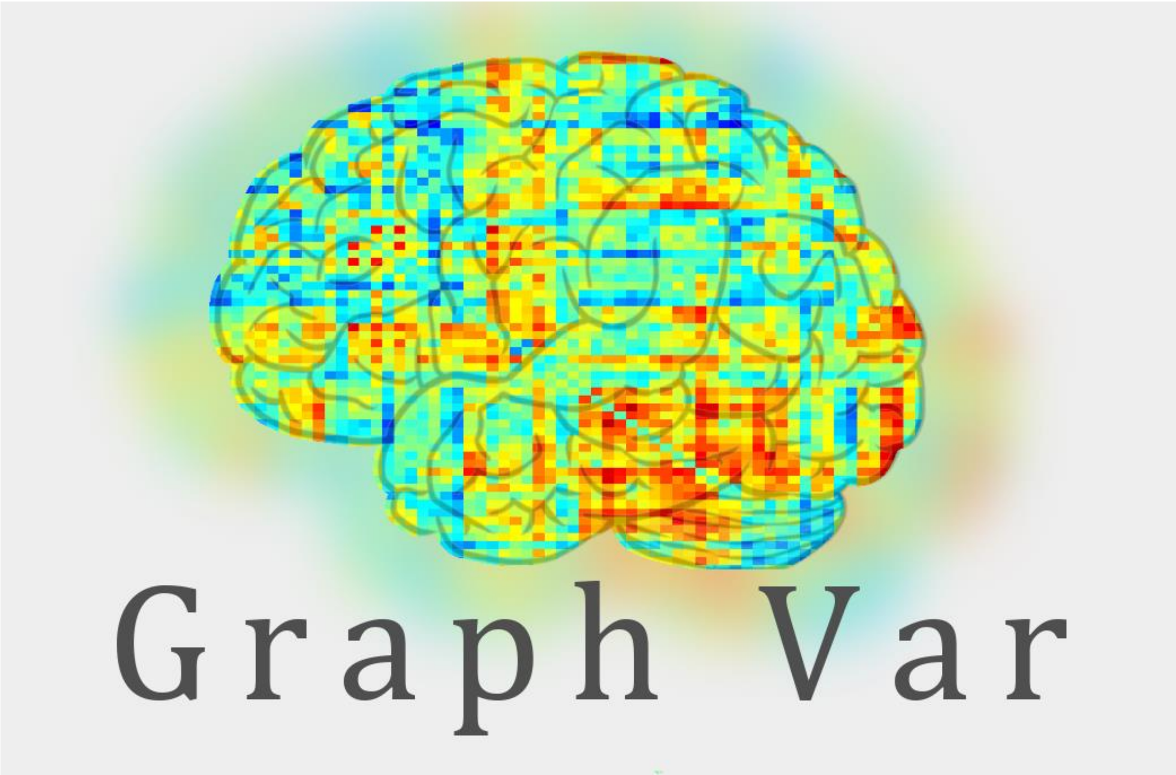
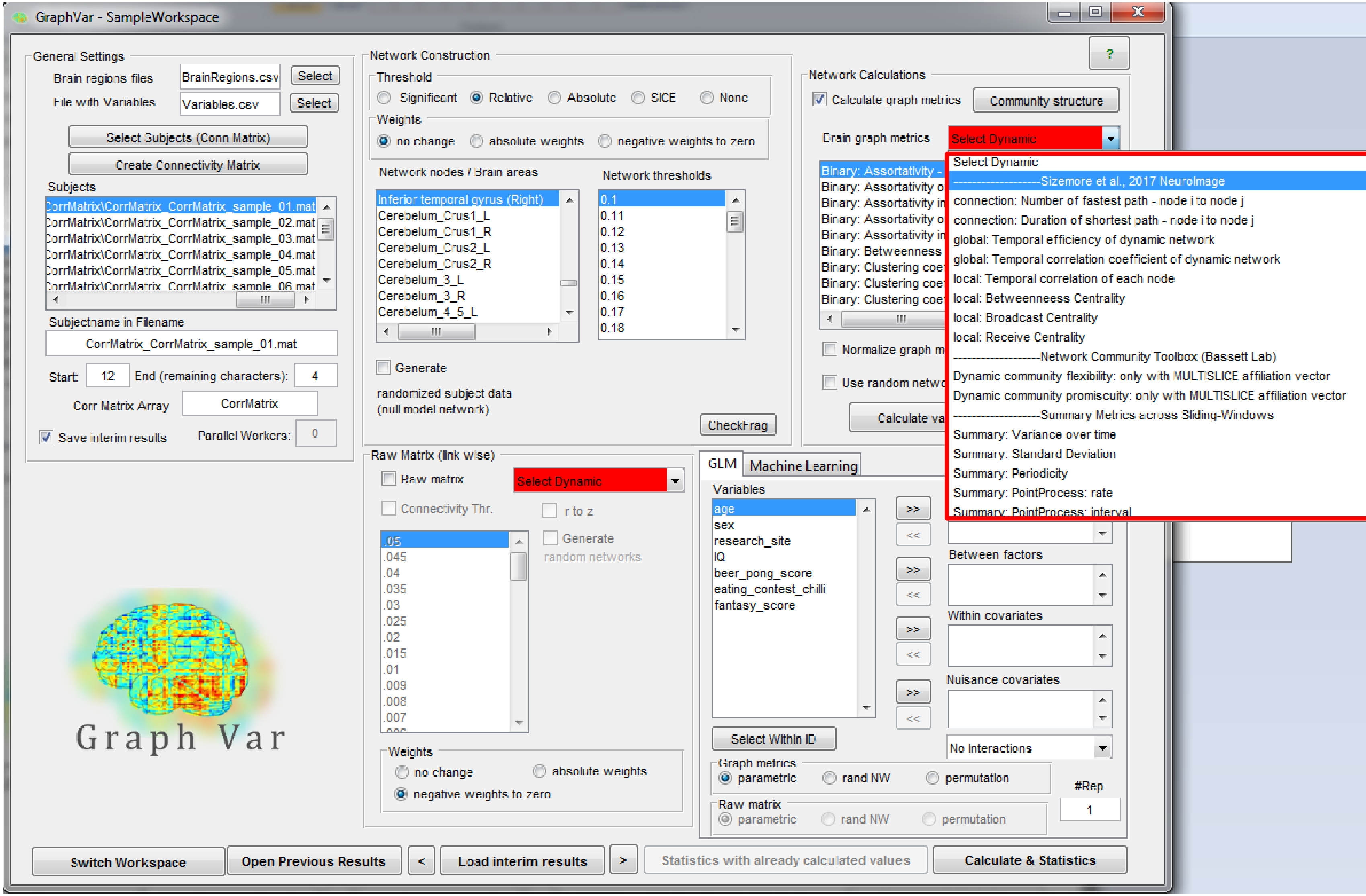
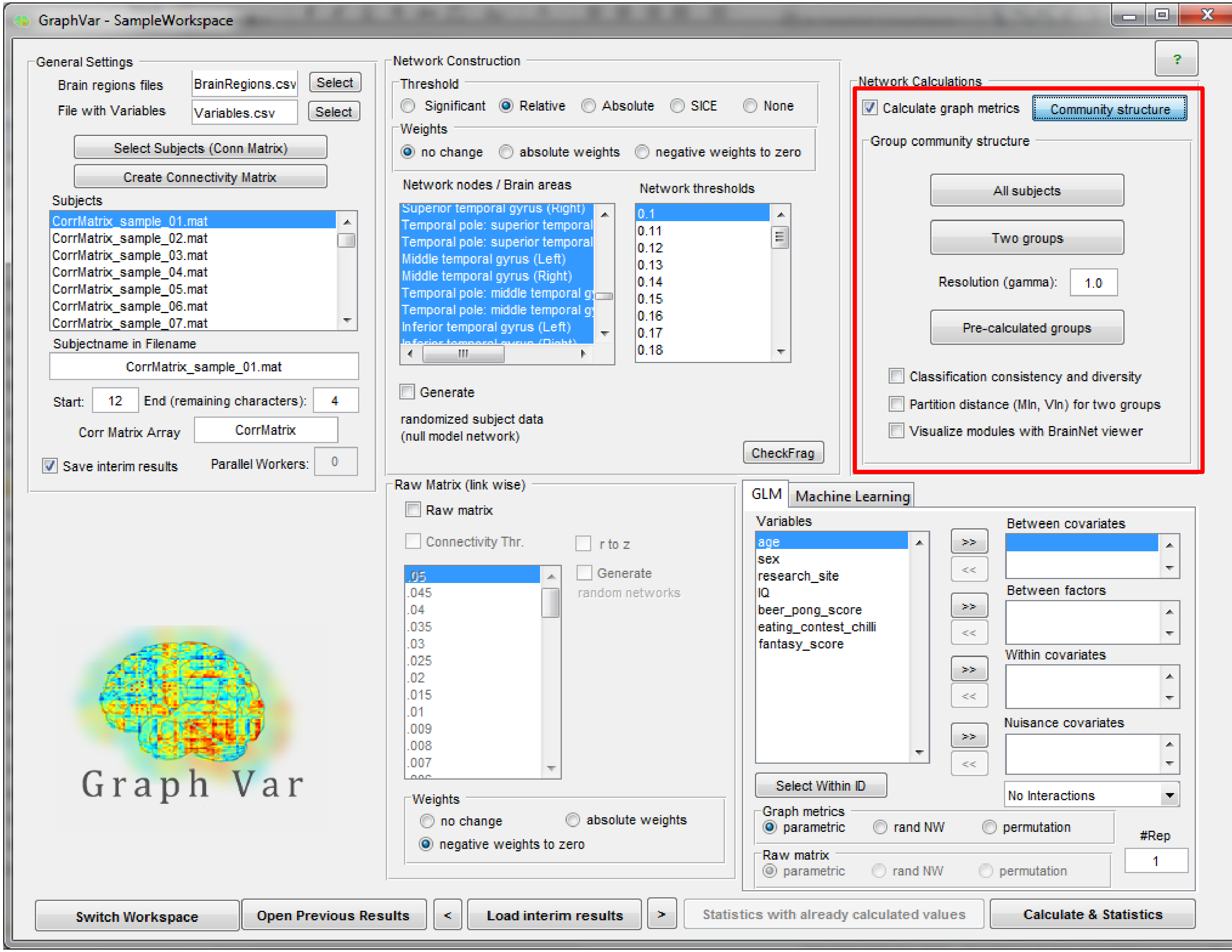
Graphar 2.02





added dynamic network measures as in [Seizemore et al., 2017]

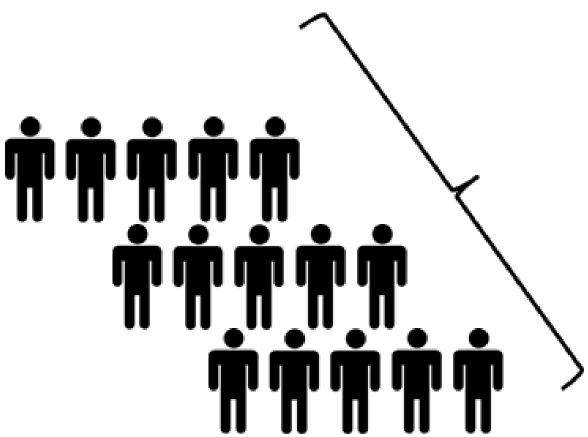


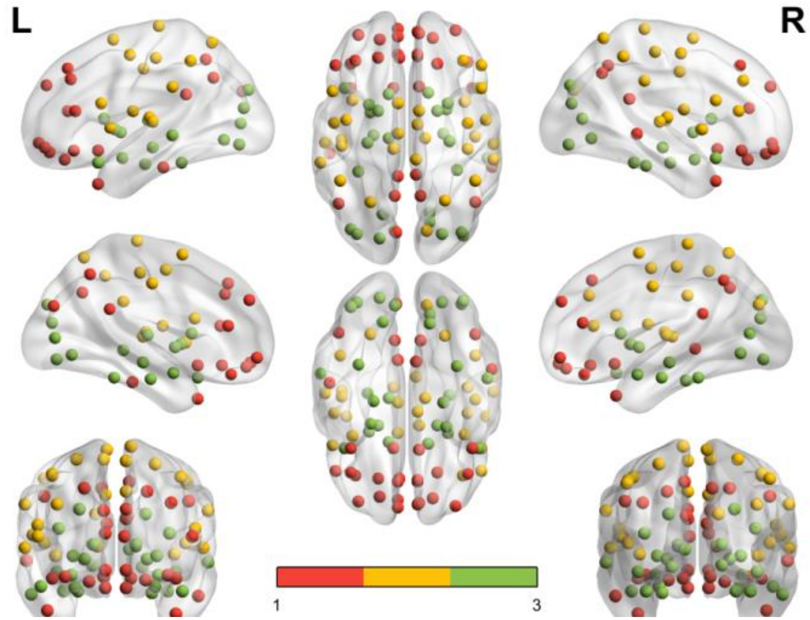
added community functionalities as in [Fornito et al., 2012]

What is this new feature?

It can be used to obtain a group based consensus of the graph decomposition

„.... it´ s like a group ICA on graphs"





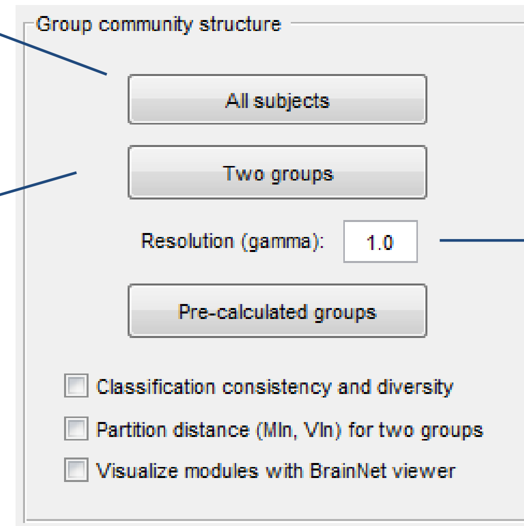
Community functionalities as in
[Fornito et al., 2012]

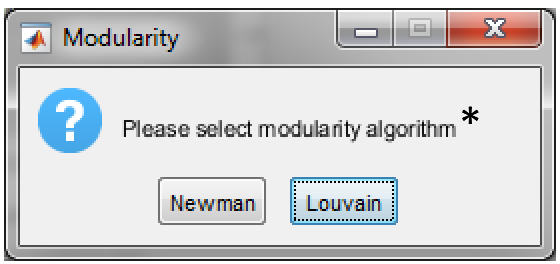
Tutorial

Computes a *consensus community structure* across all subjects

Resolution to cluster the graph
gamma>1: detects smaller modules
0<=gamma<1: detects larger modules
gamma=1: classic modularity (default)

Computes *consensus community structures* for two groups and compares them





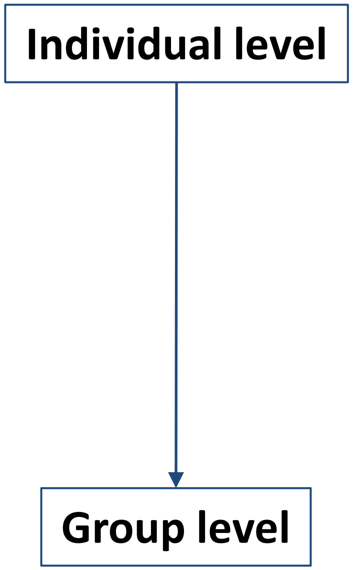
*

* as implemented in the BCT

Implemented procedures work with fully connected matrices and with thresholded graphs

added community functionalities as in e.g. [Fornito et al., 2012]

Consensus Community structure - general procedure (text adapted from Dwyer et al. 2014):



„... it' s like an ICA on graphs"

1. <u>Individual level modular decomposition</u>:

We run multiple iterations (1000) of the Louvain/Newman modularity algorithm (which is an optimization algorithm and thus produces slightly different outcomes per iteration) to obtain a set of possible clusters in the graph. To identify the final clustering solution, we use a consensus-based approach in which we generate a co-classification matrix (in which each [i, j] element contained 1 if two nodes were classified in the same module and 0 otherwise) and subsequently run a second decomposition of this co-classification matrix (c.f. Lancichinetti and Fortunato, 2012). In this manner, nodes frequently co-classified in the same module across multiple iterations of the algorithm will be assigned to the same module in the final solution.

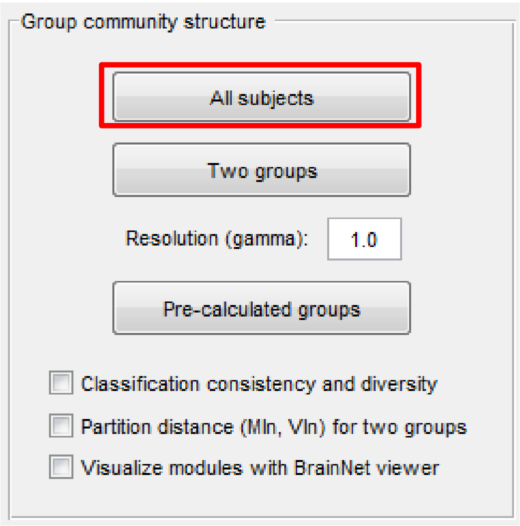
2. <u>Group-level modular decomposition</u>:

To obtain a group based consensus of the graph decomposition, we pass the final consensus decompositions for each individual to a second level to derive a group-level representation of network modularity based on a similar logic to the consensus approach used at the single-subject level. Specifically, the individuals final consensus decompositions are summed across individuals to generate a sample-level consistency matrix. A high weight in elements of this matrix indicates that two nodes were frequently classified in the same module across individuals. As such, a subsequent modular decomposition of this group-level consistency matrix ensures that nodes frequently co-classified together are likely to be assigned to the same module in the final solution.

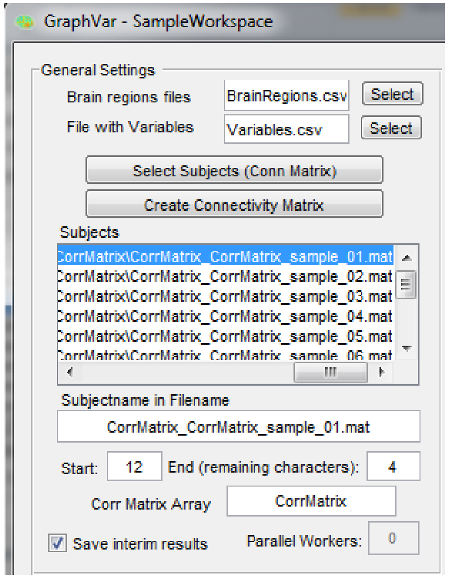
By aggregating results across single-participant decompositions, this consensus-based approach allows to derive a group-level representation of community structure while also characterizing interindividual variability in network organization using classification consistency and diversity metrics. Such analyses are not possible when decomposition is performed on a group-averaged correlation matrix. Consensus-based approaches have also been shown to yield more stable individual module solutions, given the known degeneracy of most graph theoretic module detection algorithms (Good et al., 2010; Lancichinetti and Fortunato, 2012).

All subjects:

(Variable sheet with Subject IDs recquired)

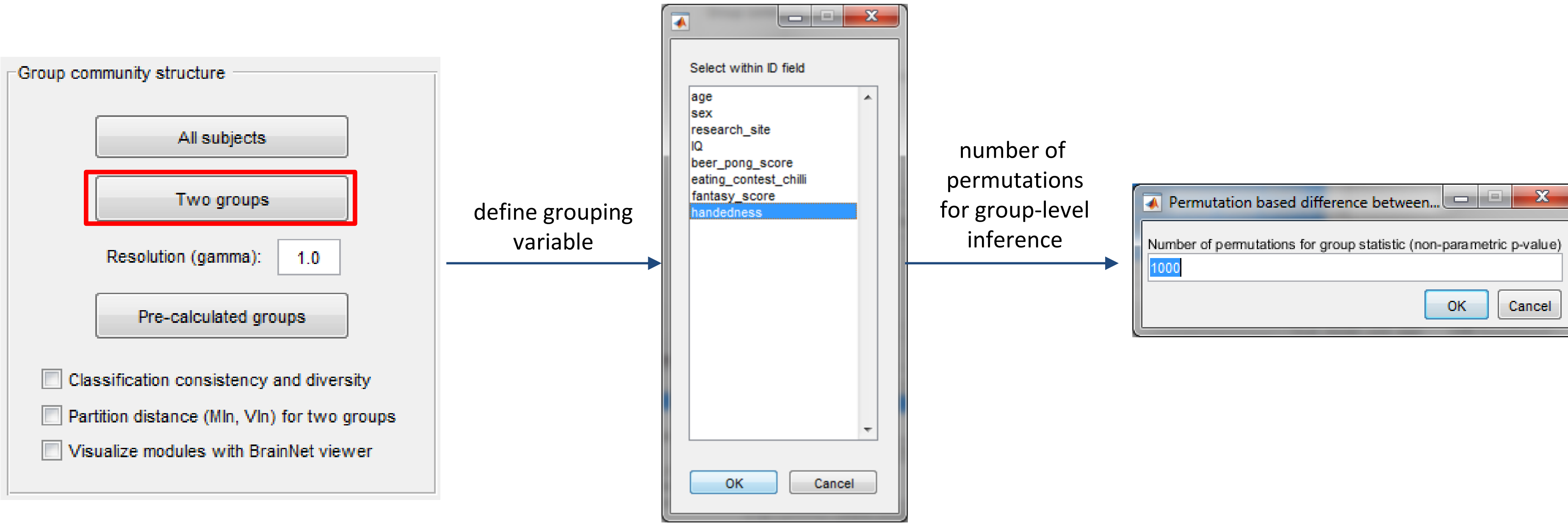


Performs a group consensus clustering across all subjects that are loaded in the current workspace



Two groups:

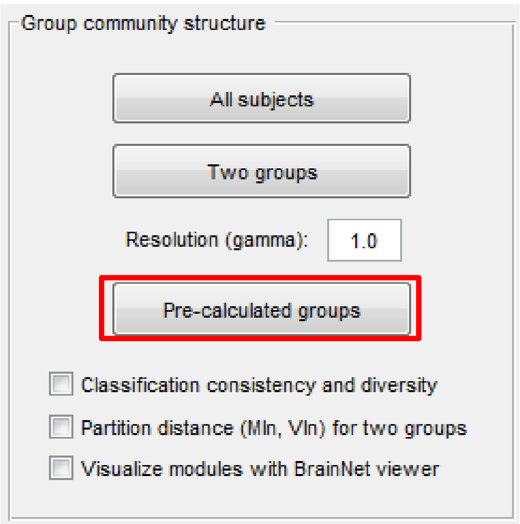
(Variable sheet with Subject IDs recquired)



<u>TESTING BETWEEN-GROUP DIFFERENCES IN MODULAR ORGANIZATION</u>:

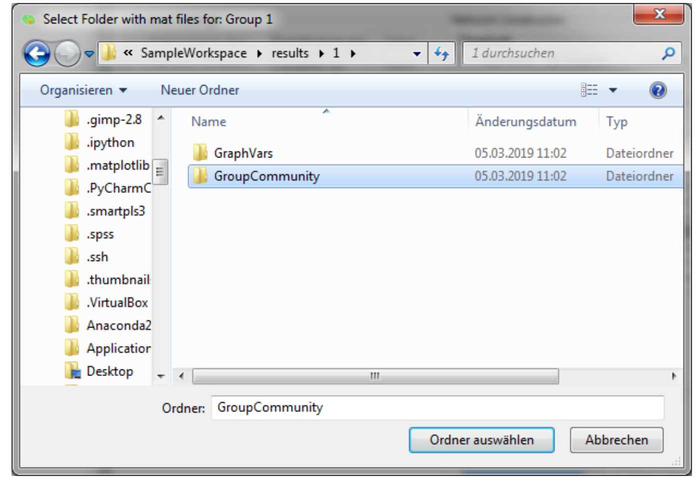
To evaluate the significance of between-goup differences in modular organization we use a permutation approach. By permuting labels across groups and re-calculating the difference between groups in the respective modularity metric (see next slide) we obtain a distribution of this group difference under the null-hypothesis. By placing the real group difference “delta” in the random distribution of deltas we can determine the significance from its percentile position in the distribution.

Pre-calculated groups:

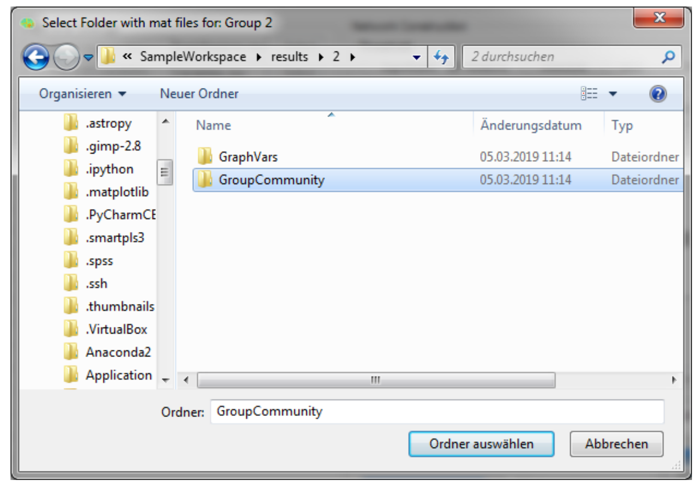


Load previous results

Group 1

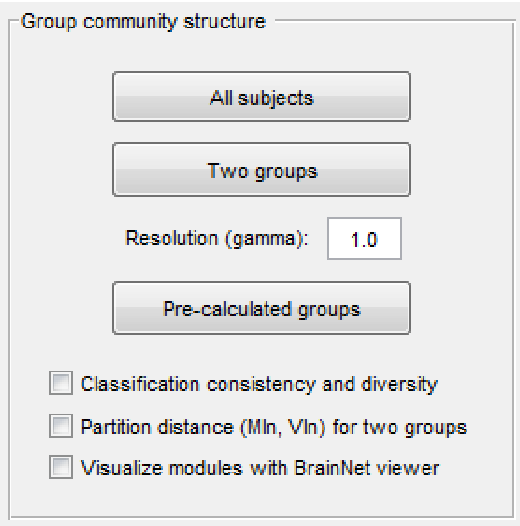


Group 2



If you have perfomed previous modularity analyses on different sets of subjects with the “All subjects” function, you can compare the results by loading the respective “GroupCommunity” folder (similar to “Two groups” function)

Measures of modular organization I:

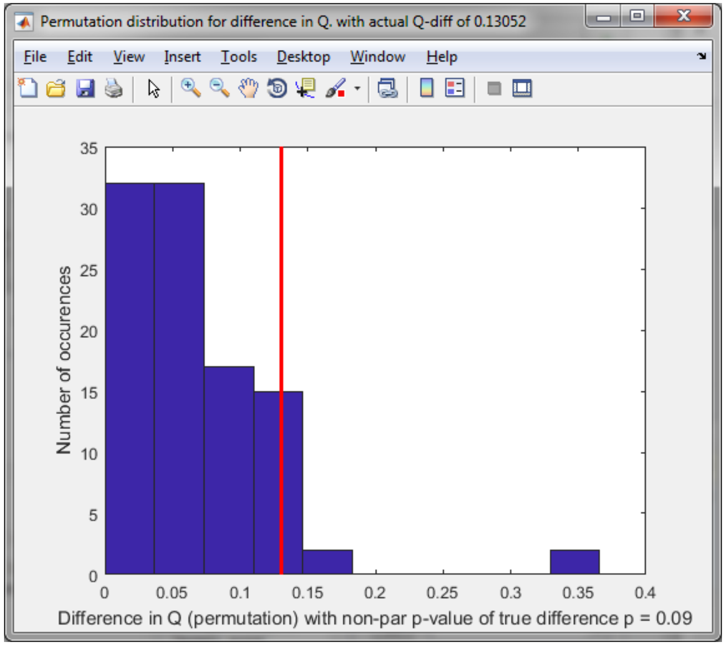


Q is always calculated (no selection needed)

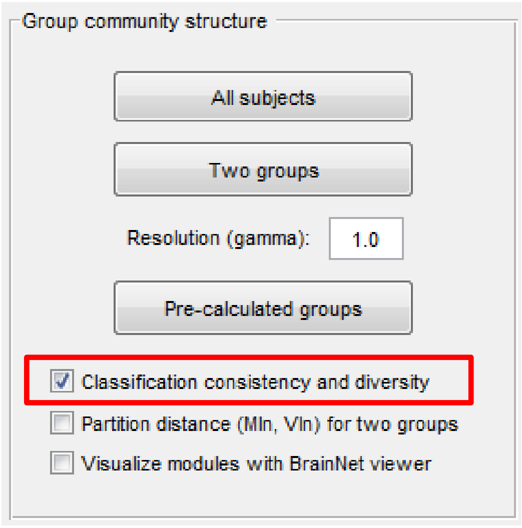
<u>OPTIMAL MODULAR DECOMPOSITION – Q</u> (text adapted from Fischi-Gomez et al., 2016):

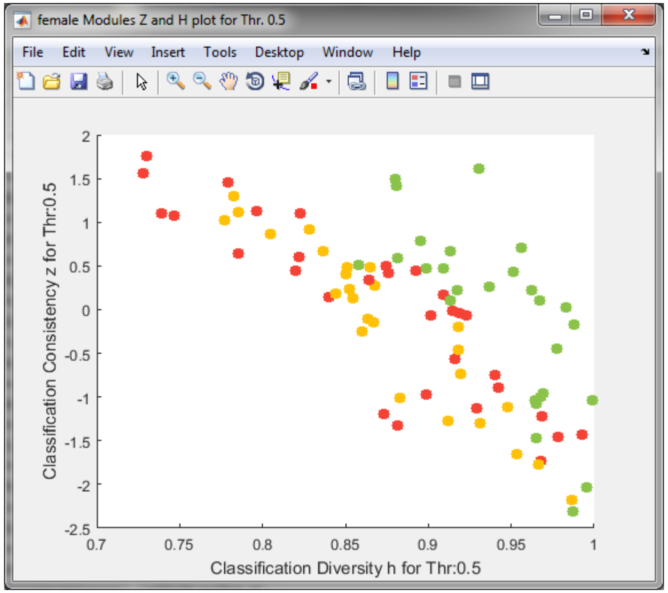
In the Louvain modularity algorithm, Q is obtained by iteratively repeating 2 steps until convergence to a modularity maximum (Q).

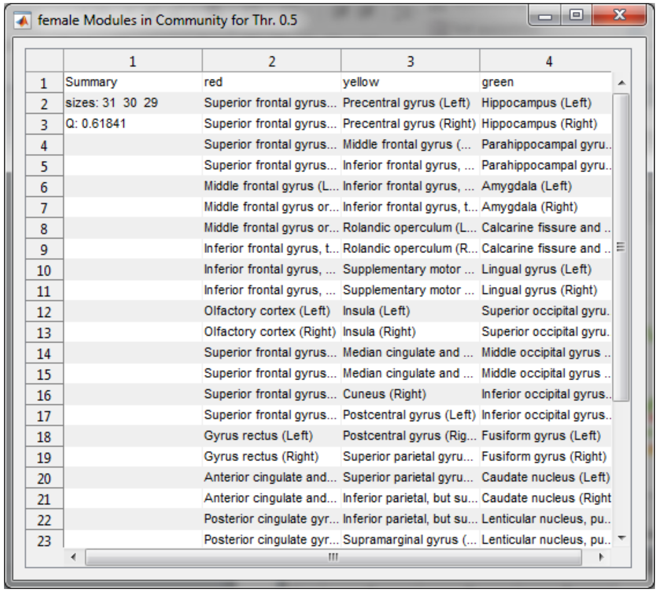
First, each node is placed in a separate module, and all possible node moves between modules are evaluated in terms of modularity gain (step 1). When no individual move can further improve the Q value, nodes belonging to the same community are agglomerated (step 2) in order to form new 'super-nodes'. Step one (moves evaluation) is repeated on the new 'super-nodes' network. The two steps are repeated until convergence.



Measures of modular organization II:







	1	2	3	4
1	Summary	red	yellow	green
2	sizes: 31 30 29	Superior frontal gyrus...	Precentral gyrus (Left)	Hippocampus (Left)
3	Q: 0.61841	Superior frontal gyrus...	Precentral gyrus (Right)	Hippocampus (Right)
4		Superior frontal gyrus...	Middle frontal gyrus (...	Parahippocampal gyru..
5		Superior frontal gyrus...	Inferior frontal gyrus, ...	Parahippocampal gyru..
6		Middle frontal gyrus (L...	Inferior frontal gyrus, ...	Amygdala (Left)
7		Middle frontal gyrus or...	Inferior frontal gyrus, t...	Amygdala (Right)
8		Middle frontal gyrus or...	Rolandic operculum (L...	Calcarine fissure and ..
9		Inferior frontal gyrus, t...	Rolandic operculum (R...	Calcarine fissure and ..
10		Inferior frontal gyrus, ...	Supplementary motor ...	Lingual gyrus (Left)
11		Inferior frontal gyrus, ...	Supplementary motor ...	Lingual gyrus (Right)
12		Olfactory cortex (Left)	Insula (Left)	Superior occipital gyru.
13		Olfactory cortex (Right)	Insula (Right)	Superior occipital gyru.
14		Superior frontal gyrus...	Median cingulate and ...	Middle occipital gyrus ..
15		Superior frontal gyrus...	Median cingulate and ...	Middle occipital gyrus ..
16		Superior frontal gyrus...	Cuneus (Right)	Inferior occipital gyrus..
17		Superior frontal gyrus...	Postcentral gyrus (Left)	Inferior occipital gyrus..
18		Gyrus rectus (Left)	Postcentral gyrus (Rig...	Fusiform gyrus (Left)
19		Gyrus rectus (Right)	Superior parietal gyru...	Fusiform gyrus (Right)
20		Anterior cingulate and...	Superior parietal gyru...	Caudate nucleus (Left)
21		Anterior cingulate and...	Inferior parietal, but su...	Caudate nucleus (Right
22		Posterior cingulate gyr...	Inferior parietal, but su...	Lenticular nucleus, pu..
23		Posterior cingulate gyr...	Supramarginal gyrus (...	Lenticular nucleus, pu..

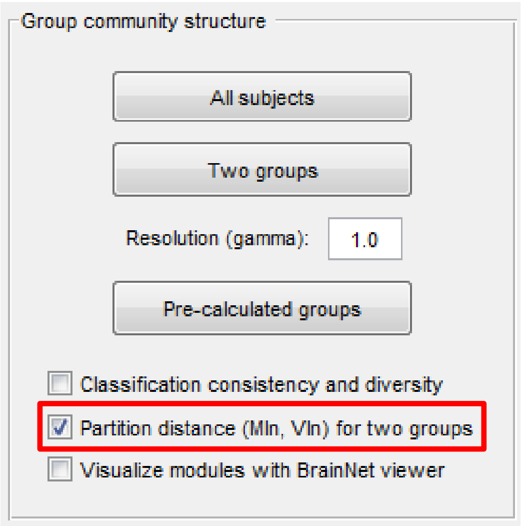
CLASSIFICATION CONSISTENCY AND DIVERSITY (text adapted from Fornito et al., 2012)**:**

To understand the functional roles played by each module and their constituent nodes, one can examine the **consistency and diversity** with which different regions are coclassified into the same module across participants.

Classification consistency is estimated by computing the within-module strength, *z*, of each node in the group-level consistency matrix. *Classification diversity* is computed using the diversity coefficient *h* .

Applied in this context, *z* quantifies the degree to which each region is classified in the same module across participants relative to other nodes in the same module. Brain regions with high *z* values represent core components of their module and thus act as local connectivity hubs. The diversity coefficient, *h*, quantifies the variability of each region's modular assignment across participants. Regions with high *h* have a relatively equal probability of being classified into different modules across participants, because their connectivity is dispersed between modules from individual to individual. These regions, therefore, represent transitional nodes that facilitate functional integration between modules.

Measures of modular organization III:

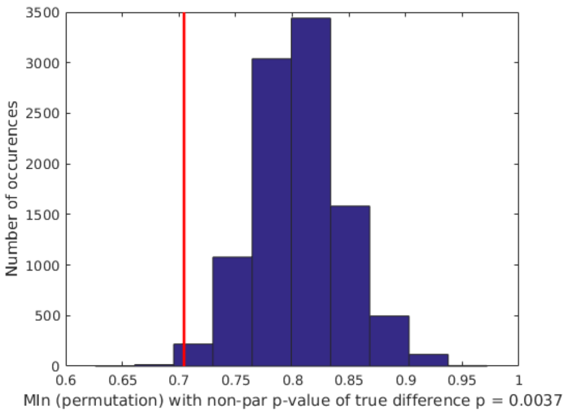


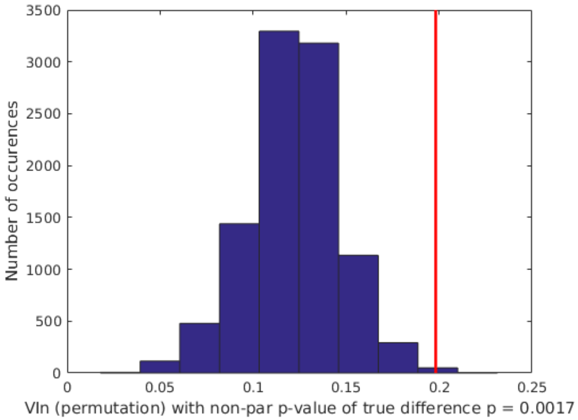
PARTITION DISTANCE (text adapted from [Fischi-Gomez et al., 2016]):

Quantifies the distance between pairs of community partitions with information theoretic measures: mutual information and variational information ([Meila, 2007]).

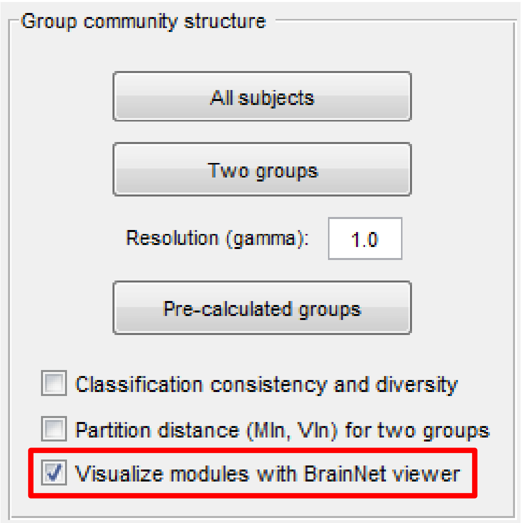
These two measures, based on the concept of entropy, quantify similarities and differences between graphs partitions. The *mutual information (MI)* quantifies how much information is shared by the two (different) partitions Ci and Cj of a given network G. Roughly speaking, MI tells how much we learn about Ci if we know Cj, and viceversa. Nevertheless the most commonly used measure of similarity in graph is the normalized mutual information (MIn), introduced by (Danon et al., 2005). This measure equals 1 if the two partitions are identical, whereas it has an expected value of 0 is the two partitions are independent.

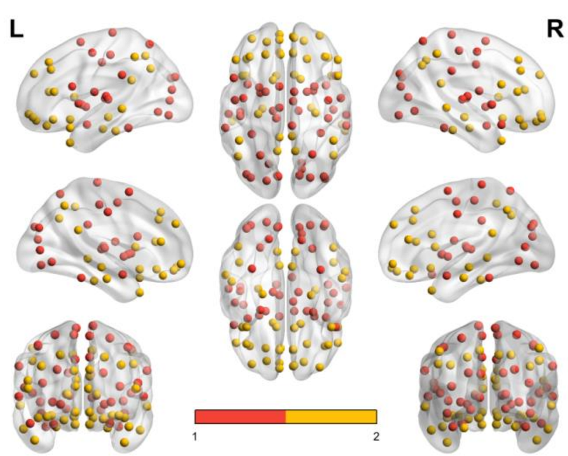
The *variation of information (VI)* expresses the quantity of information intrinsic to the two partitions, corrected by the information shared by the two partitions. VI is up-bounded by the logarithm of the number of nodes (log n) and can be therefore normalized by this value, giving a rescaled value of VI to the range [0,1].

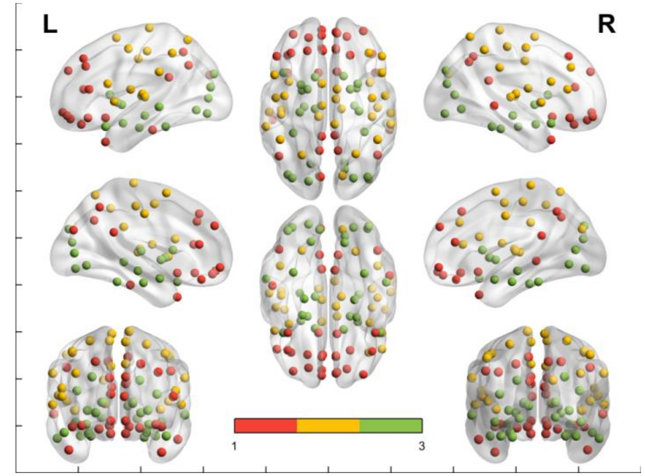


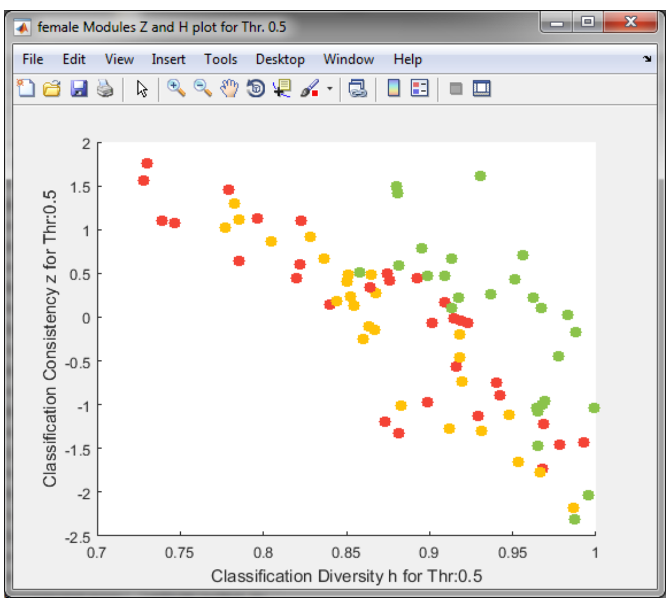


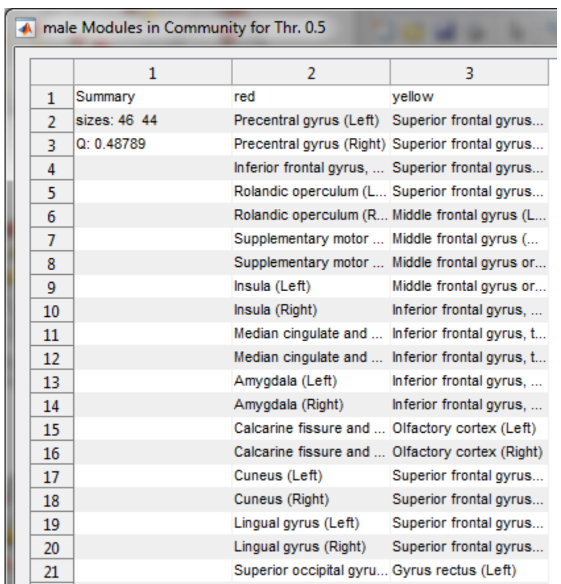
Output visualization:



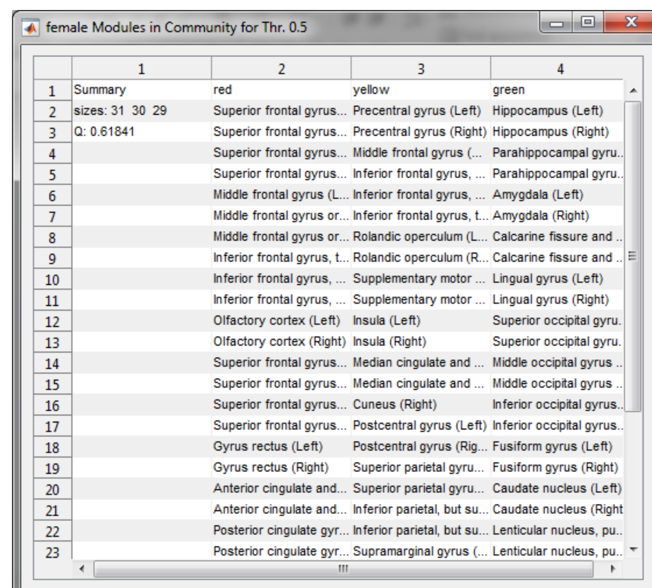







male Modules in Community for Thr. 0.5

	1	2	3
1	Summary	red	yellow
2	sizes: 46 44	Precentral gyrus (Left)	Superior frontal gyrus...
3	Q: 0.48789	Precentral gyrus (Right)	Superior frontal gyrus...
4		Inferior frontal gyrus, ...	Superior frontal gyrus...
5		Rolandic operculum (L...	Superior frontal gyrus...
6		Rolandic operculum (R...	Middle frontal gyrus (L...
7		Supplementary motor ...	Middle frontal gyrus (...
8		Supplementary motor ...	Middle frontal gyrus or...
9		Insula (Left)	Middle frontal gyrus or...
10		Insula (Right)	Inferior frontal gyrus, ...
11		Median cingulate and ...	Inferior frontal gyrus, t...
12		Median cingulate and ...	Inferior frontal gyrus, t...
13		Amygdala (Left)	Inferior frontal gyrus, ...
14		Amygdala (Right)	Inferior frontal gyrus, ...
15		Calcarine fissure and ...	Olfactory cortex (Left)
16		Calcarine fissure and ...	Olfactory cortex (Right)
17		Cuneus (Left)	Superior frontal gyrus...
18		Cuneus (Right)	Superior frontal gyrus...
19		Lingual gyrus (Left)	Superior frontal gyrus...
20		Lingual gyrus (Right)	Superior frontal gyrus...
21		Superior occipital gyru...	Gyrus rectus (Left)


female Modules in Community for Thr. 0.5

	1	2	3	4
1	Summary	red	yellow	green
2	sizes: 31 30 29	Superior frontal gyrus...	Precentral gyrus (Left)	Hippocampus (Left)
3	Q: 0.61841	Superior frontal gyrus...	Precentral gyrus (Right)	Hippocampus (Right)
4		Superior frontal gyrus...	Middle frontal gyrus (...	Parahippocampal gyru..
5		Superior frontal gyrus...	Inferior frontal gyrus, ...	Parahippocampal gyru..
6		Middle frontal gyrus (L...	Inferior frontal gyrus, ...	Amygdala (Left)
7		Middle frontal gyrus or...	Inferior frontal gyrus, t...	Amygdala (Right)
8		Middle frontal gyrus or...	Rolandic operculum (L...	Calcarine fissure and ..
9		Inferior frontal gyrus, t...	Rolandic operculum (R...	Calcarine fissure and ..
10		Inferior frontal gyrus, ...	Supplementary motor ...	Lingual gyrus (Left)
11		Inferior frontal gyrus, ...	Supplementary motor ...	Lingual gyrus (Right)
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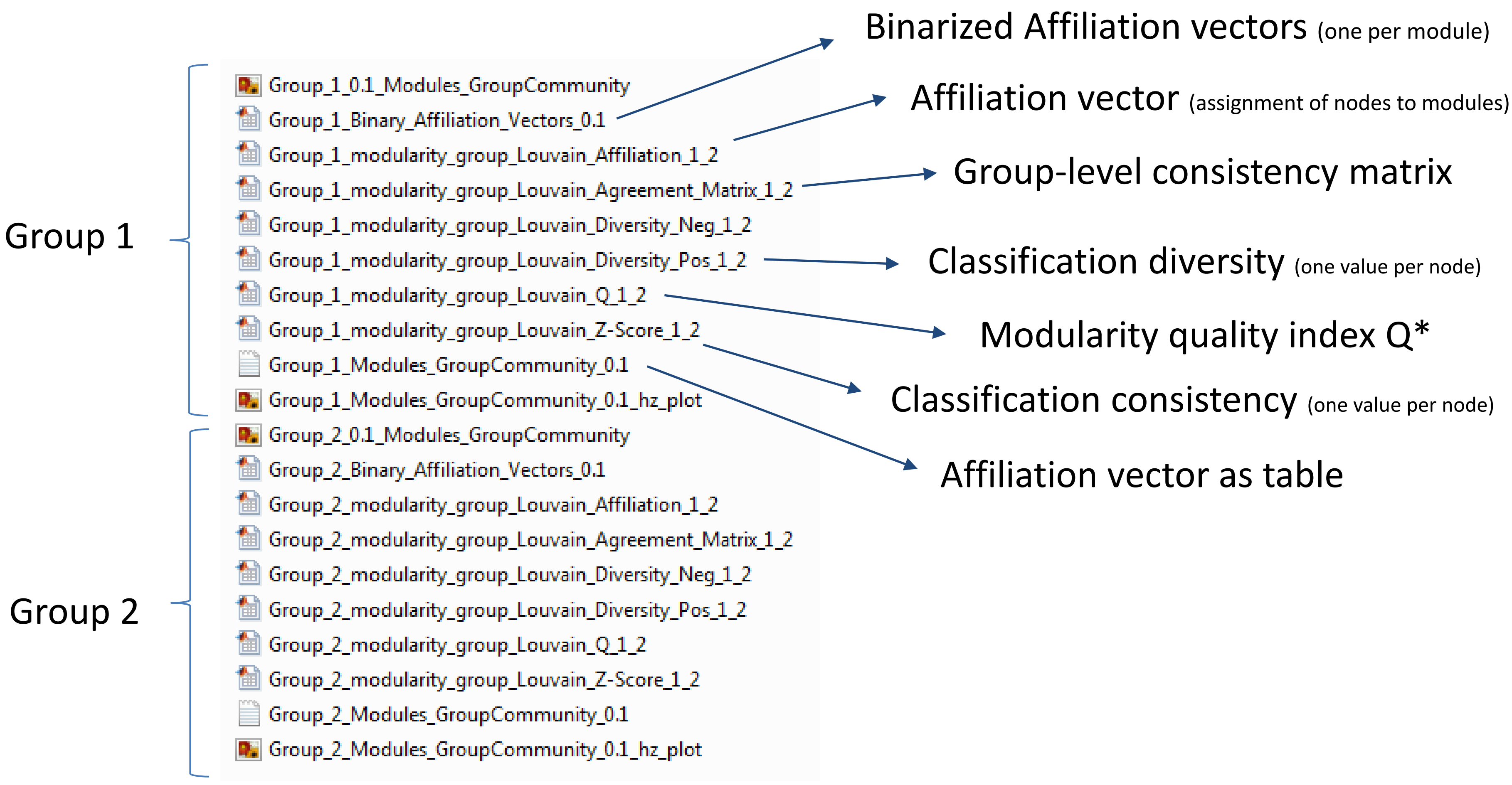
20		Anterior cingulate and...	Superior parietal gyru...	Caudate nucleus (Left)
21		Anterior cingulate and...	Inferior parietal, but su...	Caudate nucleus (Right
22		Posterior cingulate gyr...	Inferior parietal, but su...	Lenticular nucleus, pu..
23		Posterior cingulate gyr...	Supramarginal gyrus (...	Lenticular nucleus, pu..

Saved output in folder „Group Community“:



Figures created by BrainNetViewer and zh-Plots are also saved in this folder

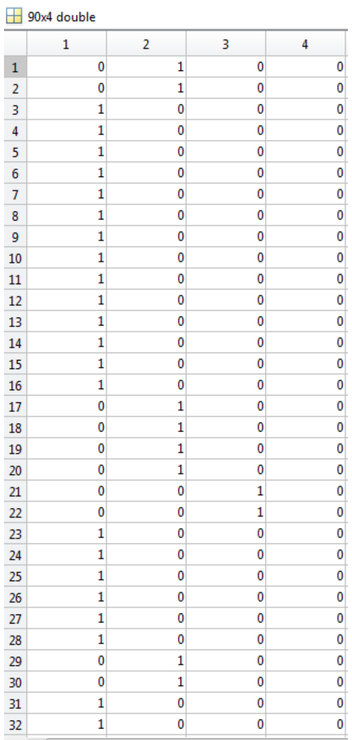
Saved output in folder „GraphVars“:

Difference in h between groups	actual_delta_h
Difference in Q between groups	actual_delta_Q
Difference in Z between groups	actual_delta_Z
MIn – between groups	actual_MIn
VIn – between groups	actual_VIn
Subject-level consistency matrices (one per subject)	agreement_matrix_1_2
Permutation distribution of difference in h (sorted)	distr_delta_h_group_perm
Permutation distribution of difference in Q (sorted)	distr_delta_Q_group_perm
Permutation distribution of difference in Z (sorted)	distr_delta_Z_group_perm
Permutation distribution MIn (sorted)	distr_MIn_group_perm
Permutation distribution VIn (sorted)	distr_VIn_group_perm
Permutation generated Affiliation vectors of rand groups	group_1_perm_C
Permutation generated h per region per permutation	group_1_perm_h
Permutation generated Q per permutation	group_1_perm_Q
Permutation generated Z per permutation	group_1_perm_Z
	group_2_perm_C
	group_2_perm_h
	group_2_perm_Q
	group_2_perm_Z
Subject-level consensus affiliation vector (one per subj)	modularity_louvain_cOut_und_1_2
Overlap of nodes in modules: Group 1 -> Group 2	Modularity_overlap_percent_1_2
Overlap of nodes in modules: Group 2 -> Group 1	Modularity_overlap_percent_2_1
P-value for h (one per region)	P_h
P-value for MIn	P_MIn
P-value for Q	P_Q
P-value for VIn	P_VIn
P-value for Z (one per region)	P_Z

Miscellaneous:

Binarized Affiliation vectors (one per module)

Group_1_Binary_Affiliation_Vectors_0.1



90x4 double

	1	2	3	4
1	0	1	0	0
2	0	1	0	0
3	1	0	0	0
4	1	0	0	0
5	1	0	0	0
6	1	0	0	0
7	1	0	0	0
8	1	0	0	0
9	1	0	0	0
10	1	0	0	0
11	1	0	0	0
12	1	0	0	0
13	1	0	0	0
14	1	0	0	0
15	1	0	0	0
16	1	0	0	0
17	0	1	0	0
18	0	1	0	0
19	0	1	0	0
20	0	1	0	0
21	0	0	1	0
22	0	0	1	0
23	1	0	0	0
24	1	0	0	0
25	1	0	0	0
26	1	0	0	0
27	1	0	0	0
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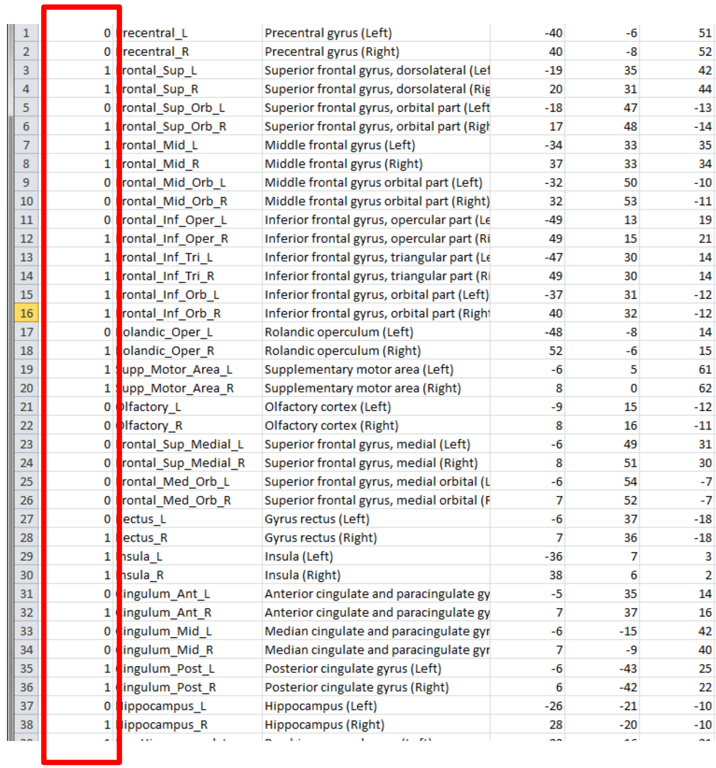
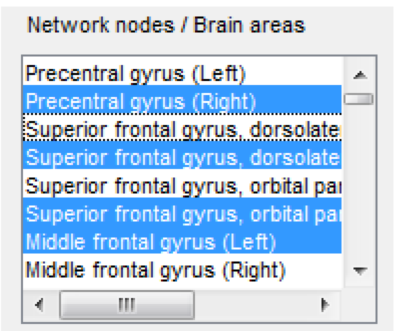
29	0	1	0	0
30	0	1	0	0
31	1	0	0	0
32	1	0	0	0



1	0	recentral_L	Precentral gyrus (Left)	-40	-6	51
2	0	recentral_R	Precentral gyrus (Right)	40	-8	52
3	1	rontal_Sup_L	Superior frontal gyrus, dorsolateral (Lef	-19	35	42
4	1	rontal_Sup_R	Superior frontal gyrus, dorsolateral (Rig	20	31	44
5	0	rontal_Sup_Orb_L	Superior frontal gyrus, orbital part (Left	-18	47	-13
6	1	rontal_Sup_Orb_R	Superior frontal gyrus, orbital part (Righ	17	48	-14
7	1	rontal_Mid_L	Middle frontal gyrus (Left)	-34	33	35
8	1	rontal_Mid_R	Middle frontal gyrus (Right)	37	33	34
9	0	rontal_Mid_Orb_L	Middle frontal gyrus orbital part (Left)	-32	50	-10
10	0	rontal_Mid_Orb_R	Middle frontal gyrus orbital part (Right)	32	53	-11
11	0	rontal_Inf_Oper_L	Inferior frontal gyrus, opercular part (Le	-49	13	19
12	1	rontal_Inf_Oper_R	Inferior frontal gyrus, opercular part (Ri	49	15	21
13	1	rontal_Inf_Tri_L	Inferior frontal gyrus, triangular part (Le	-47	30	14
14	1	rontal_Inf_Tri_R	Inferior frontal gyrus, triangular part (Ri	49	30	14
15	1	rontal_Inf_Orb_L	Inferior frontal gyrus, orbital part (Left)	-37	31	-12
16	1	rontal_Inf_Orb_R	Inferior frontal gyrus, orbital part (Right	40	32	-12
17	0	olandic_Oper_L	Rolandic operculum (Left)	-48	-8	14
18	1	olandic_Oper_R	Rolandic operculum (Right)	52	-6	15
19	1	upp_Motor_Area_L	Supplementary motor area (Left)	-6	5	61
20	1	upp_Motor_Area_R	Supplementary motor area (Right)	8	0	62
21	0	lfactory_L	Olfactory cortex (Left)	-9	15	-12
22	0	lfactory_R	Olfactory cortex (Right)	8	16	-11
23	0	rontal_Sup_Medial_L	Superior frontal gyrus, medial (Left)	-6	49	31
24	0	rontal_Sup_Medial_R	Superior frontal gyrus, medial (Right)	8	51	30
25	0	rontal_Med_Orb_L	Superior frontal gyrus, medial orbital (L	-6	54	-7
26	0	rontal_Med_Orb_R	Superior frontal gyrus, medial orbital (F	7	52	-7
27	0	ectus_L	Gyrus rectus (Left)	-6	37	-18
28	1	ectus_R	Gyrus rectus (Right)	7	36	-18
29	1	nsula_L	Insula (Left)	-36	7	3
30	1	nsula_R	Insula (Right)	38	6	2
31	0	ingulum_Ant_L	Anterior cingulate and paracingulate gy	-5	35	14
32	1	ingulum_Ant_R	Anterior cingulate and paracingulate gy	7	37	16
33	0	ingulum_Mid_L	Median cingulate and paracingulate gyr	-6	-15	42
34	0	ingulum_Mid_R	Median cingulate and paracingulate gyr	7	-9	40
35	1	ingulum_Post_L	Posterior cingulate gyrus (Left)	-6	-43	25
36	1	ingulum_Post_R	Posterior cingulate gyrus (Right)	6	-42	22
37	0	ippocampus_L	Hippocampus (Left)	-26	-21	-10
38	1	ippocampus_R	Hippocampus (Right)	28	-20	-10



Simply use (one of) the binary affiliation vectors as input to the BrainRegions xlsx sheet (first column) for subnetwork analyses