

Group of Subjects with Connectivity Multiplex Data

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October 11, 2023

For *connectivity multiplex data*, a connectivity matrix per subject is already available for different layers and can be directly imported into the relative analysis pipeline. For example, the connectivity matrix could correspond to white matter tracts obtained from dMRI or pre-calculated coactivations maps obtained from fMRI data. This Tutorial explains how to prepare and work with this kind of data.

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Subject ID	Subject Label	Brain Atlas
1	SubjectCON_MP_1	BrainAtlas(BrainAtlas ID)
2	SubjectCON_MP_2	BrainAtlas(BrainAtlas ID)
3	SubjectCON_MP_3	BrainAtlas(BrainAtlas ID)
4	SubjectCON_MP_4	BrainAtlas(BrainAtlas ID)
5	SubjectCON_MP_5	BrainAtlas(BrainAtlas ID)
6	SubjectCON_MP_6	BrainAtlas(BrainAtlas ID)
7	SubjectCON_MP_7	BrainAtlas(BrainAtlas ID)
8	SubjectCON_MP_8	BrainAtlas(BrainAtlas ID)
9	SubjectCON_MP_9	BrainAtlas(BrainAtlas ID)
10	SubjectCON_MP_10	BrainAtlas(BrainAtlas ID)
11	SubjectCON_MP_11	BrainAtlas(BrainAtlas ID)
12	SubjectCON_MP_12	BrainAtlas(BrainAtlas ID)
13	SubjectCON_MP_13	BrainAtlas(BrainAtlas ID)
14	SubjectCON_MP_14	BrainAtlas(BrainAtlas ID)
15	SubjectCON_MP_15	BrainAtlas(BrainAtlas ID)
16	SubjectCON_MP_16	BrainAtlas(BrainAtlas ID)
17	SubjectCON_MP_17	BrainAtlas(BrainAtlas ID)

Layer	br1	br2	br3	br4	br5	br6	br7	br8
br1	0	0.5703	0.8143	0.7045	0.5715	0.8341	0	0
br2	0.7294	0	0.4871	0.7770	0.5802	0.5227	0.7523	0
br3	0.8009	0.7813	0	0.5367	0.8258	0.9381	0.8523	0
br4	0.9652	0.5551	0.7038	0	0.7568	0.9069	0.8169	0
br5	0.8502	0.9675	0.6026	0.8123	0	0.6797	0.8255	0
br6	0.8153	0.7453	0.9426	0.7270	0.8479	0	0.6868	0
br7	0	0.6896	0.8820	0.9442	0.7896	0.9583	0	0
br8	0	0	0.8555	0.5478	0.8179	0.8704	0.5040	0
br9	0	0	0	0.6834	0.8599	0.9863	0.5278	0
br10	0	0	0	0	0.9619	0.5074	0.8248	0
br11	0	0	0	0	0	0.7303	0.9035	0
br12	0	0	0	0	0	0	0.5402	0
br13	0	0	0	0	0	0	0	0
br14	0.7138	0	0	0	0	0	0	0
br15	0.9223	0.5033	0	0	0	0	0	0
br16	0.7148	0.8086	0.8347	0	0	0	0	0
br17	0.7181	0.9314	0.8132	0.6630	0	0	0	0

Figure 1: GUI for a group of subjects with connectivity multiplex data. Full graphical user interface to upload a group of subjects with connectivity multiplex data in BRAPH 2.0.

Generation of Example Data

If you don't have the Example data CON_MP_XLS folder inside connectivity multiplex, then you can generate it by running the commands in Code 1.

Code 1: Code to generate the example data folder. This code can be used in the MatLab command line to generate the Example data CON_MP_XLS folder to the connectivity multiplex pipeline folder.

```
1 create_data_CON_MP_XLS() ①
2 create_data_CON_MP_TXT() ②
```

① generates the example connectivity multiplex XLS data folder.

② generates the example connectivity multiplex TXT data folder.

Open the GUI

In most analyses, the group GUI is the second step after you have selected a brain atlas. You can open it by typing `braph2` in MatLab's terminal, which allows you to select a pipeline containing the steps required to perform your analysis and upload a brain atlas. After these steps have been completed you can upload your group's data directly (Figure 2c-f) after clicking "Load Group".

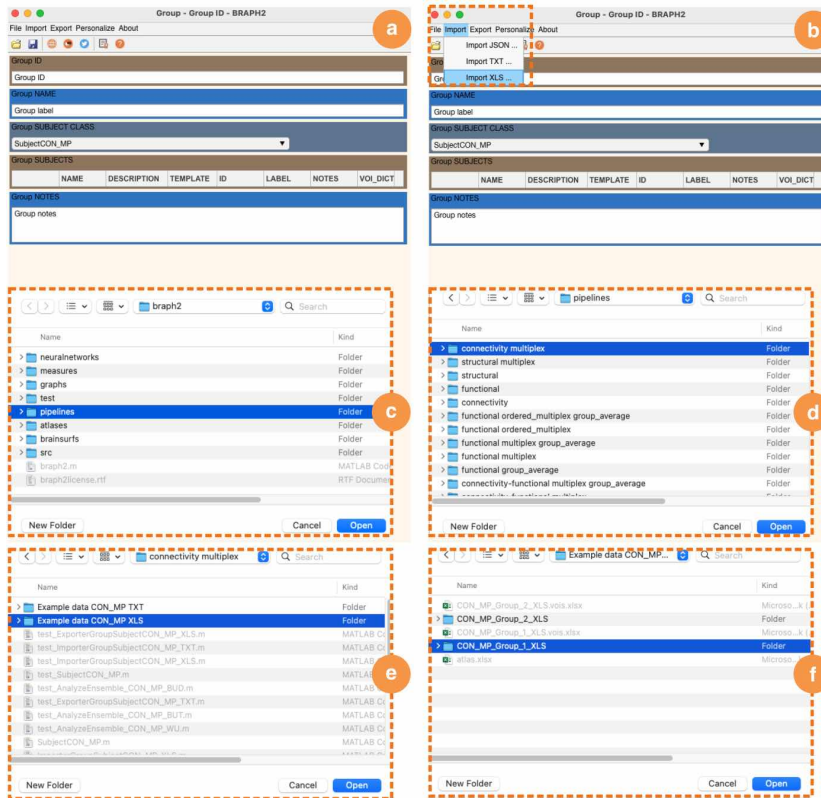


Figure 2: Upload the data of a group of subjects. Steps to upload a group of subjects with connectivity multiplex data using the GUI and an example dataset: **a** Open the group GUI. **b** Import a folder that contains one file per subject and layer with the connectivity matrix in XLS or TXT format (see below for details on their format). To upload the test connectivity multiplex data: **c-f** navigate to the BRAPH 2.0 folder pipelines, **d** connectivity multiplex, **e** Example data CON_MP_XLS, and **f** select the folder containing the connectivity matrices of one group CON_MP_Group_1_XLS.

GUI launch from command line

You can also open the GUI and upload the brain connectivity multiplex data using the command line (i.e., without opening an analysis pipeline) by typing the commands in Code 2. In this case, you can upload the data as shown in Figure 2a-f.

Code 2: Code to launch the GUI to upload a group of subjects with connectivity multiplex data. This code can be used in the MatLab command line to launch the GUI to upload a group of subjects with connectivity multiplex data without having to open a pipeline.

```
1 gr = Group('SUB_CLASS', 'SubjectCON_MP');
2
3 gui = GUIElement('PE', gr);
4 gui.get('DRAW')
5 gui.get('SHOW')
```

Visualize the Group Data

After completing the steps described in Figure 2, you can see the data (Figure 3a), and change the Group ID, name, and notes (Figure 3b).

Visualize Each Subject's Data

Finally, you can open each subject's connectivity multiplex data by selecting the subject, right click, and select "Open selection" (Figure 4a), which shows the matrix values from layer 1 (Figure 4b). Here, you can also change the subject's metadata (ID, label, notes), its variables of interest, and the values of its connectivity multiplex data.

Group - CON_MP_Group_1_XLS - BRAPH2

File Import Export Personalize About

Group ID
CON_MP_Group_1_XLS

Group NAME
CON_MP_Group_1_XLS

Group SUBJECT CLASS
SubjectCON_MP

Group SUBJECTS

	Subject ID	Subject LABEL	Brain Atlas	Variables of Interest	Layer Number	Layer Labels	Connectivity DATA LAYERS	Subject NOTES
1	<input type="checkbox"/> SubjectCON_MP_1	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
2	<input type="checkbox"/> SubjectCON_MP_10	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
3	<input type="checkbox"/> SubjectCON_MP_11	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
4	<input type="checkbox"/> SubjectCON_MP_12	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
5	<input type="checkbox"/> SubjectCON_MP_13	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
6	<input type="checkbox"/> SubjectCON_MP_14	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
7	<input type="checkbox"/> SubjectCON_MP_15	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
8	<input type="checkbox"/> SubjectCON_MP_16	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note

Group NOTES
Group loaded from /Users/anna.canal.garcia/Documents/GitHub/BRAPH2-Matlab-beta/braph2/pipelines/connectivity multiplex/Example data CON_MP_XLS/CON_MP_Group_1_XLS

Group - CON_MP_Group_1_XLS - BRAPH2

File Import Export Personalize About

Group ID
CTR

Group NAME
Controls

Group SUBJECT CLASS
SubjectCON_MP

Group SUBJECTS

	Subject ID	Subject LABEL	Brain Atlas	Variables of Interest	Layer Number	Layer Labels	Connectivity DATA LAYERS	Subject NOTES
1	<input checked="" type="checkbox"/> SubjectCON_MP_1	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 ...	2	(1 x 2)		SubjectCON_MP note
2	<input type="checkbox"/> SubjectCON_MP_10	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
3	<input type="checkbox"/> SubjectCON_MP_11	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
4	<input type="checkbox"/> SubjectCON_MP_12	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
5	<input type="checkbox"/> SubjectCON_MP_13	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
6	<input type="checkbox"/> SubjectCON_MP_14	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
7	<input type="checkbox"/> SubjectCON_MP_15	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note
8	<input type="checkbox"/> SubjectCON_MP_16	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)		SubjectCON_MP note

Group NOTES
connectivity multiplex data for Controls.

Figure 3: **Edit the group metadata.** **a** The GUI of the group's connectivity multiplex data. **b** The information you see on this GUI that can be changed. In this example, we have edited the ID, name, and notes of the group but can also change the subject's specific information.

Group - CON_MP_Group_1_XLS - BRAPH2

File Import Export Personalize About

Group ID: CTR

Group NAME:

Controls:

Group SUBJECT CLASS: SubjectCON_MP

Group SUBJECTS:

	Subject ID	Subject LABEL	Brain Atlas	Variables of Interest	Layer Number	Layer Labels	Connectivity DATA LAYERS	Subject NOTES
1	<input checked="" type="checkbox"/>	SubjectCON_MP_1	BrainAtlas(BrainAtlas ID)	IndexedDictionary with 2 VOI	2	(1 x 2)	SubjectCON_MP note	
2	<input type="checkbox"/>	Select All	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
3	<input type="checkbox"/>	Clear Selection	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
4	<input type="checkbox"/>	Invert Selection	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
5	<input type="checkbox"/>	Apply to Selection	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
6	<input type="checkbox"/>	Open Selection	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
7	<input type="checkbox"/>	Hide Selection	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	
8	<input type="checkbox"/>	Hide All	SubjectCON_MP label	BrainAtlas(BrainAtlas ID)	2	(1 x 2)	SubjectCON_MP note	

Group NOTES: connectivity mu

Export to XLS

SubjectCON_MP - SubjectCON_MP_1 - BRAPH2

File Import Export Personalize About

Subject ID: SubjectCON_MP_1

Subject LABEL: SubjectCON_MP label

Brain Atlas: BrainAtlas(BrainAtlas ID)

Variables of Interest: Age: 81, Sex: Male

Layer Number: 2

Layer Labels:

Connectivity DATA LAYERS:

layer 1

	br1	br2	br3	br4	br5	br6	br7	br8	br9	br10	br11	br12	br13	br14	br15	br16
br1	0	0.5703	0.9143	0.7045	0.5715	0.9341	0	0	0	0	0	0	0	0.8490	0.8280	0
br2	0.7294	0	0.6871	0.7770	0.5501	0.5227	0.7223	0	0	0	0	0	0	0	0.7332	0
br3	0.6059	0.7513	0	0.5367	0.8258	0.9381	0.8523	0.5242	0	0	0	0	0	0	0	0
br4	0.5652	0.5551	0.7638	0	0.7568	0.9009	0.8169	0.8267	0.8671	0	0	0	0	0	0	0
br5	0.6082	0.9675	0.5608	0.8123	0	0.6787	0.8255	0.8513	0.9477	0.5223	0	0	0	0	0	0
br6	0.5153	0.7453	0.9426	0.7270	0.6479	0	0.6849	0.7978	0.9950	0.9287	0.8841	0	0	0	0	0
br7	0	0.6896	0.8820	0.9442	0.7696	0.9593	0	0.8489	0.9704	0.7437	0.6890	0.6521	0	0	0	0
br8	0	0	0.8555	0.5478	0.8179	0.6704	0.5040	0	0.8387	0.5140	0.9624	0.6001	0.9680	0	0	0
br9	0	0	0	0.6834	0.8599	0.9863	0.5278	0.8201	0	0.6758	0.5166	0.6697	0.9604	0.9859	0	0
br10	0	0	0	0	0.9619	0.5074	0.8248	0.9376	0.8323	0	0.6950	0.7400	0.6865	0.6452	0.6919	0
br11	0	0	0	0	0	0.7303	0.9035	0.6914	0.6902	0.7652	0	0.8341	0.7943	0.5474	0.8481	0
br12	0	0	0	0	0	0	0.5402	0.8222	0.5036	0.7111	0.9847	0	0.6807	0.5671	0.9554	0
br13	0	0	0	0	0	0	0	0.8185	0.6760	0.5443	0.5712	0.8768	0	0.8404	0.7392	0
br14	0.7158	0	0	0	0	0	0	0.7301	0.8119	0.6982	0.7444	0.6182	0	0	0.5874	0
br15	0.9223	0.5033	0	0	0	0	0	0	0.8856	0.5761	0.6298	0.5119	0.7796	0	0	0
br16	0.7488	0.8368	0.6347	0	0	0	0	0	0	0.7477	0.8729	0.6092	0.5621	0.5262	0	0
br17	0.7161	0.9314	0.6132	0.6630	0	0	0	0	0	0	0.5772	0.5322	0.5675	0.8332	0	0

Subject NOTES: SubjectCON_MP notes

Figure 4: **Edit the individual subject data.** **a** Each subject's connectivity multiplex data can be opened by selecting the subject, right click, and select "Open selection". **b** In this subject GUI, it is possible to view and edit the metadata of the subject (ID, label, notes), its variables of interest (in this case, age and sex), and the connectivity multiplex data.

Preparation of the Data to be Imported

To be able to import connectivity multiplex data into BRAPH 2.0, you create a folder with the name of your group, and within this group folder, you need to include the connectivity matrices for each subject and for each layer in a single file in excel or text format. Below you can see how your group directory should look like as well as an example of a brain connectivity matrix.

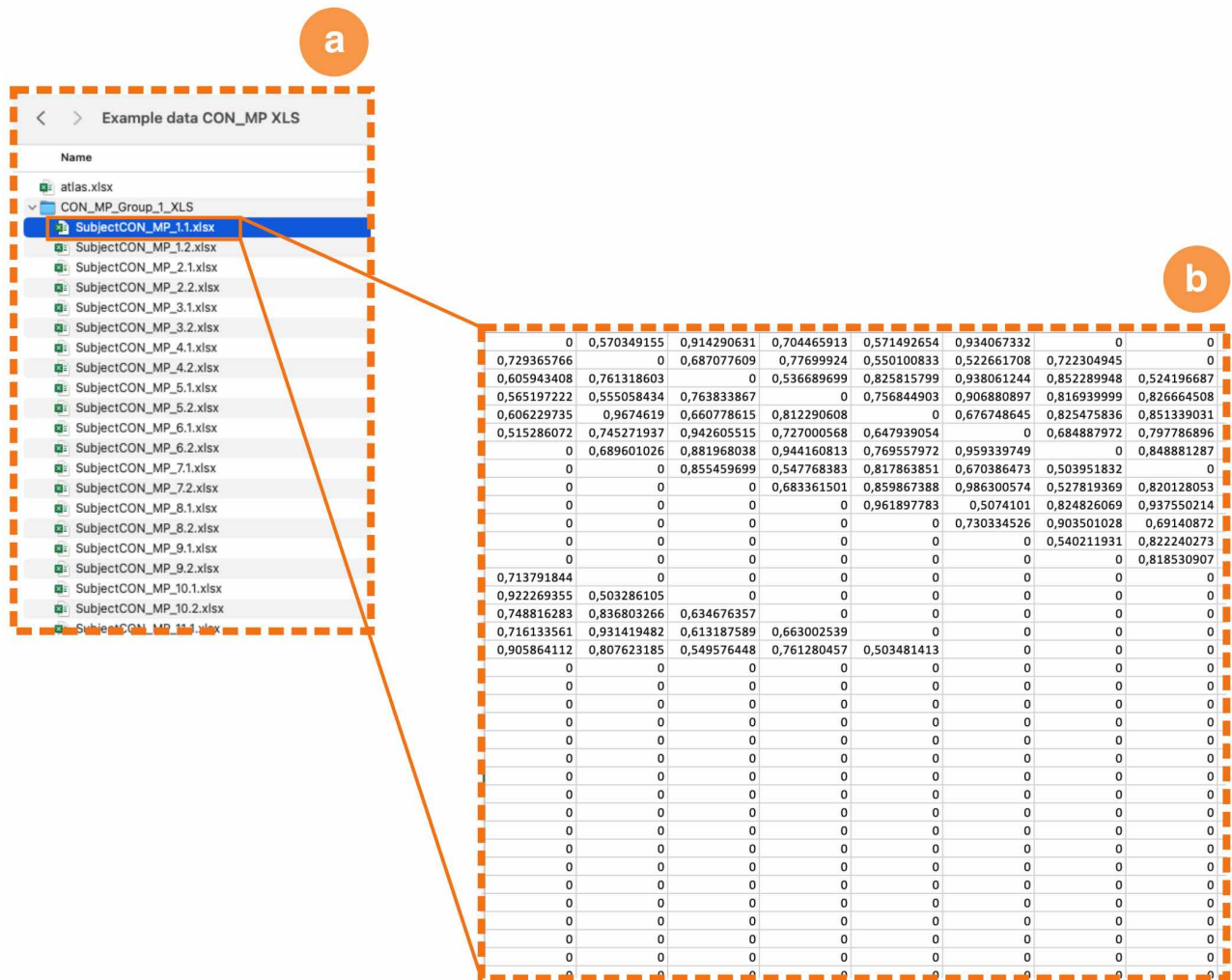


Figure 5: Data preparation. The data should be organised in the following format: **a** The connectivity matrices from each subject and each layer should be included in one folder (for example, `CON_MP_group_1.XLS`). **b** Each matrix should contain the connectivity values between each pair of brain regions denoted by the rows and columns. In this example, the (simulated) values in the matrix correspond to the fractional anisotropy (white matter integrity) of anatomical connections derived from diffusion weighted imaging.

Adding Covariates

It is very common to have *variables of interest* (i.e., *covariates* and *correlates*) in an analysis. In BRAPH 2.0, these variables of interest should be included in a separate excel file placed just outside the group's folder

a

b

	A	B	C	D	E
1	Subject ID	Age	Sex	Education	
2			Female	middle	
3	SubjectCON_MP_1	81	Male	low	
4	SubjectCON_MP_2	86	Female	middle	
5	SubjectCON_MP_3	56	Female	high	
6	SubjectCON_MP_4	34	Male	low	
7	SubjectCON_MP_5	64	Male	middle	
8	SubjectCON_MP_6	27	Male	high	
9	SubjectCON_MP_7	3	Male	high	
10	SubjectCON_MP_8	24	Male	high	
11	SubjectCON_MP_9	67	Male	low	
12	SubjectCON_MP_10	15	Female	high	

Figure 6: **Edit the Covariates.** Information that can be changed in the Covariates file: **a** The names of the variables of interest (vois). **b** In case the vois are categorical, you can state which categories they have.

and with the same name as the folder followed by .vois (Figure 6a). This file should have a specific format (Figure 6b):

Subject IDs (column A). Column A should contain the subject IDs starting from row 3.

Variables of interest (column B and subsequent columns). Column B (and subsequent columns) should contain the variables of interest (one per column). In this example we have “Age” and “Sex”, as in the example file, as well as the additional “Education”. In each column, row 1 should contain the name of the variable of interest, row 2 should contain the categories separated by a return (only for categorical variables of interest, like “Sex” and “Education”), and the subsequent rows the values of the variable of interest for each subject.