Subject_Demo

March 30, 2022

1 GLM Express: Subject / First-Level Demonstration

[1]:

```
# You can safely ignore this cell - just for local setup
%load_ext autoreload
%autoreload 2

import os
here = os.getcwd()

if '/demo' in here:
    os.chdir('..')
```

[2]:

```
# Imports
from glm_express import Subject
import nilearn.plotting as nip
from bids import BIDSLayout
import nibabel as nib
```

Hello and welcome! `GLM Express` is a lightweight package for building simple GLMs for functional neuroimaging data. Before running, consider several assumptions that this package makes:

- Your dataset is **BIDS validated**! This check is done implicitly at initialization, and the Subject object will fail if your dataset has any fatal errors
- Your dataset has been preprocessed using `fmriprep`! We assume that your raw data and events files are stored in the root of your BIDS project, and that all of your preprocessed data (confound regressors and preprocessed BOLD NifTis) are stored in a `derivatives/fmriprep` sub-directory

See below for an example dataset structure, and **see the docs** for a much more verbose explanation of BIDS and its philosophy:

[3]:

```
%%bash
tree ./bids_test/ -d
```

```
./bids_test/
  derivatives
      fmriprep
          sub-10159
              func
```

```
        sub-10171
            func
        sub-10189
            func
        sub-10206
            func
        sub-10217
            func
        sub-10225
            func
        sub-10227
            func
        sub-10228
            func
        sub-10235
            func
        sub-10249
            func
sub-10159
    beh
    func
sub-10171
    beh
    func
sub-10189
    beh
    func
sub-10206
    beh
    func
sub-10217
    beh
    func
sub-10225
    beh
    func
sub-10227
    beh
    func
sub-10228
    beh
    func
sub-10235
    beh
    func
sub-10249
    beh
    func
```

```
52 directories
```

Instantiating a BIDSLayout object is a solid sanity check to make sure your data is BIDS-compliant (this happens under the hood in GLM Express)

[4]:
```python
bids = BIDSLayout('./bids_test/')
```

[5]:
```python
print(bids.get_subjects())
```

```
['10159', '10171', '10189', '10206', '10217', '10225', '10227', '10228',
'10235', '10249']
```

1.1 Using the glm_express.Subject object

Several parameters are required to instantiate a Subject object in GLM Express:

- sub_id: Subject ID, which should match the subject's label in your BIDS project
- task: The name of the functional task, which will match all relevant files
- bids_root: The top of your BIDS project (we assume that you **are not** running GLM Express inside your BIDS project, but rather from at least one directory level above)

In addition, there are multiple parameters with **default parameters**:

- suppress: Defaults to False | Determines if a dictionary of Subject attributes print at __init__
- template_space: Defaults to MNI152NLin2009 | This is the template that your data was preprocessed to in fmriprep
- repetition_time: Defaults to 1. | The TR from you functional run
- dummy_scans: Defaults to 0 | Any non-steady state volumes detected by fmriprep; these can be updated programatically before creating your design matrix

The Subject object also creates a output directory when instantiated - this is where all of your contrast maps, plots and other data derived from your first level models will be stored

[6]:
```python
# Instantiate your Subject object
subject = Subject('10159', task='stopsignal', bids_root='./bids_test/')
```

```
{
    "Subject ID": "10159",
    "Task": "stopsignal",
    "# of Functional Runs": 1,
    "Output Directory": "./bids_test/derivatives/first-level-
output/sub-10159/task-stopsignal",
    "Defined Contrasts": "default",
    "Confound Regressors": [
        "GlobalSignal",
        "FramewiseDisplacement",
        "WhiteMatter",
        "stdDVARS"
    ]
}
```

[7]:

```
subject.first_level_output
```

[7]:

```
'./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal'
```

1.1.1 Subject Attributes

As we noted above, the `Subject` object defaults to several parameters but these can be easily overridden with the built-in `set_{ }` functions

[8]:

```
subject.template_space
```

[8]:

```
'MNI152NLin2009'
```

[9]:

```
subject.set_template_space('MNI152Lin6')
subject.template_space
```

[9]:

```
'MNI152Lin6'
```

[10]:

```
subject.dummy_scans
```

[10]:

```
0
```

[11]:

```
subject.set_dummy_scans(2)
subject.dummy_scans
```

[11]:

```
2
```

[12]:

```
subject.t_r
```

[12]:

```
1.0
```

[13]:

```
subject.set_tr(2.)
subject.t_r
```

[13]:

```
2.0
```

The `Subject` object also creates a `bids_container` attribute - this is a dictionary with keys per functional run AND keys per data type (e.g., functional, events, confounds)

[14]:

```
subject.bids_container
```

[14]:

```
{'run-1': {'func':
'./bids_test/derivatives/fmriprep/sub-10159/func/sub-10159_task-
stopsignal_bold_space-MNI152NLin2009cAsym_preproc.nii.gz',
  'event': './bids_test/sub-10159/func/sub-10159_task-stopsignal_events.tsv',
  'confound': './bids_test/derivatives/fmriprep/sub-10159/func/sub-10159_task-
stopsignal_bold_confounds.tsv'},
 'all_func': ['./bids_test/derivatives/fmriprep/sub-10159/func/sub-10159_task-
stopsignal_bold_space-MNI152NLin2009cAsym_preproc.nii.gz'],
 'all_events': ['./bids_test/sub-10159/func/sub-10159_task-
stopsignal_events.tsv'],
 'all_confounds':
['./bids_test/derivatives/fmriprep/sub-10159/func/sub-10159_task-
stopsignal_bold_confounds.tsv']}
```

This dictionary is also saved locally to the current subject's output directory in a JSON file

[15]:
```
os.listdir(subject.first_level_output)
```

[15]:
```
['models', 'plots', 'sub-10159_task-stopsignal_bids-container.json']
```

1.1.2 Building a Model

To build a simple GLM, we need the **preprocessed NifTi files** and a **design matrix corresponding to each functional run** … `GLM Express` is optimized to accept run arguments, but defaults to **"ALL"**, which gives you an aggregated DataFrame of either events or confounds

[16]:
```
# We'll start with a fresh Subject to model with
subject = Subject('10159', task='stopsignal', bids_root='./bids_test/')
```

```
{
    "Subject ID": "10159",
    "Task": "stopsignal",
    "# of Functional Runs": 1,
    "Output Directory": "./bids_test/derivatives/first-level-
output/sub-10159/task-stopsignal",
    "Defined Contrasts": "default",
    "Confound Regressors": [
        "GlobalSignal",
        "FramewiseDisplacement",
        "WhiteMatter",
        "stdDVARS"
    ]
}
```

[17]:
```
subject.load_events(run=1)
```

[17]:
```
          onset  duration trial_type PresentedStimulusArrowDirection  \
0      0.006134     1.500         GO                            LEFT
1      0.000000     2.250        NaN                     BLANKSCREEN
2      3.762595     1.500         GO                           RIGHT
3      0.000000     0.750        NaN                     BLANKSCREEN
```

```
4      6.013056     1.500         GO                               LEFT
..          …          …        …                                 …
251    0.000000     0.500        NaN                        BLANKSCREEN
252  347.888159     1.500         GO                               LEFT
253    0.000000     1.500        NaN                        BLANKSCREEN
254  350.883213     1.500         GO                              RIGHT
255    0.000000     0.625        NaN                        BLANKSCREEN

     ReactionTime SubjectResponseButton  SubjectResponseButtonCode  \
0        0.416274                  LEFT                          5
1        0.000000                   NaN                          0
2        0.395370                 RIGHT                         28
3        0.000000                   NaN                          0
4        0.397906                  LEFT                          5
..            …                   …                        …
251      0.000000                   NaN                          0
252      0.515824                  LEFT                          5
253      0.000000                   NaN                          0
254      0.383631                 RIGHT                         28
255      0.000000                   NaN                          0

    SubjectResponseCorrectness  TrialOutcome  StopSignalDelay  LadderNumber  \
0              CorrectResponse  SuccessfulGo              0.0             0
1                          NaN           NaN              0.0             0
2              CorrectResponse  SuccessfulGo              0.0             0
3                          NaN           NaN              0.0             0
4              CorrectResponse  SuccessfulGo              0.0             0
..                         …           …              …          …
251                        NaN           NaN              0.0             0
252            CorrectResponse  SuccessfulGo              0.0             0
253                        NaN           NaN              0.0             0
254            CorrectResponse  SuccessfulGo              0.0             0
255                        NaN           NaN              0.0             0

     LadderTime  LadderMovement  TimeCourse  onset_noTriggerAdjust  \
0             0               0       0.000               0.006134
1             0               0       1.500               0.000000
2             0               0       3.750               3.762595
3             0               0       5.250               0.000000
4             0               0       6.000               6.013056
..          …             …         …                    …
251           0               0     347.375               0.000000
252           0               0     347.875             347.888159
253           0               0     349.375               0.000000
254           0               0     350.875             350.883213
255           0               0     352.375               0.000000
```

```
     TimeCourse_noTriggerAdjust  run
0                         0.000    1
1                         1.500    1
2                         3.750    1
3                         5.250    1
4                         6.000    1
..                          …   …
251                     347.375    1
252                     347.875    1
253                     349.375    1
254                     350.875    1
255                     352.375    1

[256 rows x 17 columns]
```

[18]:

```
subject.load_confounds(run=1)
```

[18]:

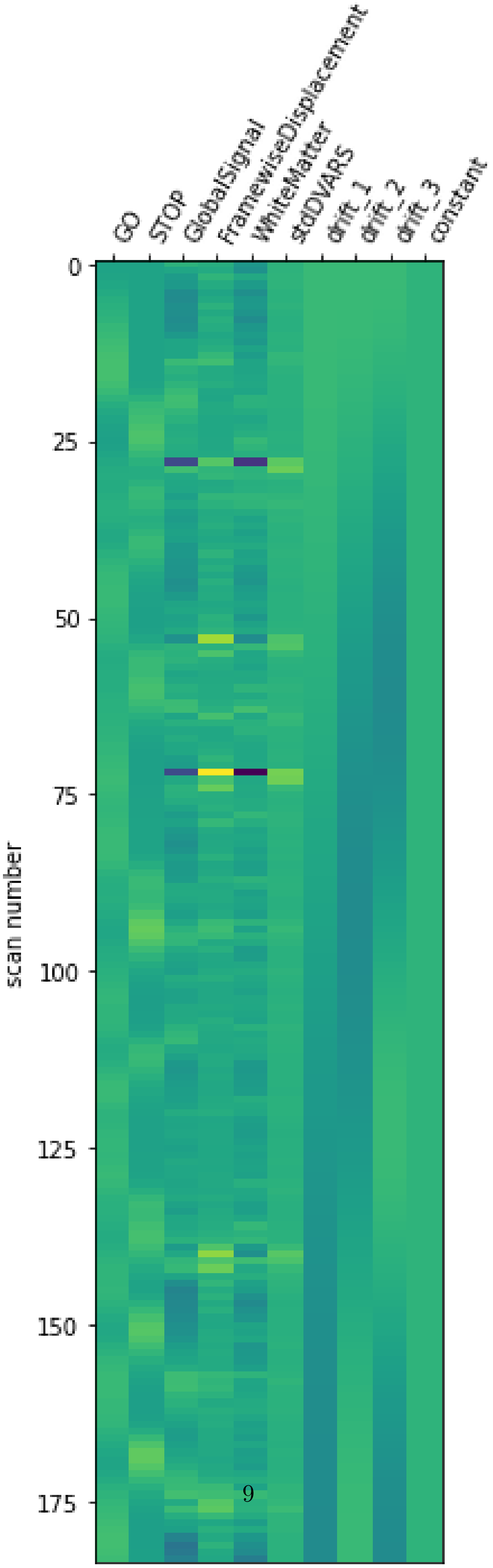
```
     WhiteMatter  GlobalSignal  stdDVARS  non-stdDVARS  vx-wisestdDVARS  \
0      -0.899719      2.227516       NaN           NaN              NaN
1      -1.246341      0.326954  1.090498     24.634428         1.026863
2       0.366020     -1.068786  1.151430     26.010887         1.027507
3      -0.564770     -1.443347  1.106344     24.992373         0.920317
4      -1.436600     -3.153236  0.914109     20.649788         0.871629
..           …             …         …            …                …
179     0.513565     -0.389184  1.118991     25.278082         0.983155
180    -0.904468     -4.511670  1.011077     22.840292         0.980504
181    -1.420769     -6.542420  0.993432     22.441696         0.958697
182    -1.746273     -5.993458  1.013192     22.888075         0.931125
183    -2.754395     -4.735695  0.930990     21.031126         0.854723

     FramewiseDisplacement  tCompCor00  tCompCor01  tCompCor02  tCompCor03  \
0                      NaN   -0.118771    0.113172   -0.032137    0.041810
1                 0.099904   -0.181387    0.036984    0.113388    0.048676
2                 0.252018   -0.046286   -0.033369   -0.076722    0.032938
3                 0.122212   -0.043669   -0.053250   -0.036809   -0.024905
4                 0.014257   -0.074981   -0.079292    0.079099   -0.054966
..                     …           …           …           …           …
179               0.183595   -0.089380    0.077009    0.035236   -0.036337
180               0.085425   -0.113513   -0.016334    0.127348   -0.157195
181               0.226487   -0.108002   -0.102629    0.051931   -0.220408
182               0.086695   -0.099087   -0.080652   -0.075379   -0.196365
183               0.058631   -0.091480   -0.032773   -0.024237   -0.147408

     …  aCompCor03  aCompCor04  aCompCor05         X         Y         Z  \
0    …    0.018290   -0.106118    0.188625  0.143525 -0.052645 -0.274967
1    …    0.058030   -0.015722    0.111118  0.163622 -0.028109 -0.263217
2    …   -0.052342   -0.031574   -0.061752  0.118415 -0.006555 -0.167094
```

```
3    …    0.010522   -0.061436    0.018885  0.096408 -0.006393 -0.137269
4    …    0.063985   -0.049137    0.070348  0.102231 -0.006412 -0.136650
..   …         …          …          …         …         …         …
179  …    0.146618    0.032852    0.061648 -0.239208  0.295401 -0.695440
180  …    0.196972   -0.086517    0.093522 -0.239296  0.272096 -0.659105
181  …    0.158629   -0.156444   -0.031886 -0.222895  0.271756 -0.580863
182  …    0.161150   -0.022039   -0.135137 -0.239418  0.252843 -0.598063
183  …    0.180771   -0.010333   -0.025773 -0.261471  0.252864 -0.606944

         RotX      RotY      RotZ  run
0    0.001024  0.001434  0.000467    1
1    0.000837  0.002068  0.000516    1
2    0.001868  0.001368  0.000464    1
3    0.000894  0.000948  0.000454    1
4    0.001024  0.000948  0.000429    1
..        …         …         …   …
179  0.015381  0.000187 -0.008214    1
180  0.015512  0.000204 -0.008579    1
181  0.014104  0.000714 -0.009290    1
182  0.014242  0.000242 -0.009219    1
183  0.013995  0.000127 -0.009028    1

[184 rows x 25 columns]
```

Likewise, the `generate_design_matrix` function takes a `run` argument as well … for each functional run, this function aggregates relevant columns from the events file and your selected confounds (defined externally in the `task_information.json` file)

[19]:
```
nip.plot_design_matrix(subject.generate_design_matrix(run=1))
```

[19]:
```
<AxesSubplot:label='conditions', ylabel='scan number'>
```


GO
STOP
GlobalSignal
FramewiseDisplacement
WhiteMatter
stdDVARS
drift_1
drift_2
drift_3
constant
0
25
50
75
100
125
150
175
scan number

The confounds below were selected for demonstrative purposes, but can be overriden by either:

- Updating the `task_information.json` file manually, or
- Updating the `Subject` attributes using `set_confound_regressors`

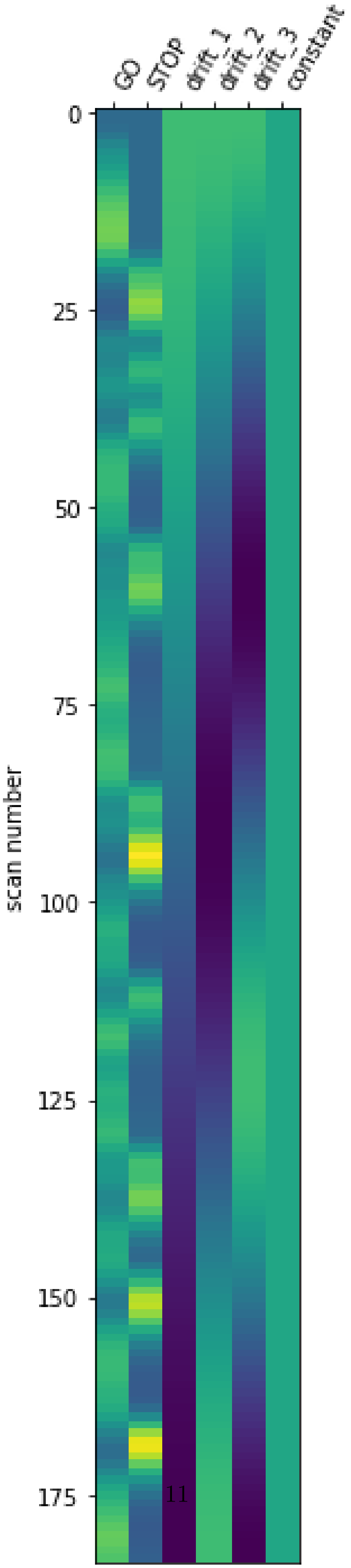
```
[20]: subject.confound_regressors
```

```
[20]: ['GlobalSignal', 'FramewiseDisplacement', 'WhiteMatter', 'stdDVARS']
```

```
[21]: subject.set_confound_regressors([])
```

```
[22]: nip.plot_design_matrix(subject.generate_design_matrix(run=1))
```

```
[22]: <AxesSubplot:label='conditions', ylabel='scan number'>
```


GO
STOP
drift_1
drift_2
drift_3
constant
scan number
0
25
50
75
100
125
150
175

The contrasts for each task are `'default'` when the `task_information.json` file is created … you can either update the file with a dictionary of contrasts, or feed your `Subject` a dictionary of contrasts

In either case, you should follow `{contrast_name: column1 - column2}` format

```
[23]: subject.contrasts
```

```
[23]: 'default'
```

```
[24]: subject.set_design_contrasts({'new_contrast':'STOP - GO'})
```

```
[25]: subject.contrasts
```

```
[25]: {'new_contrast': 'STOP - GO'}
```

Your subject's first level output directory is empty by default:

```
[26]: %%bash
      tree ./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
```

```
./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
  models
      condition-maps
      contrast-maps
  plots
      condition-maps
      contrast-maps
  sub-10159_task-stopsignal_bids-container.json

6 directories, 1 file
```

Calling the `run_first_level_glm` function will create design matrices for each functional run, and fit a model to your specifications:

```
[27]: subject.run_first_level_glm()
```

```



Running first-level designs for STOPSIGNAL with the following parameters:




                Non-steady state regressors:        False


                Modulators:                         False
```

```
            Auto-block regressors:              False

            Motion outliers:                    True

            Fixation trials:                    True




=== Fitting GLM ===

  0%|          | 0/2 [00:00<?, ?it/s]


=== Mapping condition z-scores ===


100%|     | 2/2 [00:08<00:00,  4.27s/it]
  0%|          | 0/1 [00:00<?, ?it/s]


=== Mapping contrast z-scores ===


100%|     | 1/1 [00:05<00:00,  5.69s/it]



=== STOPSIGNAL contrasts computed! Subject 10159 has been mapped ===
```

All contrast maps, plots, and summary data files have been successfully stored in your subject's first level output directory:

[28]:

```
%%bash
tree ./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
```

```
./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
  models
      condition-maps
          sub-10159_condition-GO_smoothing-8mm_z-map.nii.gz
          sub-10159_condition-STOP_smoothing-8mm_z-map.nii.gz
      contrast-maps
           sub-10159_contrast-new_contrast_smoothing-8mm_z-map.nii.gz
  plots
      condition-maps
          sub-10159_condition-GO_smoothing-8mm_contrast-summary.html
          sub-10159_condition-GO_smoothing-8mm_plot-stat-map.png
```

```
            sub-10159_condition-STOP_smoothing-8mm_contrast-summary.html
            sub-10159_condition-STOP_smoothing-8mm_plot-stat-map.png
        contrast-maps
            sub-10159_contrast-new_contrast_smoothing-8mm_contrast-summary.html
            sub-10159_contrast-new_contrast_smoothing-8mm_plot-stat-map.png
        sub-10159_task-stopsignal_run-1_design-matrix.jpg
    sub-10159_task-stopsignal_bids-container.json

6 directories, 11 files
```

The `smoothing` parameter defaults to `8.`, but can be updated as you see fit. This also updates the naming conventions for all output files, so you don't have to worry about files being overwritten:

[29]:

```python
subject.run_first_level_glm(smoothing=4.)
```

```



Running first-level designs for STOPSIGNAL with the following parameters:



            Non-steady state regressors:        False

            Modulators:                         False

            Auto-block regressors:              False

            Motion outliers:                    True

            Fixation trials:                    True





=== Fitting GLM ===

  0%|          | 0/2 [00:00<?, ?it/s]


=== Mapping condition z-scores ===


100%|      | 2/2 [00:09<00:00,  4.69s/it]
  0%|          | 0/1 [00:00<?, ?it/s]


=== Mapping contrast z-scores ===
100%|     | 1/1 [00:06<00:00,  6.84s/it]
```

```
=== STOPSIGNAL contrasts computed! Subject 10159 has been mapped ===
```

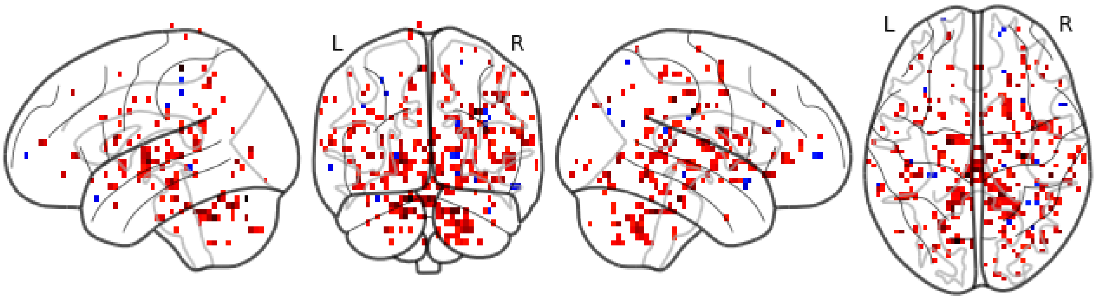
[30]:

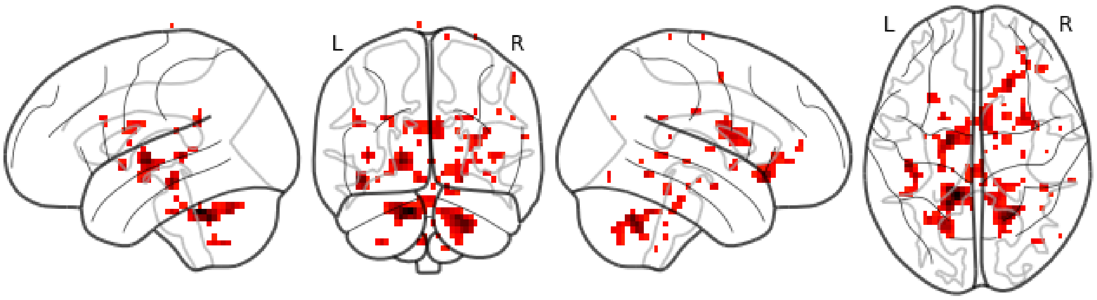
```
%%bash
tree ./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
```

```
./bids_test/derivatives/first-level-output/sub-10159/task-stopsignal/
  models
      condition-maps
          sub-10159_condition-GO_smoothing-4mm_z-map.nii.gz
          sub-10159_condition-GO_smoothing-8mm_z-map.nii.gz
          sub-10159_condition-STOP_smoothing-4mm_z-map.nii.gz
          sub-10159_condition-STOP_smoothing-8mm_z-map.nii.gz
      contrast-maps
          sub-10159_contrast-new_contrast_smoothing-4mm_z-map.nii.gz
          sub-10159_contrast-new_contrast_smoothing-8mm_z-map.nii.gz
  plots
      condition-maps
          sub-10159_condition-GO_smoothing-4mm_contrast-summary.html
          sub-10159_condition-GO_smoothing-4mm_plot-stat-map.png
          sub-10159_condition-GO_smoothing-8mm_contrast-summary.html
          sub-10159_condition-GO_smoothing-8mm_plot-stat-map.png
          sub-10159_condition-STOP_smoothing-4mm_contrast-summary.html
          sub-10159_condition-STOP_smoothing-4mm_plot-stat-map.png
          sub-10159_condition-STOP_smoothing-8mm_contrast-summary.html
          sub-10159_condition-STOP_smoothing-8mm_plot-stat-map.png
      contrast-maps
          sub-10159_contrast-new_contrast_smoothing-4mm_contrast-summary.html
          sub-10159_contrast-new_contrast_smoothing-4mm_plot-stat-map.png
          sub-10159_contrast-new_contrast_smoothing-8mm_contrast-summary.html
          sub-10159_contrast-new_contrast_smoothing-8mm_plot-stat-map.png
      sub-10159_task-stopsignal_run-1_design-matrix.jpg
  sub-10159_task-stopsignal_bids-container.json

6 directories, 20 files
```

[31]:

```
contrast_dirs = os.path.join(subject.first_level_output, 'models/contrast-maps')
contrasts = [os.path.join(contrast_dirs, x) for x in os.listdir(contrast_dirs)]

for file in contrasts:
    nip.plot_glass_brain(file, threshold=2.8, plot_abs=False,␣
 ↪display_mode='lyrz')
```





C'est voila! Two different smoothing kernels have been successfully applied to the data, and now we can repeat for all subjects in our BIDS Project. Happy modeling!