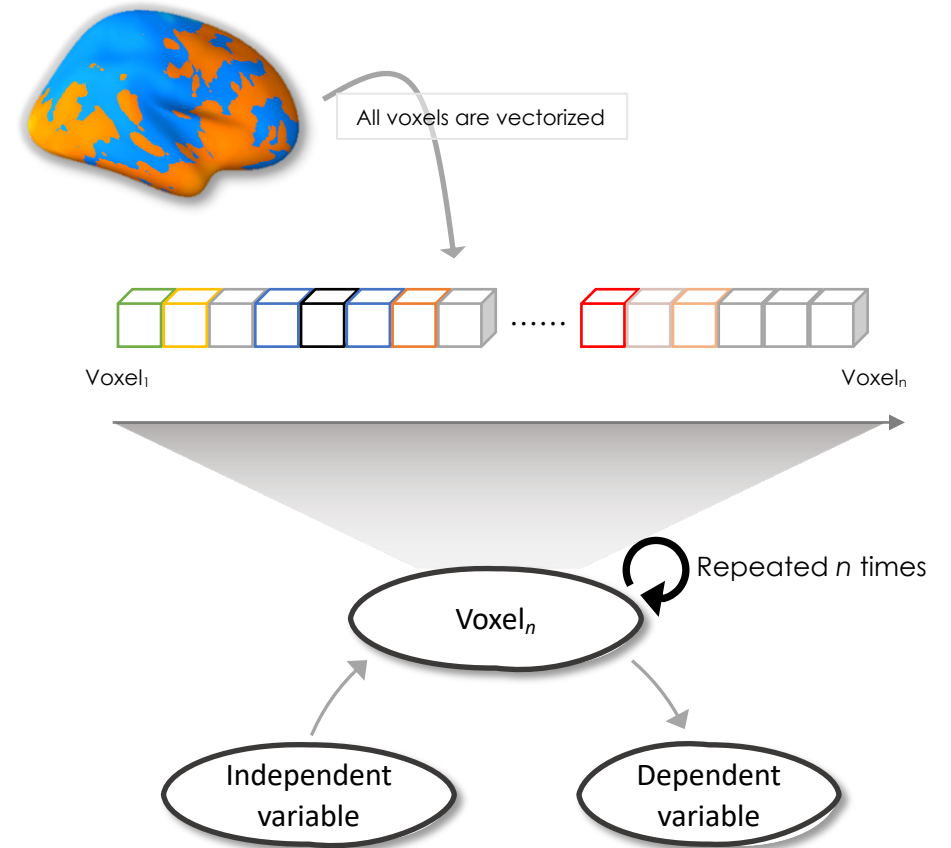


- **mediation_dream**

(<https://github.com/cocoanlab/cocoanCORE>)

- Motivation 1:
: When performing multilevel mediation analysis for whole brain, It takes a lot of time to get results because only one CPU core is working for the analysis
e.g., if you have 200,000 voxels, the analysis will be performed 200,000 times sequentially



It usually takes two weeks to finish this analysis

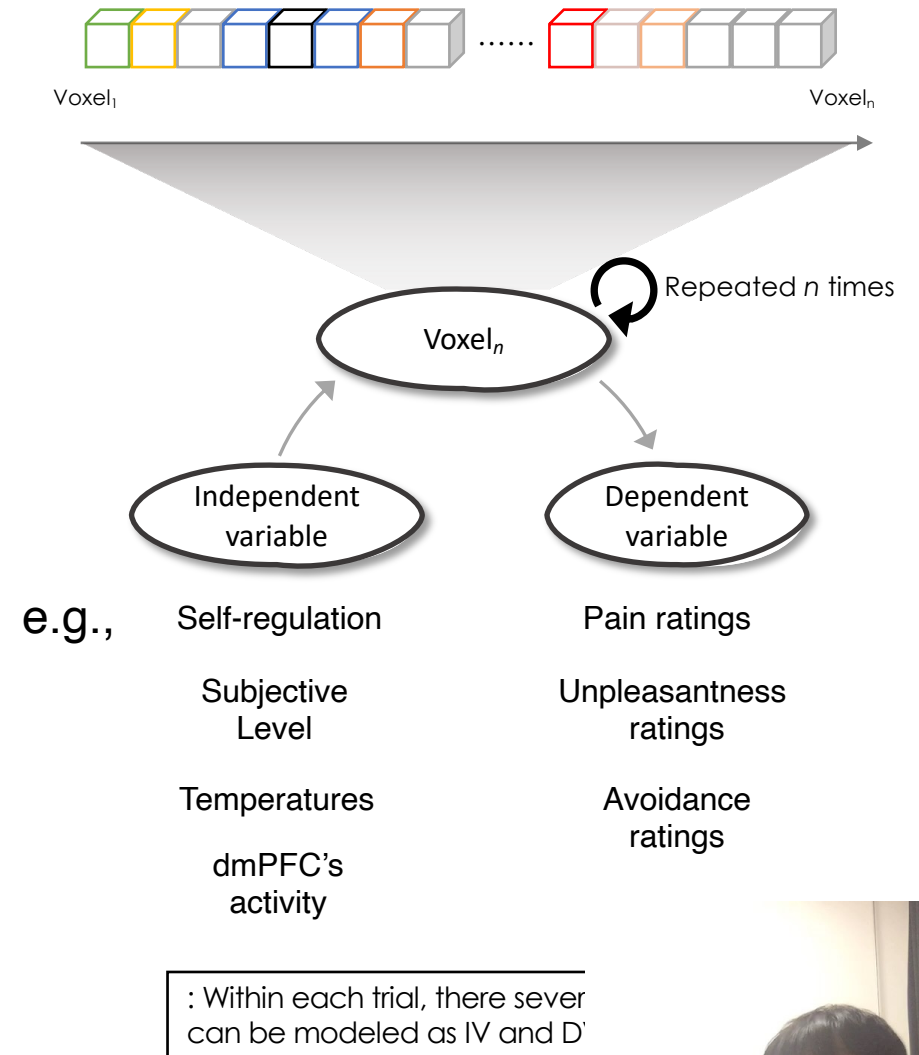
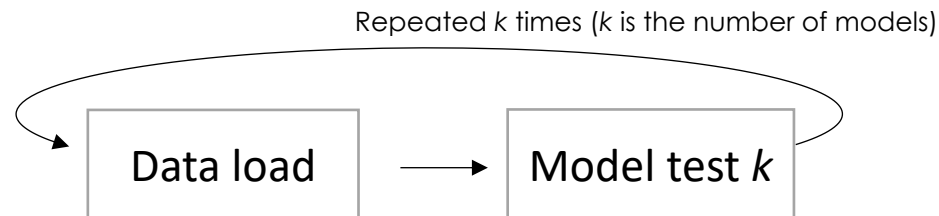


Introduction to Mediation_Dream

- **mediation_dream**

(<https://github.com/cocoanlab/cocoanCORE>)

- Motivation 2:
 - : If we want to test several models, it is also hugely influenced by the number of the models.
 - : Whenever the models are tested, same fMRI data should be loaded repeatedly



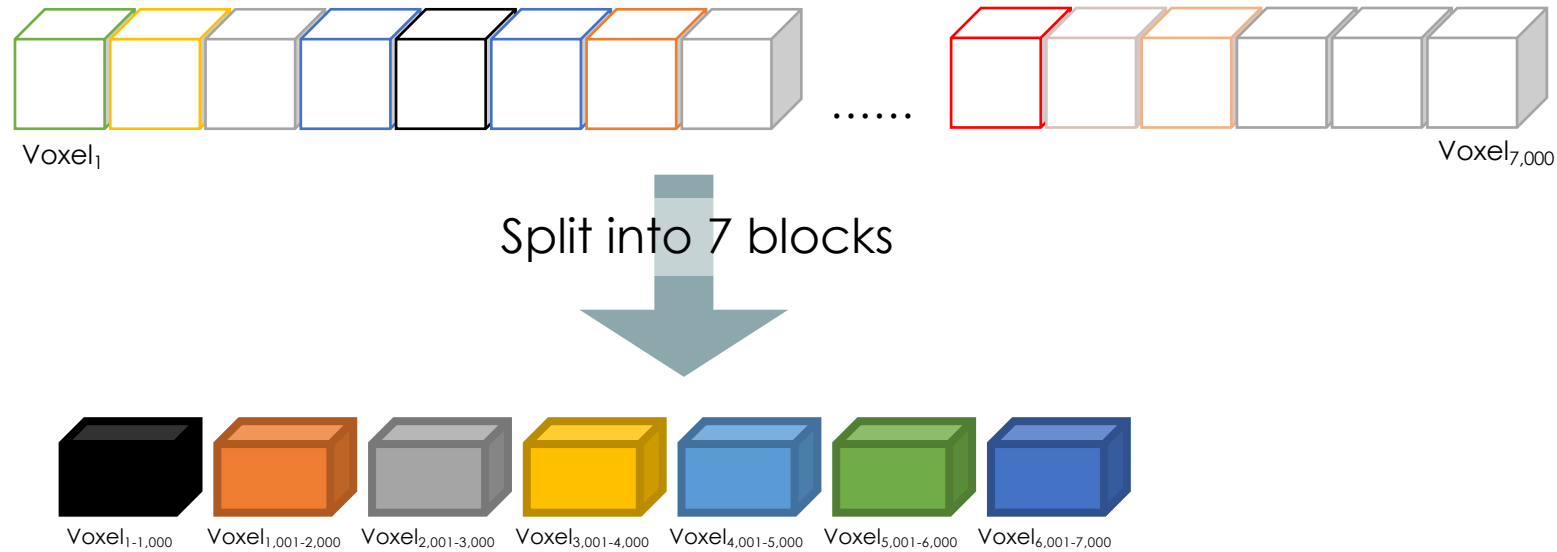
- **mediation_dream** (<https://github.com/cocoanlab/cocoanCORE>)
 - To overcome these issues (*WE WANT TO GET ANALYSIS RESULTS FASTER*), this function was created
 - You can reduce a processing time from 2 weeks to 3 or 4 days
 - It is intended to performing parallel processing of whole-brain multilevel mediation analysis
 - **CanlabCORE, cocoanCORE and mediationToolbox** must be added to your path
 - Recommendations
 - It is for the multilevel whole—brain mediation analysis especially,
 - with bootstrap option
 - voxels > 1,000 and models > 2
 - A high-performance computer with several CPU cores and RAM storage is needed



- The algorithm of *mediation_dream*

- If you want to perform seven simultaneous the whole-brain mediation analysis

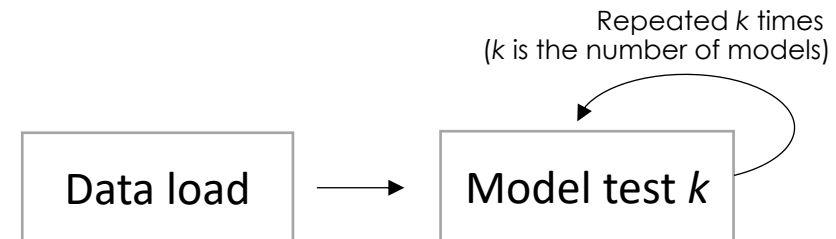
1. All voxels in brain are divided into **7 blocks**



- The algorithm of *mediation_dream*

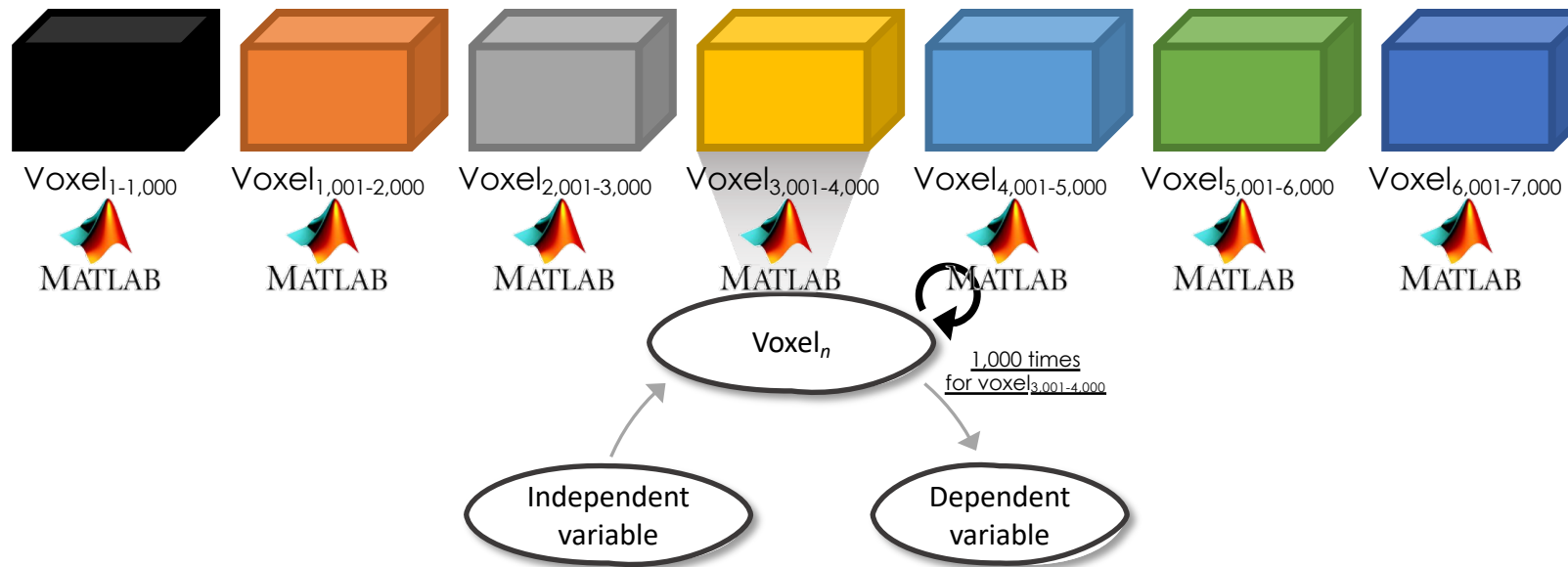
- If you want to perform seven simultaneous the whole-brain mediation analysis
 1. All voxels in brain are divided into **7 blocks**
 2. Put all models you want to test in the function

| | IV | DV |
|----------------|------------------|------------------------|
| Model 1 | Self-regulation | Pain ratings |
| Model 2 | Subjective Level | Unpleasantness ratings |
| Model 3 | Temperatures | Avoidance ratings |
| Model 4 | dmPFC's activity | Pain ratings |



- The algorithm of *mediation_dream*

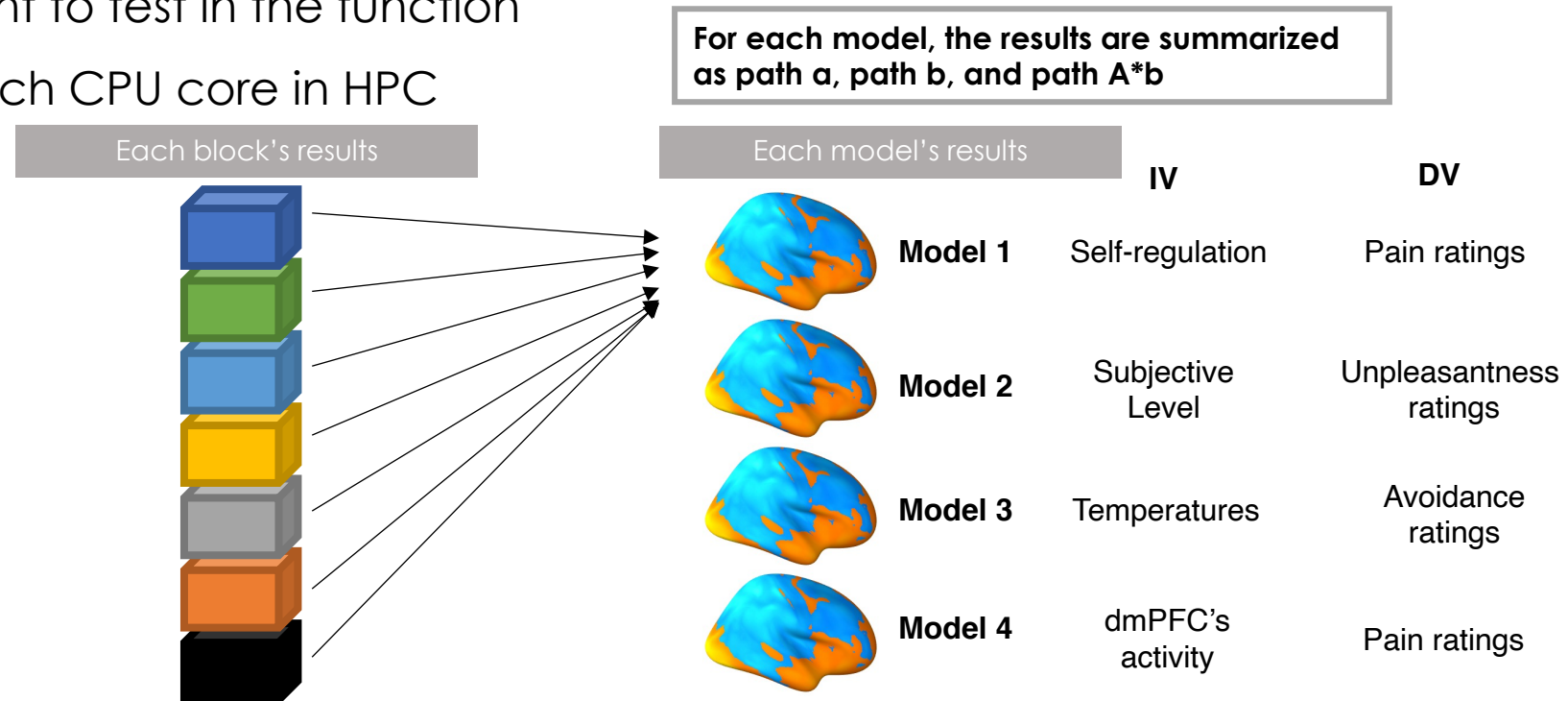
- If you want to perform seven simultaneous the whole-brain mediation analysis
 1. All voxels in brain are divided into **7 blocks**
 2. Put all models you want to test in the function
 3. Run each script on each CPU core in HPC



- The algorithm of *mediation_dream*

- If you want to perform seven simultaneous the whole-brain mediation analysis

1. All voxels in brain are divided into **7 blocks**
2. Put all models you want to test in the function
3. Run each script on each CPU core in HPC
4. Summarize the results



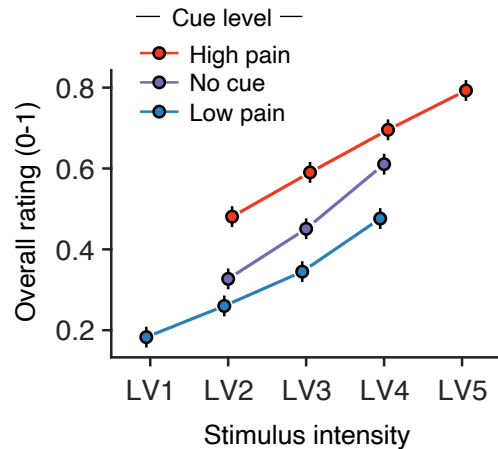
- Be careful
 - This function uses **a global variable**
 - Making a brain mask for own study is important
 - Even if each brain was spatially normalized, some voxels can have zero values (especially, in the brainstem)
 - If this situation happens, it can generate an error regarding no variance



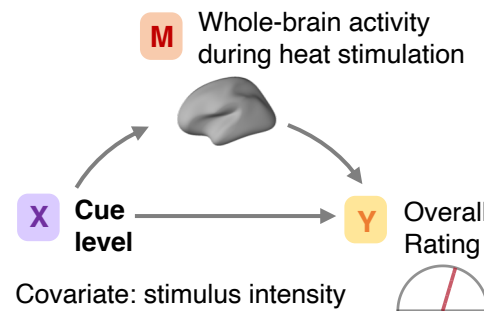
Mediation_Dream: Examples

- STEP1: Make variable structure
- STEP2: Build models
- STEP3: Divide fMRI data and scripts for parallel processing (mediation_dream_wani.m)
- STEP4: Run each script in MATLAB with each CPU core (1 CPU core = 1 script)
- STEP5: Summarize each result (mediation_dream_combined_wani.m)

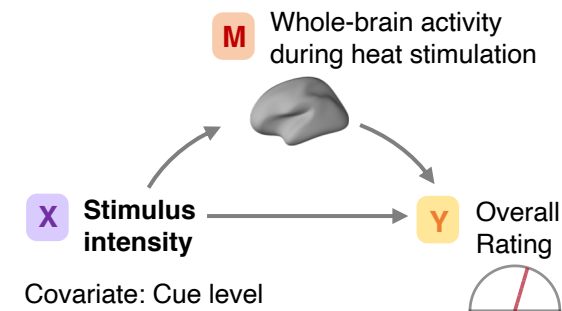
a Behavioral results: overall pain rating



b Whole-brain mediation for the cue effects



c Whole-brain mediation for the stimulus intensity



(Gim et al., in prep)



Mediation_Dream: Examples

- STEP1: Make variable structure

(see `cocoanCORE/Statistics/mediation_dream/mediation_dream_suhwan_example_code_3.m`)

The structure of 'med_vars'

```
med_vars =  
  
    struct with fields:  
  
        M: {1×58 cell}  
        X1: {1×58 cell}  
        X2: {1×58 cell}  
        Y: {1×58 cell}  
        model_name: '/sas1/cocoanlab/data/SEMIC/analysis/imaging/first_level/model03a_
```

med_vars.X1 = stimulus intensity
med_vars.X2 = cue level
med_vars.Y = overall pain rating
med_vars.M = the address of heat-stimulation induced brain activity (fMRI data_

The address of fMRI data should be included as cell type

```
med_vars.M{1}  
  
ans =  
  
    66×1 cell array  
  
    {'/sas1/cocoanlab/data/SEMIC/analysis/imaging/first_level/model03a_SPM_SINGLE_TRIAL_PAIN/sub-semic001/beta_0001.nii'}  
    {'/sas1/cocoanlab/data/SEMIC/analysis/imaging/first_level/model03a_SPM_SINGLE_TRIAL_PAIN/sub-semic001/beta_0002.nii'}  
    {'/sas1/cocoanlab/data/SEMIC/analysis/imaging/first_level/model03a_SPM_SINGLE_TRIAL_PAIN/sub-semic001/beta_0003.nii'}
```



Mediation_Dream: Examples

- STEP2: Build models

You build model to test in **models.name{k}** and **models.fns{k}**

The mediation function you want to perform

```
models.name{1} = 'model01_X:_Stim_Y:_angle_M:_brain_Cov:_cue';
models.name{2} = 'model02_X:_Cue_Y:_angle_M:_brain_Cov:_Stim';

models.fns{1} = ['mediation(med_vars.X1, med_vars.Y, M, 'cov', med_vars.X2, 'boot', 'bootsamples', 10000)'];
models.fns{2} = ['mediation(med_vars.X2, med_vars.Y, M, 'cov', med_vars.X1, 'boot', 'bootsamples', 10000)'];

>> disp(models.fns{1})
mediation(med_vars.X1, med_vars.Y, M, 'covs', med_vars.X2, 'boot', 'bootsamples', 10000)
>> disp(models.fns{2})
mediation(med_vars.X2, med_vars.Y, M, 'covs', med_vars.X1, 'boot', 'bootsamples', 10000)
```

k = the number of model



Mediation_Dream: Examples

- STEP3: Divide fMRI data and scripts for parallel processing (mediation_dream_wani.m)

Run mediation_dream_wani.m (or _suhwan.m)

The number of job you want to divide

For specific environment

med_vars.imgs

```
jobn = 26;
wh_loc = 'HPC';
% it should change directory or filename

outputdir = fullfile('/sas1/cocoanlab/data','SEMIC','191203_2mm_whole_brain_onlySELF','outputs');
if ~exist(outputdir, 'dir'), mkdir(outputdir); end

med_vars.imgs = med_vars.M;
%models.name{1} = sprintf('Model01_STIM_phase_%02d_of_08_whole_brain',sec_i);
%models.name{2} = sprintf('Model02_CUE_phase_%02d_of_08_whole_brain',sec_i);
for i = 1:length(models.fns)
    models.savepaths{i} = [1,2,3,4,5]; % including all path
end

code_filename = fullfile(outputdir, sprintf('SEMIC_mediation_brain_%02d_of_32_run_suhwan.m',sec_i));
study_scriptdir = fullfile('/sas1/cocoanlab/data/SEMIC','scripts');

%% make mediation distributed scripts
mediation_dream_suhwan(med_vars, models, jobn, mask, code_filename, study_scriptdir, 'wh_loc', wh_loc)
```

This function is for my specific environment
You can use **_wani** or modify it for your environment



Mediation_Dream: Examples

- STEP4: Run each script in MATLAB with each CPU core (1CPU core = 1 script)

These data (.mat) and scripts (.m) was generated

outputss

001

002

mediation_SETUP_SEMIC_mediation_brain_32_of_32_run_suhwan.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_1.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_2.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_3.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_4.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_5.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_6.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_7.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_8.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_9.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_10.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_11.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_12.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_13.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_14.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_15.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_16.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_17.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_18.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_19.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_20.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_21.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_22.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_23.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_24.mat

res_SEMIC_mediation_brain_32_of_32_run_suhwan_25.mat

SEMIC_mediation_brain_32_of_32_run_suhwan_001.m

SEMIC_mediation_brain_32_of_32_run_suhwan_002.m

SEMIC_mediation_brain_32_of_32_run_suhwan_003.m

SEMIC_mediation_brain_32_of_32_run_suhwan_004.m

SEMIC_mediation_brain_32_of_32_run_suhwan_005.m

SEMIC_mediation_brain_32_of_32_run_suhwan_006.m

SEMIC_mediation_brain_32_of_32_run_suhwan_007.m

SEMIC_mediation_brain_32_of_32_run_suhwan_008.m

SEMIC_mediation_brain_32_of_32_run_suhwan_009.m

SEMIC_mediation_brain_32_of_32_run_suhwan_010.m

SEMIC_mediation_brain_32_of_32_run_suhwan_011.m

SEMIC_mediation_brain_32_of_32_run_suhwan_012.m

SEMIC_mediation_brain_32_of_32_run_suhwan_013.m

SEMIC_mediation_brain_32_of_32_run_suhwan_014.m

SEMIC_mediation_brain_32_of_32_run_suhwan_015.m

SEMIC_mediation_brain_32_of_32_run_suhwan_016.m

SEMIC_mediation_brain_32_of_32_run_suhwan_017.m

SEMIC_mediation_brain_32_of_32_run_suhwan_018.m

SEMIC_mediation_brain_32_of_32_run_suhwan_019.m

SEMIC_mediation_brain_32_of_32_run_suhwan_020.m

SEMIC_mediation_brain_32_of_32_run_suhwan_021.m

SEMIC_mediation_brain_32_of_32_run_suhwan_022.m

SEMIC_mediation_brain_32_of_32_run_suhwan_023.m

SEMIC_mediation_brain_32_of_32_run_suhwan_024.m

SEMIC_mediation_brain_32_of_32_run_suhwan_025.m



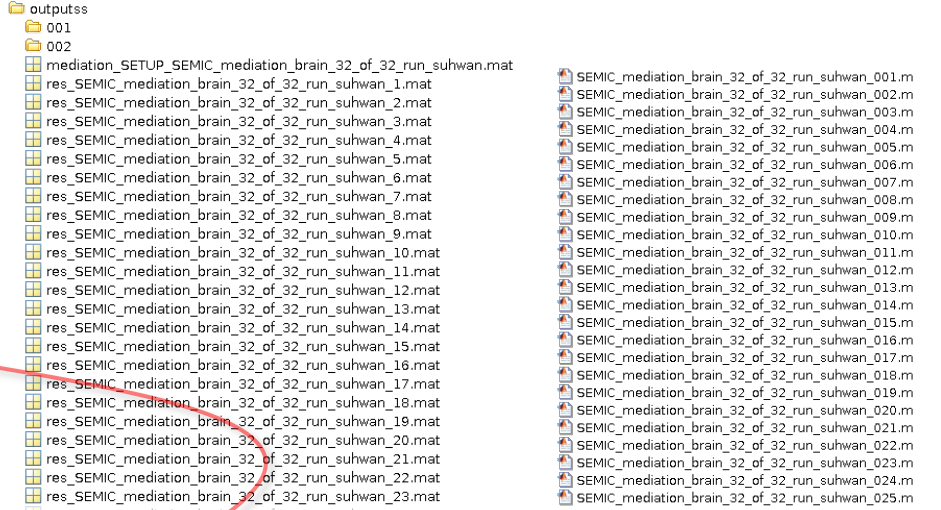
Mediation_Dream: Examples

- STEP4: Run each script in MATLAB with each CPU core (1CPU core = 1 script)



```
suhwan@cnir00:~  
suhwan@cnir00:~ (ssh)  
[suhwan@cnir00 ~]$  
[suhwan@cnir00 ~]$  
[suhwan@cnir00 ~]$  
[suhwan@cnir00 ~]$  
[suhwan@cnir00 ~]$  
[suhwan@cnir00 ~]$
```

matlab_org: can be differ depending on the environment
script location: /sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_014.m



outputs
001
002
mediation_SETUP_SEMIC_mediation_brain_32_of_32_run_suhwan.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_1.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_2.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_3.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_4.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_5.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_6.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_7.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_8.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_9.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_10.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_11.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_12.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_13.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_14.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_15.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_16.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_17.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_18.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_19.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_20.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_21.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_22.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_23.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_24.mat
res_SEMIC_mediation_brain_32_of_32_run_suhwan_25.mat
SEMIC_mediation_brain_32_of_32_run_suhwan_001.m
SEMIC_mediation_brain_32_of_32_run_suhwan_002.m
SEMIC_mediation_brain_32_of_32_run_suhwan_003.m
SEMIC_mediation_brain_32_of_32_run_suhwan_004.m
SEMIC_mediation_brain_32_of_32_run_suhwan_005.m
SEMIC_mediation_brain_32_of_32_run_suhwan_006.m
SEMIC_mediation_brain_32_of_32_run_suhwan_007.m
SEMIC_mediation_brain_32_of_32_run_suhwan_008.m
SEMIC_mediation_brain_32_of_32_run_suhwan_009.m
SEMIC_mediation_brain_32_of_32_run_suhwan_010.m
SEMIC_mediation_brain_32_of_32_run_suhwan_011.m
SEMIC_mediation_brain_32_of_32_run_suhwan_012.m
SEMIC_mediation_brain_32_of_32_run_suhwan_013.m
SEMIC_mediation_brain_32_of_32_run_suhwan_014.m
SEMIC_mediation_brain_32_of_32_run_suhwan_015.m
SEMIC_mediation_brain_32_of_32_run_suhwan_016.m
SEMIC_mediation_brain_32_of_32_run_suhwan_017.m
SEMIC_mediation_brain_32_of_32_run_suhwan_018.m
SEMIC_mediation_brain_32_of_32_run_suhwan_019.m
SEMIC_mediation_brain_32_of_32_run_suhwan_020.m
SEMIC_mediation_brain_32_of_32_run_suhwan_021.m
SEMIC_mediation_brain_32_of_32_run_suhwan_022.m
SEMIC_mediation_brain_32_of_32_run_suhwan_023.m
SEMIC_mediation_brain_32_of_32_run_suhwan_024.m
SEMIC_mediation_brain_32_of_32_run_suhwan_025.m

```
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_014.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_015.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_016.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_017.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_018.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_019.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_020.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_021.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_022.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_023.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_024.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_025.m'); quit" > output.txt 2>&1 </dev/null &  
nohup matlab_orig -singleCompThread -nodesktop -nodisplay -nosplash -r "run ('/sas1/cocoanlab/data/SEQ_additional_analysis/SEQ_Medi_dream/BMRK3/SEQ_A_mediation_brain_run_suhwan_026.m'); quit" > output.txt 2>&1 </dev/null &
```



Mediation_Dream: Examples

- STEP5: Summarize each result (mediation_dream_combined_wani.m)

```
%modeldir = fullfile('/sas1/cocoanlab/data/SEMIC/', '191023_2mm_whole_brain_onlySELF', 'outputss');  
modeldir = fullfile('/sas1/cocoanlab/data/SEMIC/', '191203_2mm_whole_brain_onlySELF', 'outputs');  
sec_i = 32;  
SETUP_dir = fullfile(modeldir, sprintf('mediation_SETUP_SEMIC_mediation_brain_%02d_of_32_run_suhwan.mat', sec_i));  
  
mediation_dream_combine_results_suhwan(modeldir, SETUP_dir);
```

This function is for my specific environment
You can use **_wani** or modify it for your environment



Mediation_Dream: Examples

- STEP5: Summarize each results (mediation_dream_combined_wani.m)

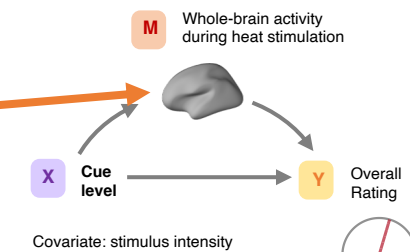
```
%modeldir = fullfile('/sas1/cocoonlab/data/SEMIC/', '191023_2mm_whole_brain_onlySELF', 'outputss');  
modeldir = fullfile('/sas1/cocoonlab/data/SEMIC/', '191203_2mm_whole_brain_onlySELF', 'outputs');  
sec_i = 32;  
SETUP_dir = fullfile(modeldir, sprintf('mediation_SETUP_SEMIC_mediation_brain_%02d_of_32_run_suhwan.mat', sec_i));  
  
mediation_dream_combine_results_suhwan(modeldir, SETUP_dir);
```

You can get combined results for each model

| 001 | 002 |
|--------------------------------|--------------------------------|
| firstlevel_M-Ybetas.nii | firstlevel_M-Ybetas.nii |
| firstlevel_X-Mbetas.nii | firstlevel_X-Mbetas.nii |
| firstlevel_X-M-Ybetas.nii | firstlevel_X-M-Ybetas.nii |
| firstlevel_X-Y_directbetas.nii | firstlevel_X-Y_directbetas.nii |
| firstlevel_X-Y_totalbetas.nii | firstlevel_X-Y_totalbetas.nii |
| M-Y_effect.nii | M-Y_effect.nii |
| M-Y_pvals.nii | M-Y_pvals.nii |
| M-Y_ste.nii | M-Y_ste.nii |
| X-M_effect.nii | X-M_effect.nii |
| X-M_pvals.nii | X-M_pvals.nii |
| X-M_ste.nii | X-M_ste.nii |
| X-M-Y_effect.nii | X-M-Y_effect.nii |
| X-M-Y_pvals.nii | X-M-Y_pvals.nii |
| X-M-Y_ste.nii | X-M-Y_ste.nii |
| X-Y_direct_effect.nii | X-Y_direct_effect.nii |
| X-Y_direct_pvals.nii | X-Y_direct_pvals.nii |
| X-Y_direct_ste.nii | X-Y_direct_ste.nii |
| X-Y_total_effect.nii | X-Y_total_effect.nii |
| X-Y_total_pvals.nii | X-Y_total_pvals.nii |
| X-Y_total_ste.nii | X-Y_total_ste.nii |

Mediation effects

a Whole-brain mediation for the cue effects



Mediation_Dream: Summary of example

- STEP1: Make variable structure
- STEP2: Build models
- STEP3: Divide fMRI data and scripts for parallel processing (mediation_dream_wani.m)
- STEP4: Run each script in MATLAB with each CPU core (1CPU core = 1 script)
- STEP5: Summarize each results (mediation_dream_combined_wani.m)

