Multiple ways to process multi-echo FMRI data with AFNI

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AFNI's afni_proc.py can flexibly set up analyses for: single- or multi-echo FMRI; with/without physio; with/without B0 correction; on a surface or in a volume; for rest- or task-modeling; etc...

Here we present convenient ways to process multi-echo (ME) FMRI data using AFNI's [1] main tool for pipeline design at the single subject level, **afni_proc.py**. This includes: both volumetric and surface analyses; integrating with TEDANA for ME-ICA [2] or "optimally combining" echos; and incorporating B0-distortion correction and cardiac/respiratory regressors. (We also show single echo processing, for comparison.)

Standard (single echo) FMRI

+ a slice is acquired after a single, fixed echo time (TE)
+ images are essentially T2* weighted
+ echo spacing maximizes signal in GM; produces BOLD signal

Multi-echo FMRI (ME-FMRI)

+ multiple echos per volume
+ echos can be combined in various ways to identify+remove noise features [3,4]

Data details

This dataset was acquired using a GE 3T scanner at NIH in accord with IRB protocols (details in [5,6]). It includes a T1w anatomical volume: voxels=1x1x1 mm^3; matrix=172x256x256. Six ME-FMRI runs were acquired for a naming task of visually-presented event stimuli: TR=2200ms; TE=12.5,27.6,42.7 ms; voxels=3.2x3.2x3.5 mm^3; matrix=64x64x33; N=237 volumes (each run). One ME-FMRI resting state run (N=220 volumes) was acquired with the same parameters. A single-echo reverse encoded EPI set (N=10, TE=27.6ms) was acquired for B0-correction. Cardiac and respiratory data were collected for each scan.

Processing details

Here we perform various combinations of analyses for the large dataset available. Censoring at enorm=0.2 and outlier fraction=5% was performed in all cases. For surface analyses FreeSurfer v7 [7] was first run to estimate surfaces from the T1w anatomical; results were converted to NIFTI volumes and standard mesh surfaces for use in SUMA [8,9]. For all volumetric analyses, AFNI's @SSwarper calculated nonlinear alignment to MNI space, and warps were applied within afni_proc.py; also, a blur of 5mm was used. In some volumetric cases, B0-distortion correction was also used, via nonlinear alignment of opposite-phase encoded EPIs.

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We present 5 resting state processing examples to highlight the ease of implementing different analysis choices with afni_proc.py.

Processing variations with afni_proc.py

Method 1: single echo with basic processing ("control").
Method 2: ME-FMRI with echos "optimally combined".
Method 3: same as #2, but with added B0-correction.
Method 4: same as #3, but also used TEDANA to create regressors of no interest for the regression model.
Method 5: same as #4, but with surface analysis.

How hard is it to adapt afni_proc.py for each? *Not very...*

Method 1 → 2:

+ add "combine" block, with lists of ME datasets and times:

```
-dsets_me_run          ${dsets_epi_me}
-echo_times            ${me_times}
-combine_method        OC
```

Method 2 → 3:

+ add the names of reverse-phase encoded (blip) datasets:

```
-blip_forward_dset    ${epi_forward}
-blip_reverse_dset    ${epi_reverse}
```

Method 3 → 4:

+ change the ME combination method and include an option:

```
-combine_method        OC_tedort
-combine_tedort_reject_midk   no
```

Method 4 → 5:

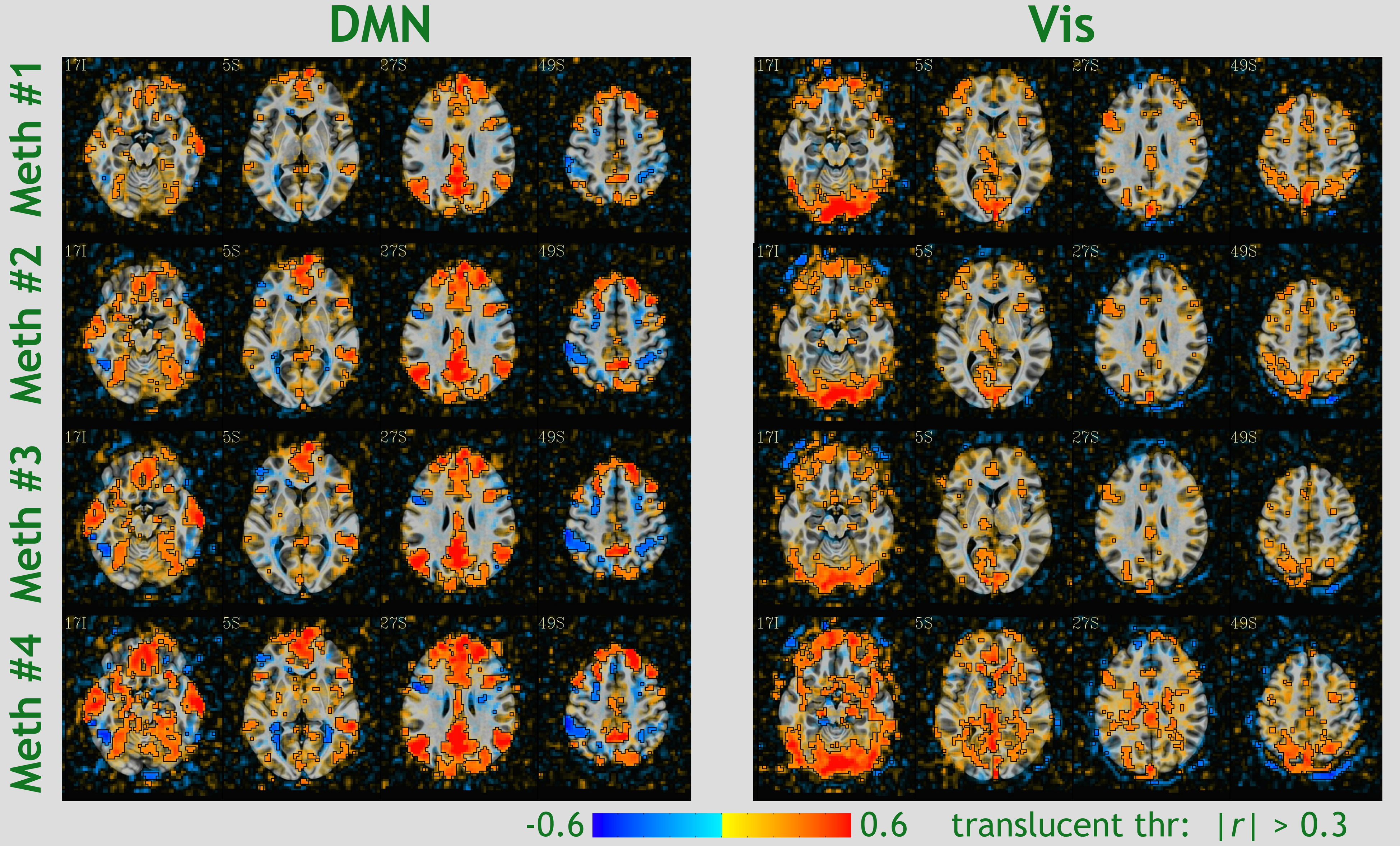
+ change "tlrc" to "surf", and input surface datasets

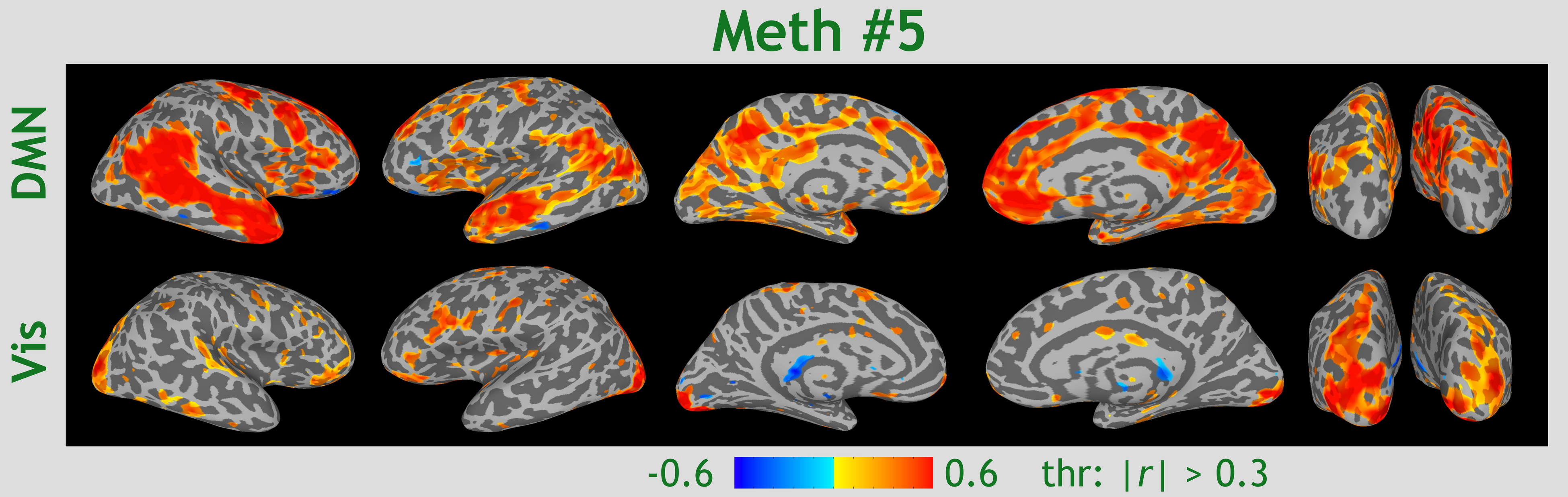
Download this ME-FMRI Demo from AFNI

+ You can (and should!) get the full Demo data+scripts. Run:

```
@Install_AP_MULTI_DEMO1
```

Let's look at some seed-based correlation maps from each method, via the automatic QC HTML: DMN (seed in lh-PCC) and Visual network (seed in rh-cort-vis).





Results tend to be similar, but ME methods show larger, more symmetric correlation patterns than single echo. Though, Method #4 shows high correlation in several areas of WM.

You can test them all (and more) using afni_proc.py!

[1] Cox 1996. CBR 29:162-173, 1996.
[2] Kundu et al. 2012. NI 603:1759-1770.
[3] Barth et al. 1999. MRI 17:321-329.
[4] Posse et al. 1999. MRM 42:87–97.
[5] Gilmore et al. 2019. Neuropsy 124:31-43.
[6] Gotts et al. 2020. NI 205:116289.
[7] Fischl et al. 2002. Neuron 333341-55.
[8] Saad et al. 2004. IEEE-ISBI 1510-1513.
[9] Argall et al. 2006. HBM 27(1):14-27.