XCP-D: Extensible Connectivity Pipeline-DCAN

XCP-D: A Robust Pipeline for the post-processing of fMRI data

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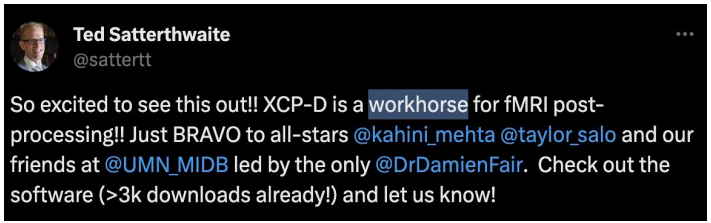


This fMRI post-processing and noise regression pipeline is developed by the Satterthwaite lab at the University of Pennslyvania (**XCP**; eXtensible Connectivity Pipeline) and Developmental Cognition and Neuroimaging lab at the University of Minnesota (**-DCAN**) for open-source software distribution.

About

XCP-D paves the final section of the reproducible and scalable route from the MRI scanner to functional connectivity data in the hands of neuroscientists. We developed XCP-D to extend the BIDS and NiPrep apparatus to the point where data is most commonly consumed and analyzed by neuroscientists studying functional connectivity. Thus, with the development of XCP-D, data can be automatically preprocessed and analyzed in BIDS format, using NiPrep-style containerized code, all the way from the scanner to functional connectivity matrices.

Ciric et al., 2018 in *Nature*

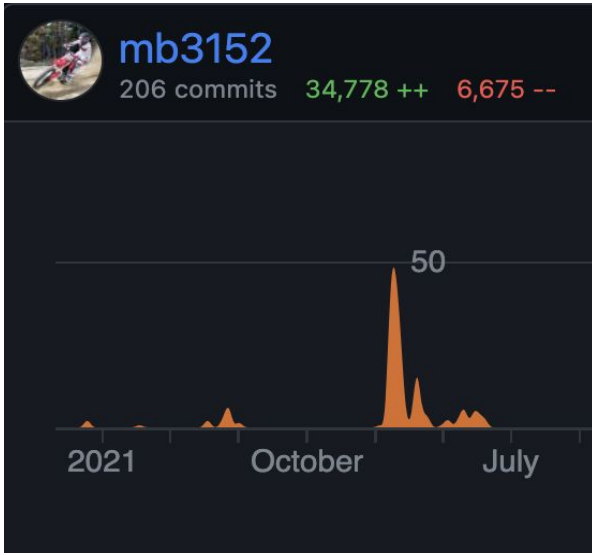
Protocol | Published: 16 November 2018

Mitigating head motion artifact in functional connectivity MRI

Rastko Ciric, Adon F. G. Rosen, Guray Erus, Matthew Cieslak, Azeez Adebimpe, Philip A. Cook, Danielle S. Bassett, Christos Davatzikos, Daniel H. Wolf & Theodore D. Satterthwaite ✉

Nature Protocols **13**, 2801–2826 (2018) | Cite this article

Beginning to refactor...

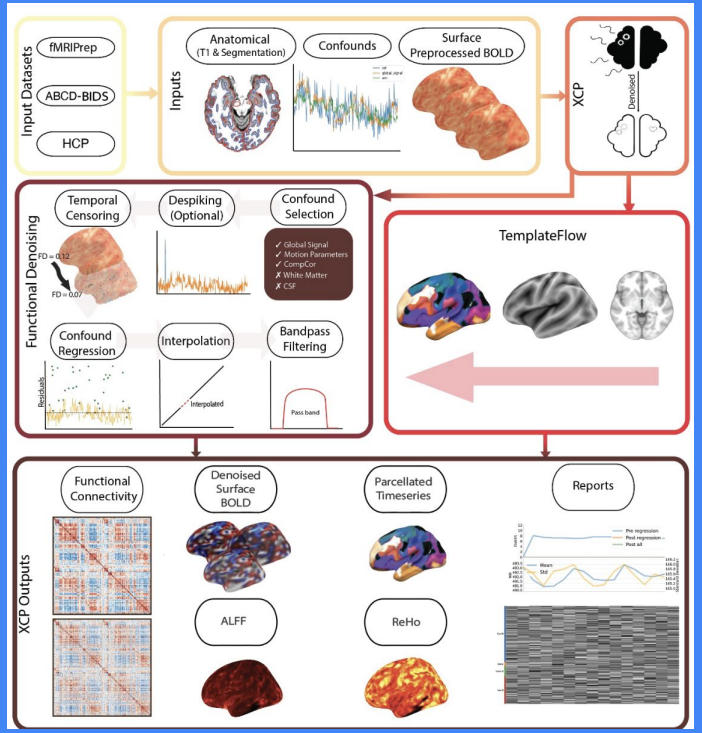


Why the refactor?

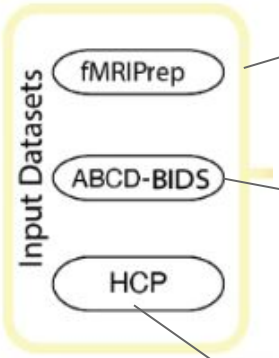
1. Substantial technical debt accumulated - easier to maintain in Python than bash
2. Ensuring modularity via Nipype
3. BIDS compliance
4. Allowing ingestion from HCP-YA, ABCD-BIDS and fMRIPrep
5. Allowing for a more flexible denoising pipeline
6. Ensuring all modules are tested
7. Ensuring best software engineering practices (eg: reviews required before merging, Circle CI testing)

Alternative solutions

So what does XCP-D do now?



Ingestion



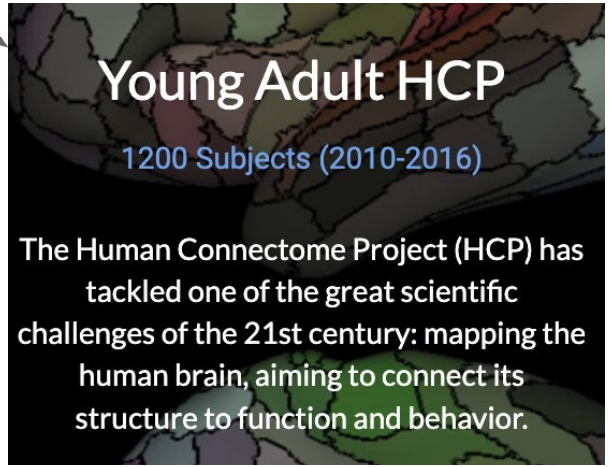
Default

fMRIPrep: A Robust Preprocessing Pipeline for fMRI Data

fMRIPrep is a *NiPreps (NeuroImaging PREProcessing toolS)* application (www.nipreps.org) for the preprocessing of task-based and resting-state functional MRI (fMRI).

docker nipreps/fmriprep | Open in Code Ocean | circleci failing | docs passing | pypi v23.1.4

doi 10.1038/s41592-018-0235-4 | RRID SCR_016216



Adolescent Brain Cognitive Development (ABCD) Community MRI Collection and Utilities

Eric Feczko, Greg Conan, Scott Marek, Brenden Tervo-Clemmens, Michaela Cordova, Olivia Doyle, Eric Earl, Anders Perrone, Darrick Sturgeon, Rachel Klein, Gareth Harman, Dakota Kilamovich, Robert Hermosillo, Oscar Miranda-Dominguez, Azeez Adebimpe, Maxwell Bertolero, Matthew Cieslak, Sydney Covitz, Timothy Hendrickson, Anthony C. Juliano, Kathy Snider, Lucille A. Moore, Johnny Uriartel, Alice M. Graham, Finn Calabro, Monica D. Rosenberg, Kristina M. Rapuano, BJ Casey, Richard Watts, Donald Hagler, Wesley K. Thompson, Thomas E. Nichols, Elizabeth Hoffman, Beatriz Luna, Hugh Garavan, Theodore D. Satterthwaite, Sarah Feldstein Ewing, Bonnie Nagel, Nico U.F. Dosenbach, Damien A. Fair

doi: https://doi.org/10.1101/2021.07.09.451638

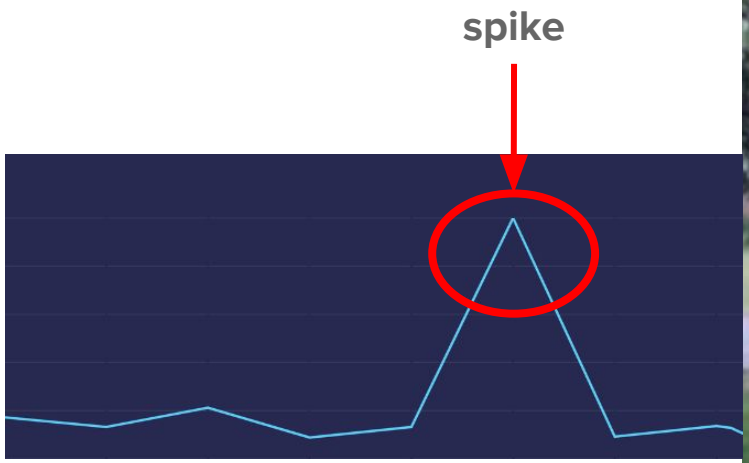
Removal of non-steady state (dummy) volumes

Hello,

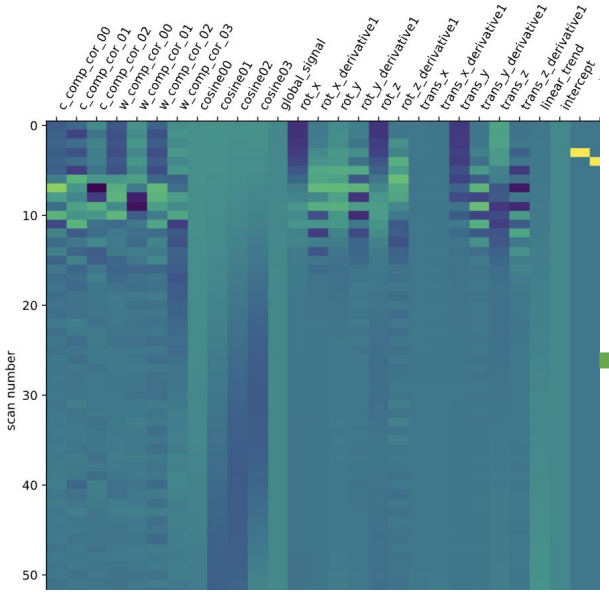
I've been collecting data recently off our Siemens Prisma scanner, which automatically discards the first 8 "dummy" volumes. That being said, I've noticed that occasionally in the confounds files a volume or two is designated as a non-steady state volume. For a first level regression analysis, is it appropriate (or at least acceptable) to censor these volumes out, or is there a different method?

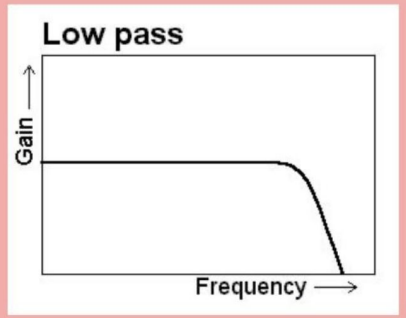
Thanks!

Despiking

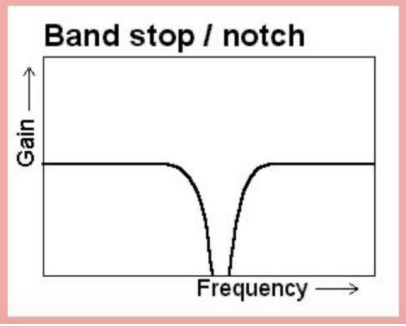


Filtering of realignment parameters



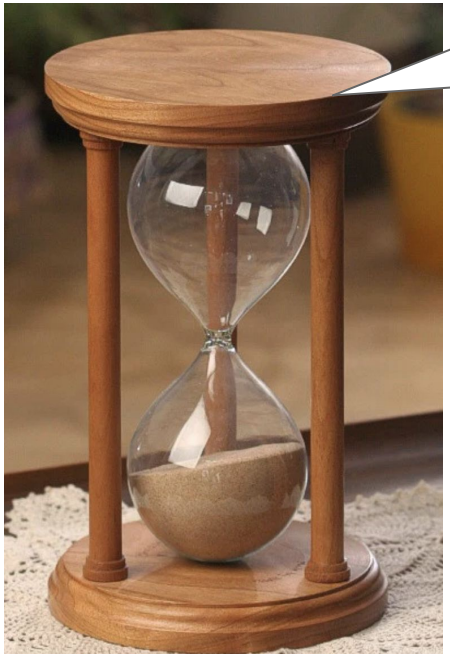


SINGLE-BAND
(Gratton et al., 2020)



MULTIBAND
(Fair et al., 2020)

Temporal censoring



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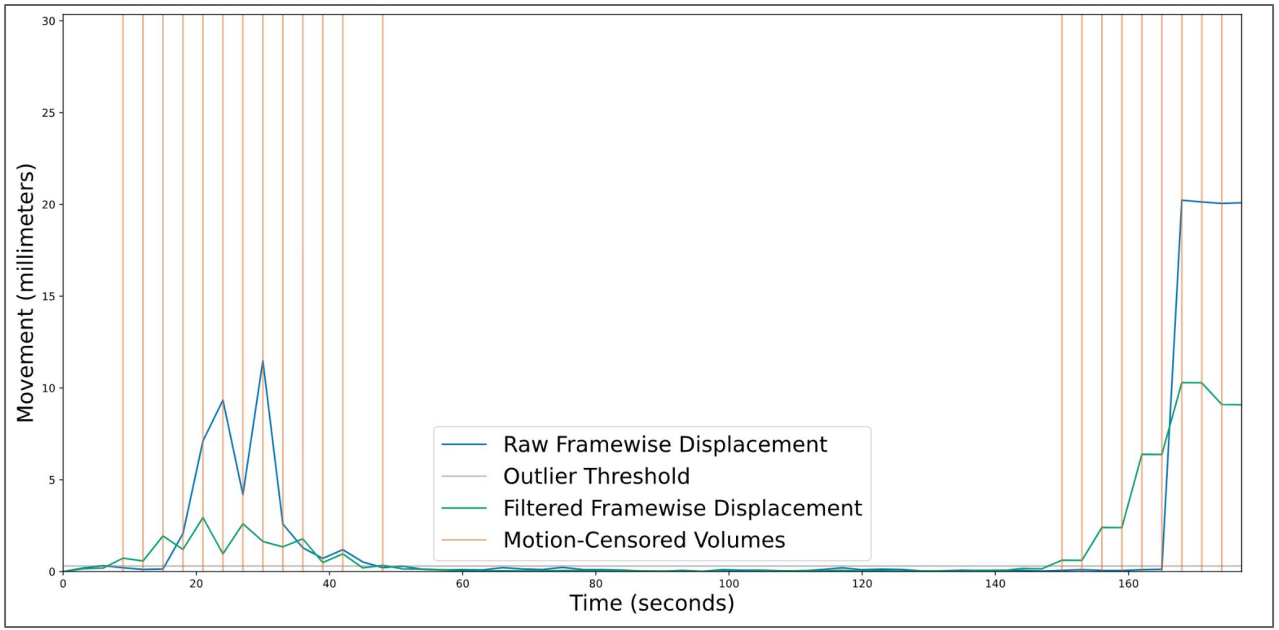
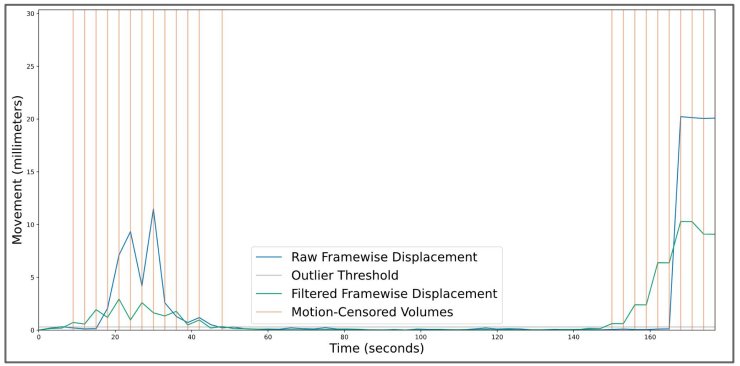


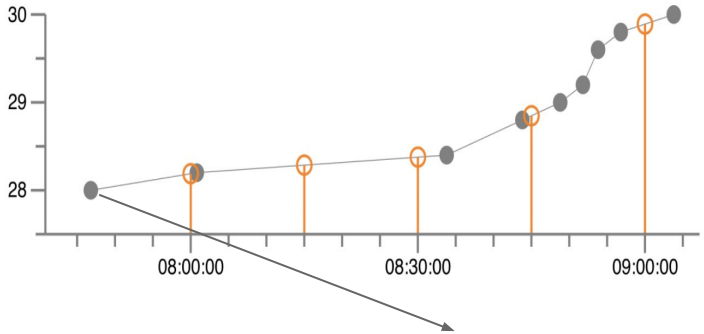
Confound selection & regression (Satterthwaite et al., 2013; Ciric et al., 2017)

Pipelines	Six Motion Estimates	White Matter	CSF	Global Signal	ACompCor	AROMA	Linear Trend	Intercept
24P	X, X^2, dX, dX^2						X	X
27P	X, X^2, dX, dX^2	X	X	X			X	X
36P	X, X^2, dX, dX^2	X, X^2, dX, dX^2	X, X^2, dX, dX^2	X, X^2, dX, dX^2			X	X
acompcor_gsr	X, dX			X	10 com, 5WM, 5CSF		X	X
acompcor	X, dX				10 com, 5WM, 5CSF		X	X
aroma_gsr	X, dX	X	X	X		X	X	X
aroma	X, dX	X	X			X	X	X
none								

Interpolation & filtering

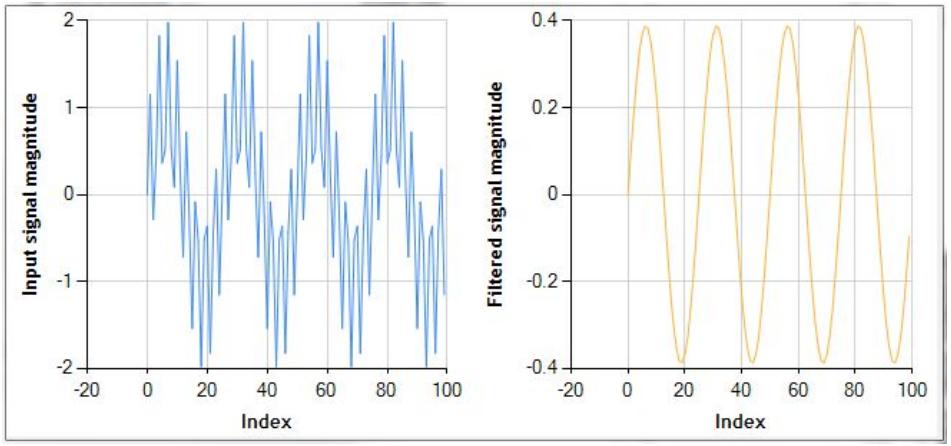
Interpolated Timeseries



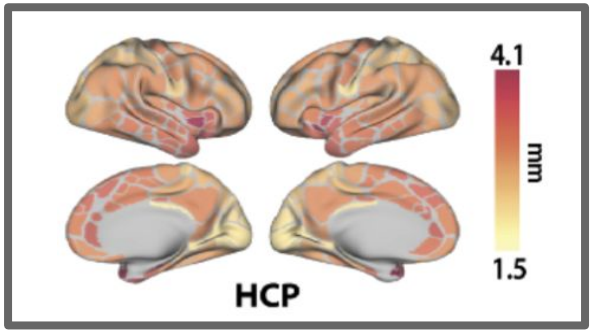


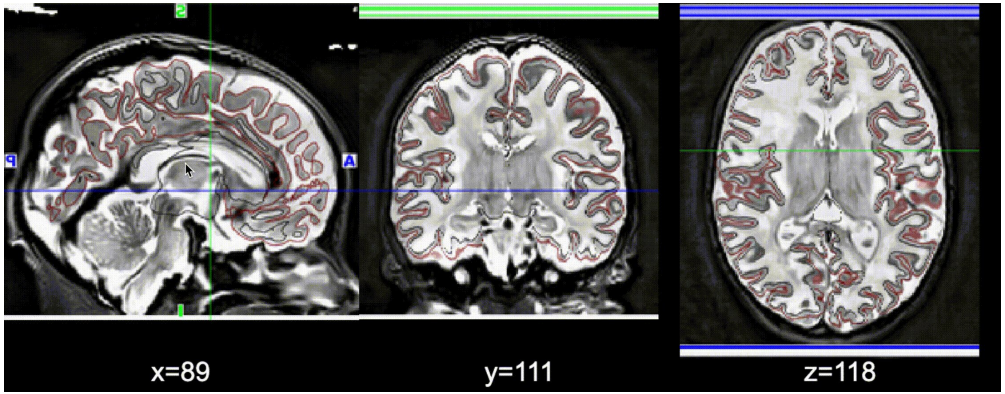
Data interpolated into censored timepoint

Butterworth filter

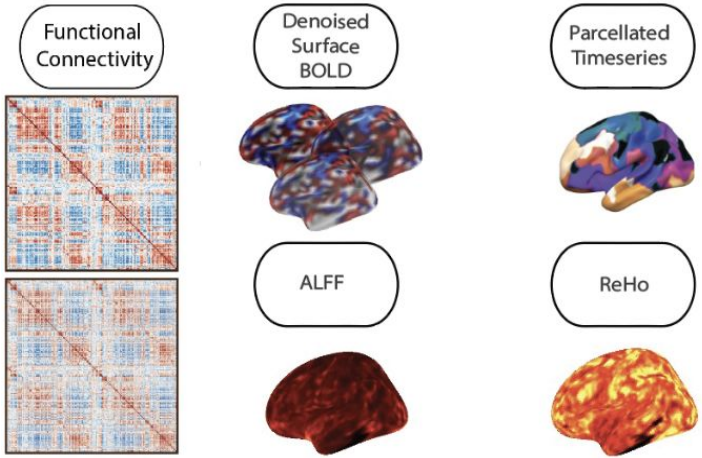


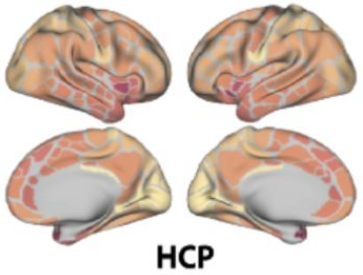
Experimental/other options: Anatomical Workflow + Concatenation



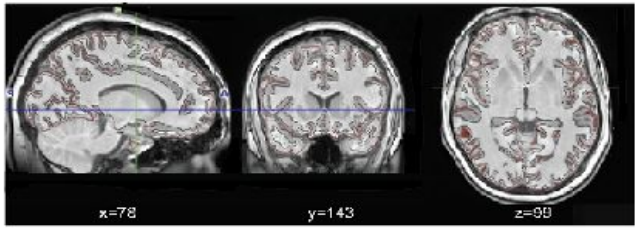


Outputs generated

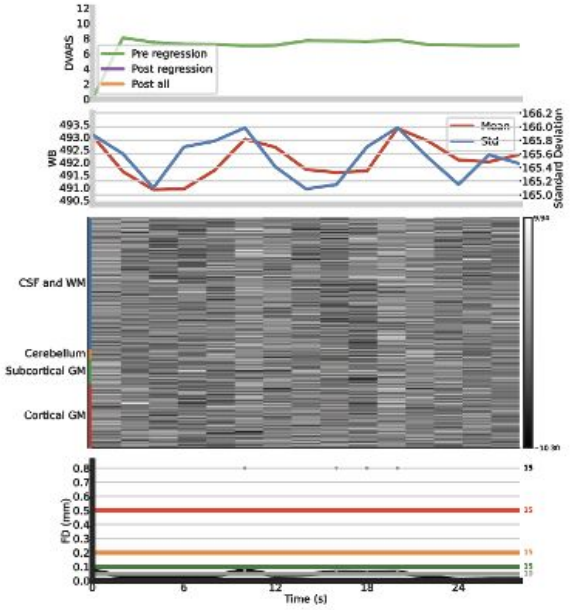




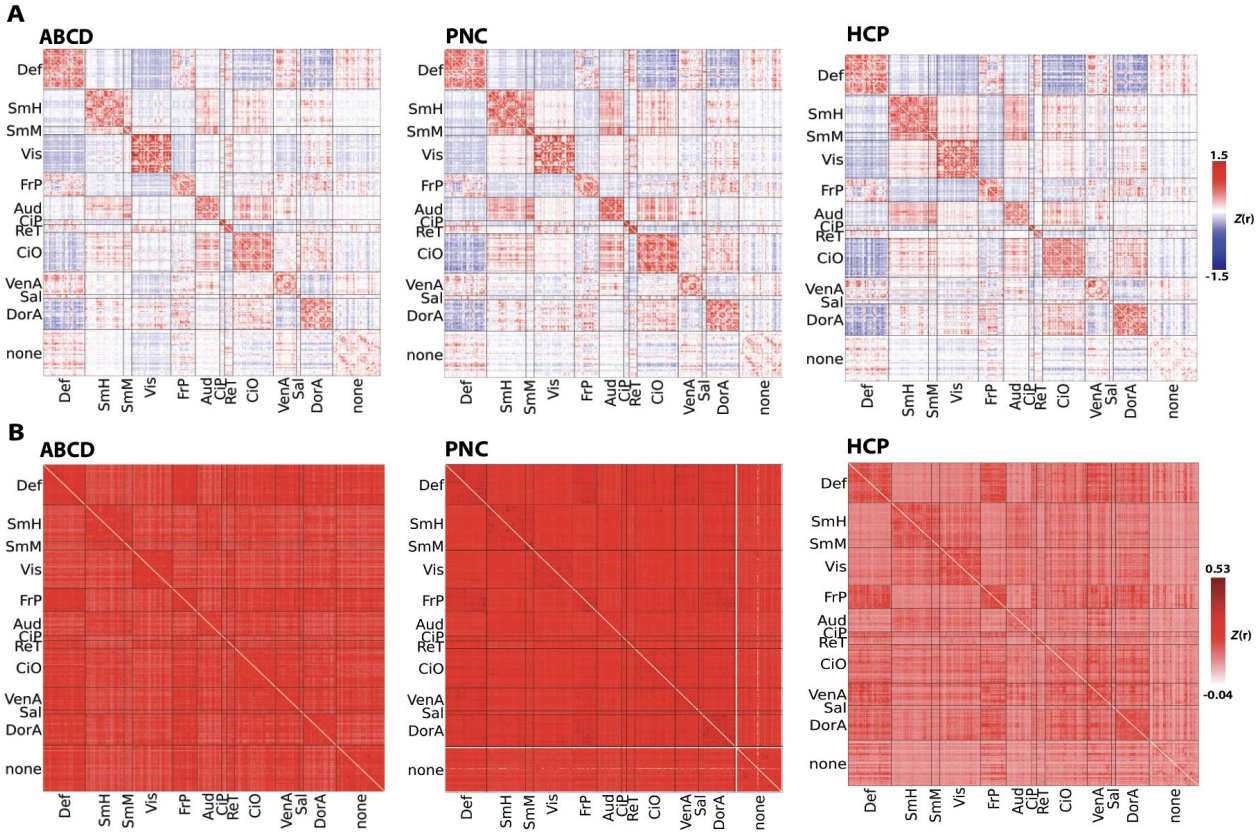
A. BrainSprite



B. DVARS Graph, Carpet Plots, and Framewise Displacement Graph



Demonstration of efficacy in N=600

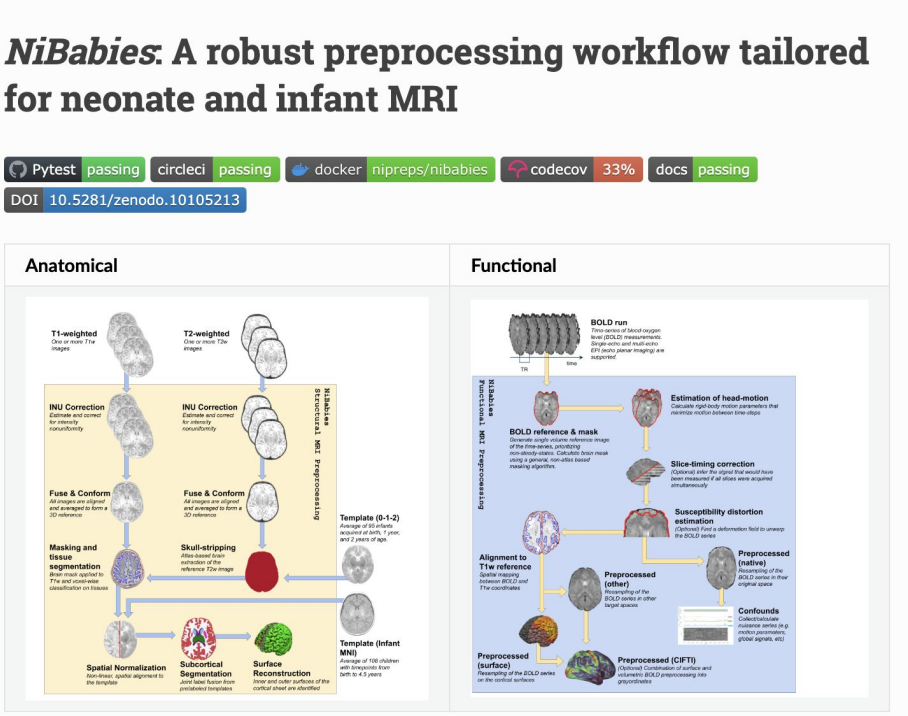


Mean (**Panel A**) and standard deviation (**Panel B)** functional connectivity generated by XCP-D for each dataset in our large-scale application, displayed after Fisher's *Z* transformation. Data are displayed using the Gordon atlas (Gordon et al., 2016). *Def: default mode network; SmH: somatomotor hands network; SmM: somatomotor mouth network; Vis: visual network; FrP: Frontoparietal network; Aud: auditory network; CiP: cinguloparietal network; CiO: cingulo-opercular network; VenA: ventral attention network; Sal: salience network; DorA: dorsal attention network*

Limitations + future directions

1. Does not support physiological confounds - roadmap
2. Does not support task data - out of scope for now
3. Or Nibabies - plans to implement this in the future.

Contributions always welcome via pull requests :)



Reflections

- Learning an existing codebase
- Following best coding practices
- Working on the software with team members
- Collaborating across institutions
- Writing a paper on evolving software

Questions?

Preprint:

read-the-docs:

Github:

List/location of datasets run through XCP available via internal lab documentation.

THANK YOU!

LINC lifespan informatics & neuroimaging center

XCP-D: A Robust Pipeline for the post-processing of fMRI data

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Category: fMRI, software, reproducibility, functional connectivity, image processing, denoising