

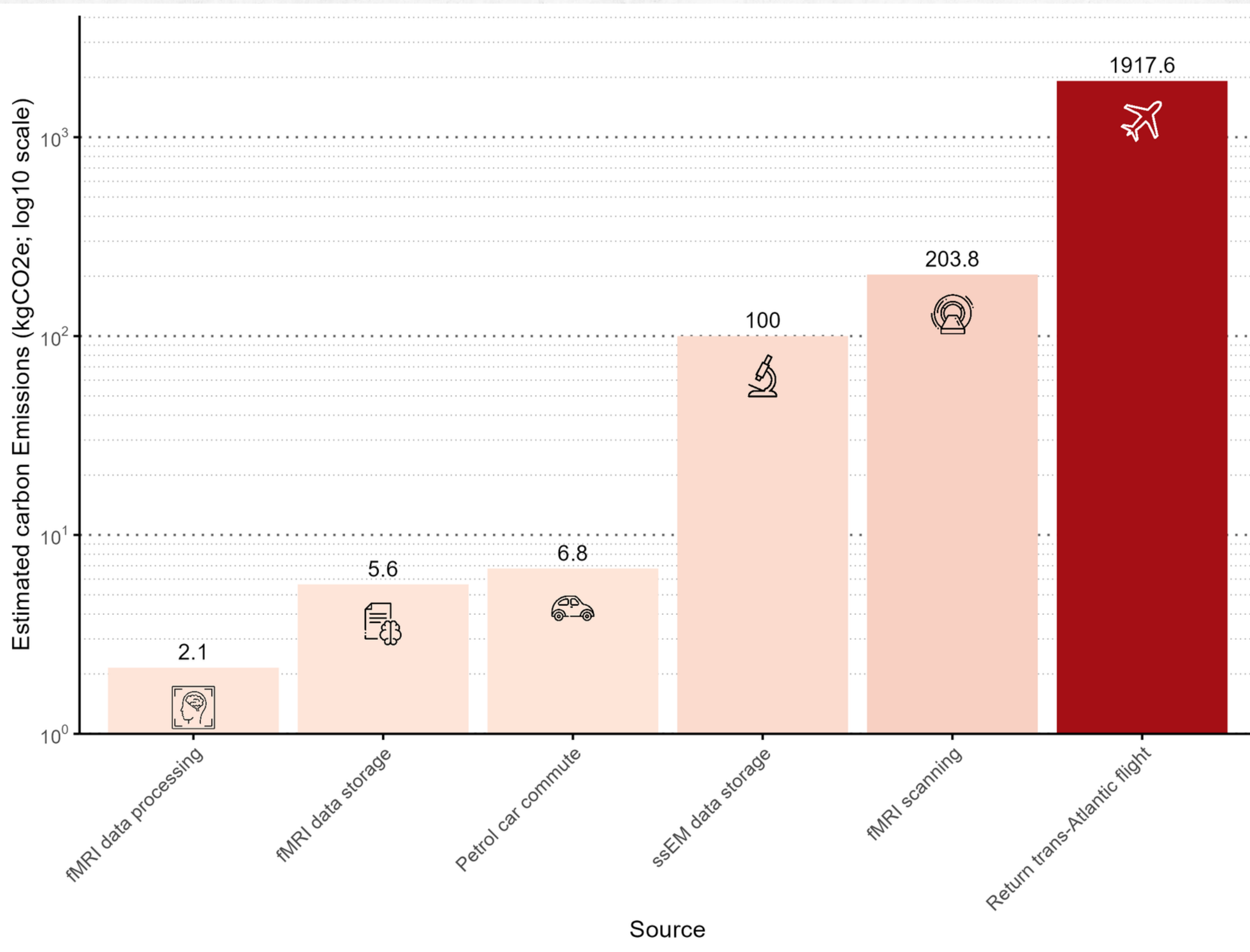


# GREEN COMPUTING IN NEUROIMAGING RESEARCH

IDENTIFYING STRATEGIES TO REDUCE  
ENERGY CONSUMPTION, AND TRAINING  
END USERS THROUGH ROVING  
WORKSHOPS

**NICK SOUTER**





Volume 1


2023




Imaging  
Neuroscience

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## Ten recommendations for reducing the carbon footprint of research computing in human neuroimaging

Nicholas E. Souter , Loïc Lanelongue, Gabrielle Samuel, Chris Racey, Lincoln J. Colling, Nikhil Bhagwat, Raghavendra Selvan, Charlotte L. Rae

 Check for updates

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## BOX 1. SUMMARY OF TEN RECOMMENDATIONS FOR REDUCING THE CARBON FOOTPRINT OF NEUROIMAGING COMPUTING

1. *Preregister a study analysis plan in order to avoid repetitions*
2. *Quantify and report the carbon footprint of your computing using available carbon tracking tools*
3. *Only run the preprocessing and analysis steps that you need*
4. *Run your computing at lower carbon intensity times and in lower carbon intensity locations*
5. *Regularly remove files that you do not need*
6. *Plan where, and for how long, you will store files, aided by research technicians*
7. *Advocate for non-commercial and centralised data storage solutions*
8. *Publicly share sufficient data to ensure it is FAIR (Findable, Accessible, Interoperable, Reusable), but consider the extent of what others will actually need or use*
9. *Make use of existing preprocessed data when possible, instead of acquiring and processing new data*
10. *Discuss the importance of greener computing with other neuroimagers and advocate for systemic change*

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**#1**

***Preregister*** a study  
***analysis plan in order***  
***to avoid repetitions***

**#3**

**Only run the *preprocessing*  
*and analysis steps* that you  
need**

# #8

***Publicly share sufficient data to ensure it is **FAIR** (Findable, Accessible, Interoperable, Reusable), but consider the extent of **what others will actually need or use*****

**#9**

**Make use of *existing preprocessed data* when possible, instead of acquiring and processing new data**

# Dark Data & Junk Data

**Dark data** - Potentially usable data that is poorly indexed, and becomes functionally invisible over time.

**Junk data** - Data that is useless (often intermediary files) that takes up unnecessary space.

# fMRIPrepCleanup

## NickESouter/ fMRIPrepCleanup

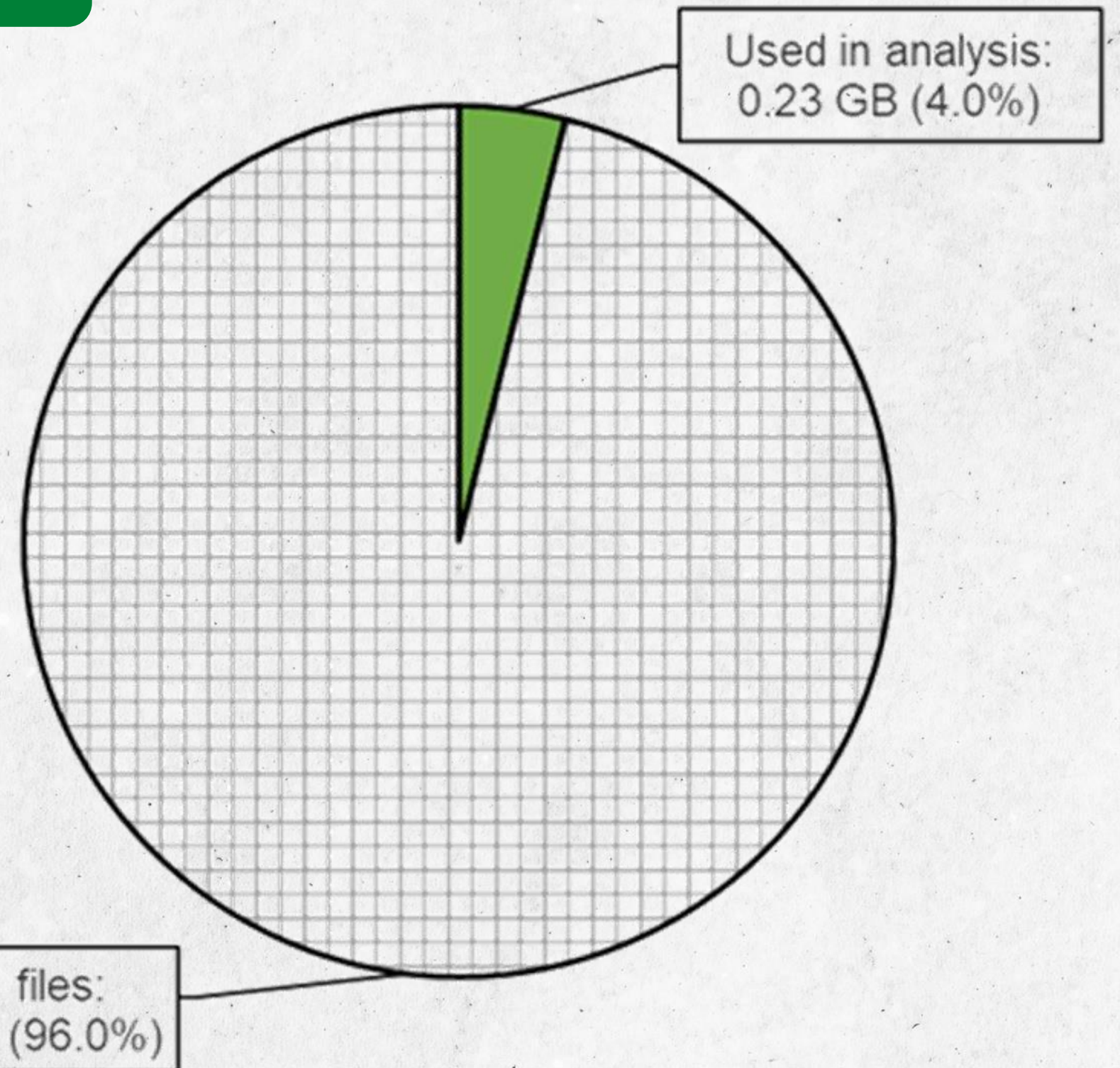
A script used to delete 'junk' files produced by fMRIPrep, to reduce storage space used by up to 95%

1 Contributor 0 Issues 2 Stars 0 Forks

**NickESouter/fMRIPrepCleanup: A script used to delete 'junk' files produced by fMRIPrep, to reduce storage space used by up to 95%**

A script used to delete 'junk' files produced by fMRIPrep, to reduce storage space used by up to 95% - NickESouter/fMRIPrepCleanup

GitHub



$$5.07\text{GB} \times 257 = 1.3 \text{ TB}$$




# Reducing Use: Case studies from neuroimaging

**Measuring and reducing  
the carbon footprint of  
fMRI preprocessing  
in fMRIPrep**

TECHNICAL REPORT |  Open Access |  

## Measuring and reducing the carbon footprint of fMRI preprocessing in fMRIPrep

Nicholas E. Souter  Nikhil Bhagwat, Chris Racey, Reese Wilkinson, Niall W. Duncan, Gabrielle Samuel, Loïc Lannelongue, Raghavendra Selvan, Charlotte L. Rae

First published: 26 August 2024 | <https://doi.org/10.1002/hbm.70003>



# Carbon Emissions

(CPU + RAM energy)

x

Power use effectiveness

x

Carbon intensity

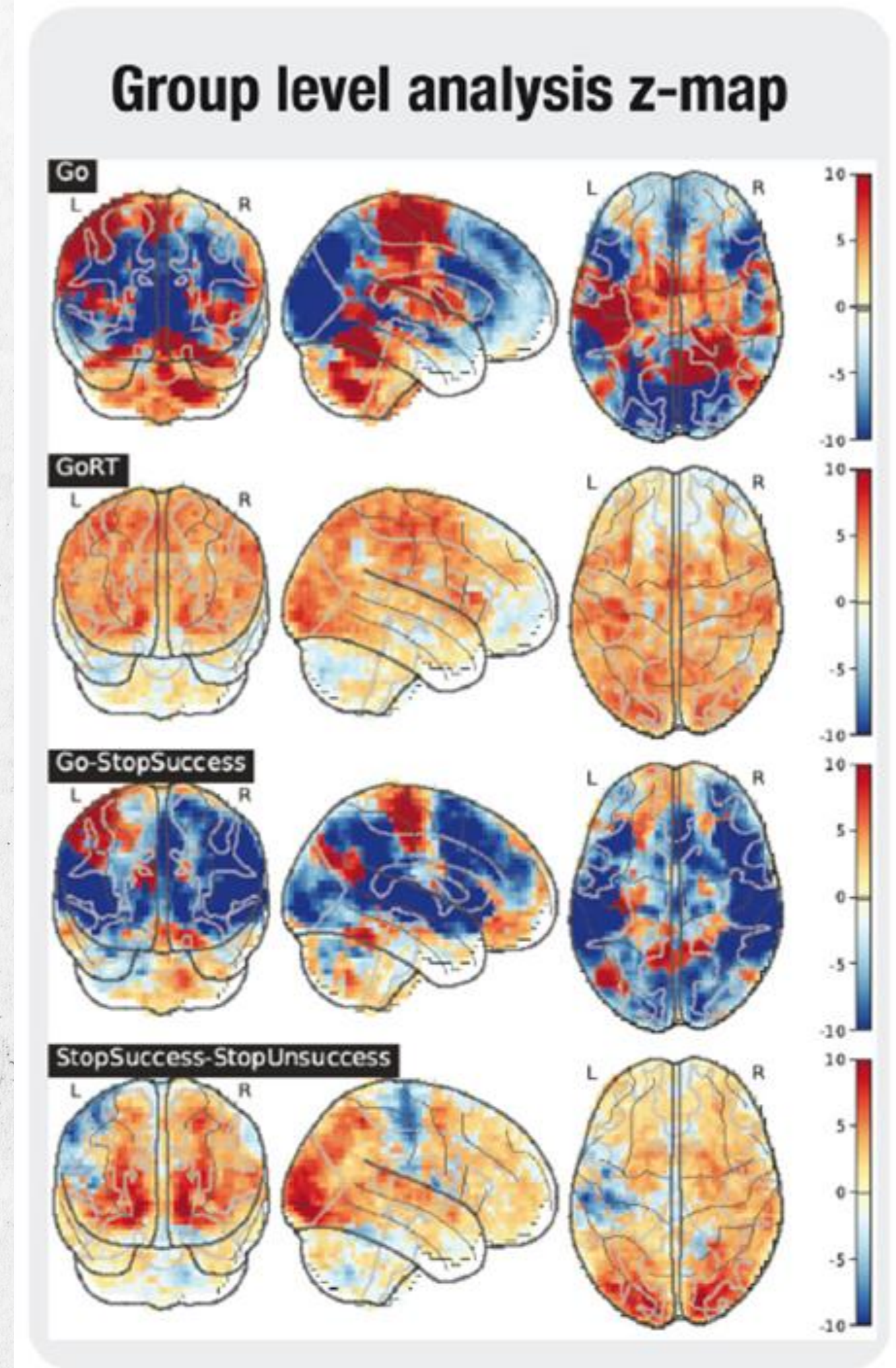
```
usage: fmriprep [-h] [--version] [--skip_bids_validation]
               [--participant-label PARTICIPANT_LABEL [PARTICIPANT_LABEL ...]]
               [-t TASK_ID] [--echo-idx ECHO_IDX] [--bids-filter-file FILE]
               [--anat-derivatives PATH] [--bids-database-dir PATH]
               [--nprocs NPROCS] [--omp-nthreads OMP_NTHREADS]
               [--mem MEMORY_MB] [--low-mem] [--use-plugin FILE]
               [--anat-only] [--boilerplate_only] [--md-only-boilerplate]
               [--error-on-aroma-warnings] [-v]
               [--ignore {fieldmaps,slicetiming,sbref,t2w,flair}
               [{fieldmaps,slicetiming,sbref,t2w,flair} ...]]
               [--longitudinal] [--output-spaces [OUTPUT_SPACES ...]]
               [--me-output-echos] [--bold2t1w-init {register,header}]
               [--bold2t1w-dof {6,9,12}] [--force-bbr] [--force-no-bbr]
               [--medial-surface-nan] [--slice-time-ref SLICE_TIME_REF]
               [--dummy-scans DUMMY_SCANS] [--random-seed _RANDOM_SEED]
               [--use-aroma]
               [--aroma-melodic-dimensionality AROMA_MELODIC_DIM]
               [--return-all-components]
               [--fd-spike-threshold REGRESSORS_FD_TH]
               [--dvars-spike-threshold REGRESSORS_DVARS_TH]
               [--skull-strip-template SKULL_STRIP_TEMPLATE]
               [--skull-strip-fixed-seed]
               [--skull-strip-t1w {auto,skip,force}] [--fmap-bspline]
               [--fmap-no-demean] [--topup-max-vols TOPUP_MAX_VOLS]
               [--use-syn-sdc [{warn,error}]] [--force-syn]
               [--fs-license-file FILE] [--fs-subjects-dir PATH]
               [--no-submm-recon] [--cifti-output [{91k,170k}] |
               --fs-no-reconall] [--output-layout {bids,legacy}]
               [-w WORK_DIR] [--clean-workdir] [--resource-monitor]
               [--reports-only] [--config-file FILE] [--write-graph]
```

# fmriprep

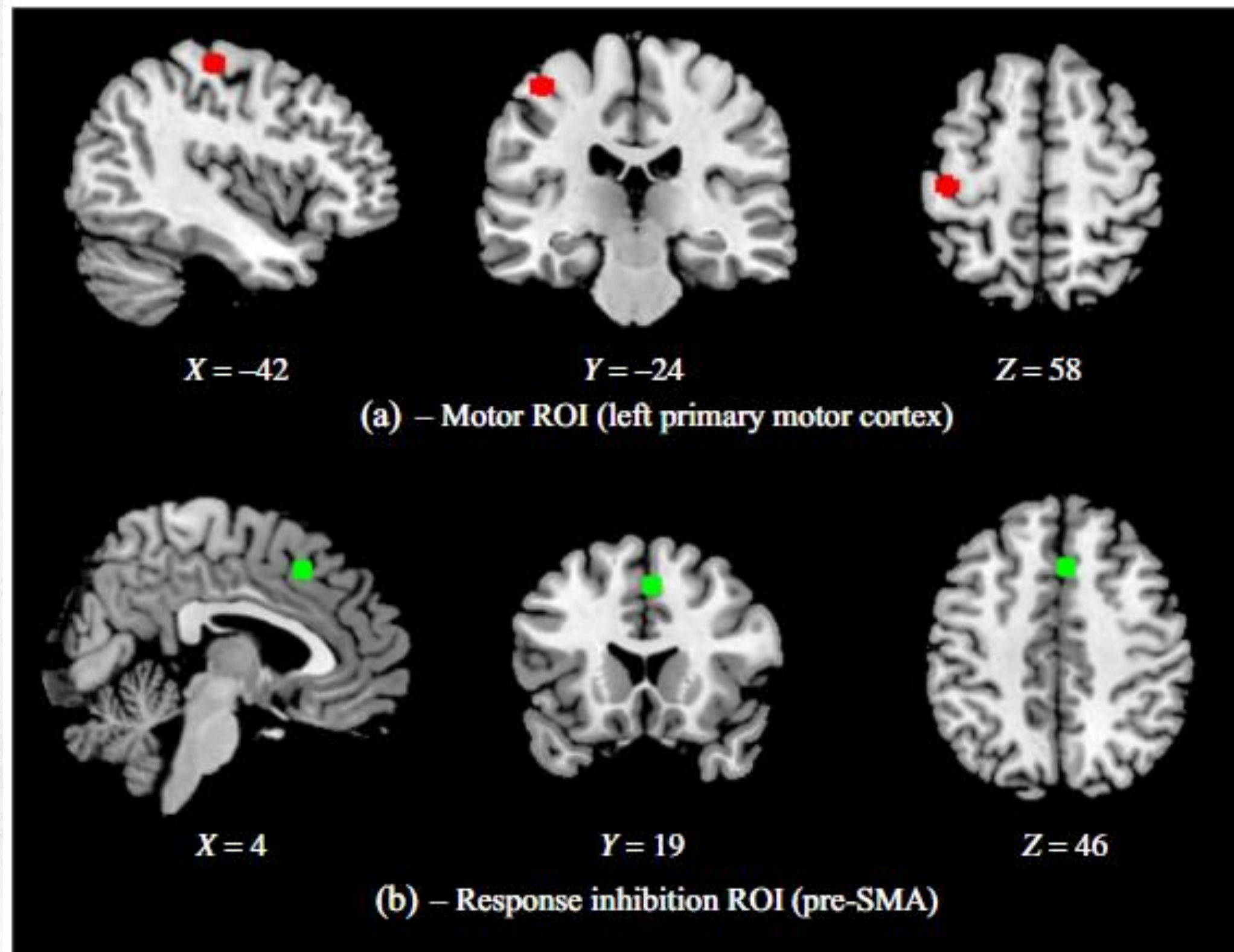
# *The Data*

UCLA Consortium for  
Neuropsychiatric Phenomics  
LA5c Study

1 run of a stop signal task  
for 257 subjects



# Measuring Performance



**FIGURE 1** ROIs for use in FSL Featquery, including the left primary motor cortex for motor response activation, and the pre-SMA for successful response inhibition activation. pre-SMA, pre-supplementary motor area; ROI, region of interest.

# fMRIPrep pipeline variants

**P0: Baseline**

---

**P1: No FreeSurfer  
surface reconstruction**

**P2: 'Sloppy' testing  
mode**

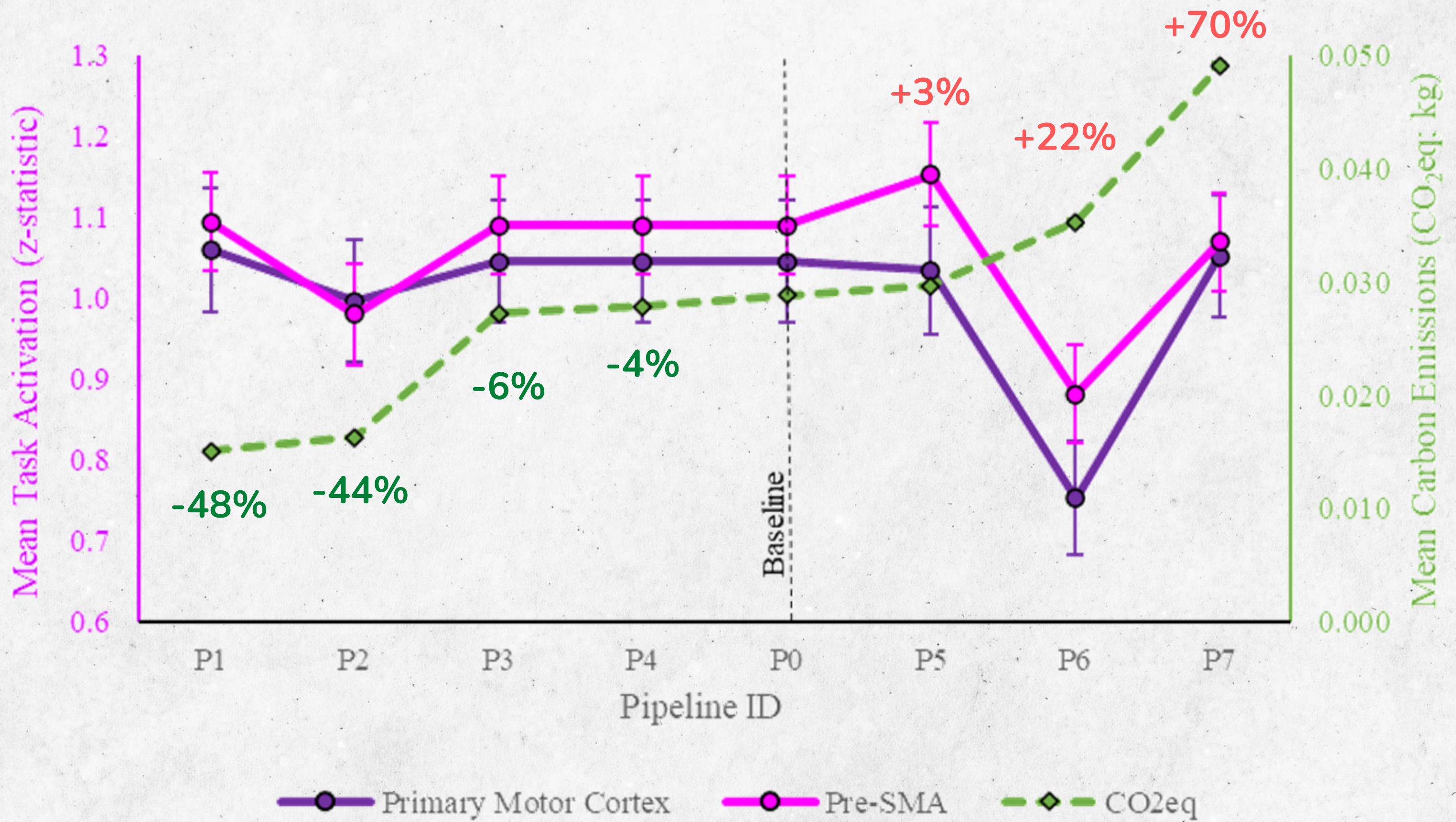
**P3: Low memory  
mode**

**P4: Add surface  
output space**

**P5: ICA-AROMA**

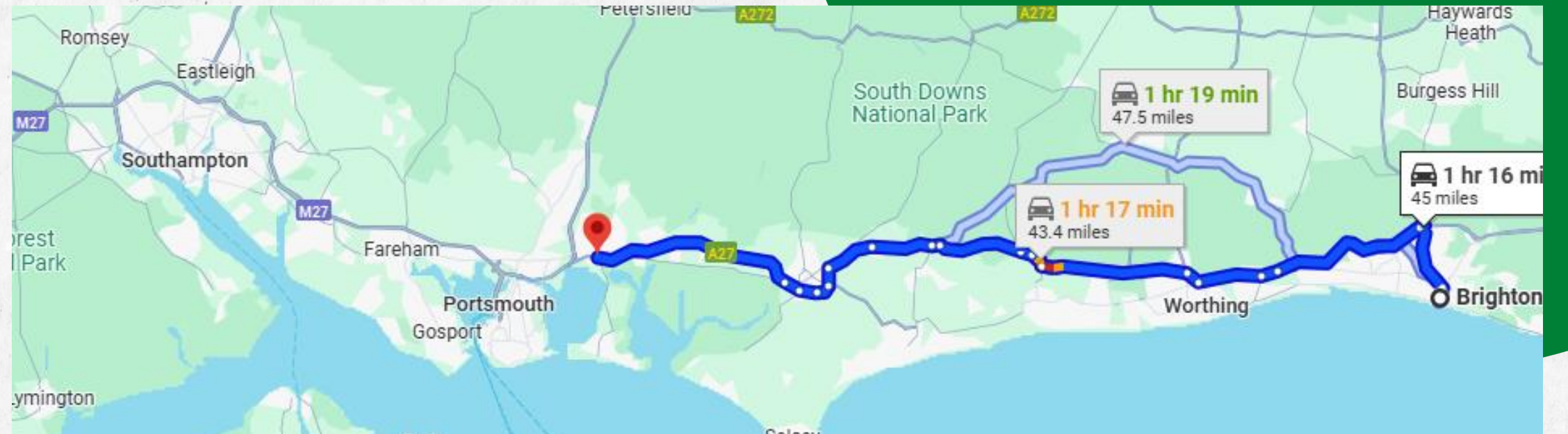
**P6: Fieldmap-free  
distortion correction**

**P7: Increased output  
space resolution**



# Road trip

P0 - Baseline  
7.5 kg = 43 miles  
Portsmouth

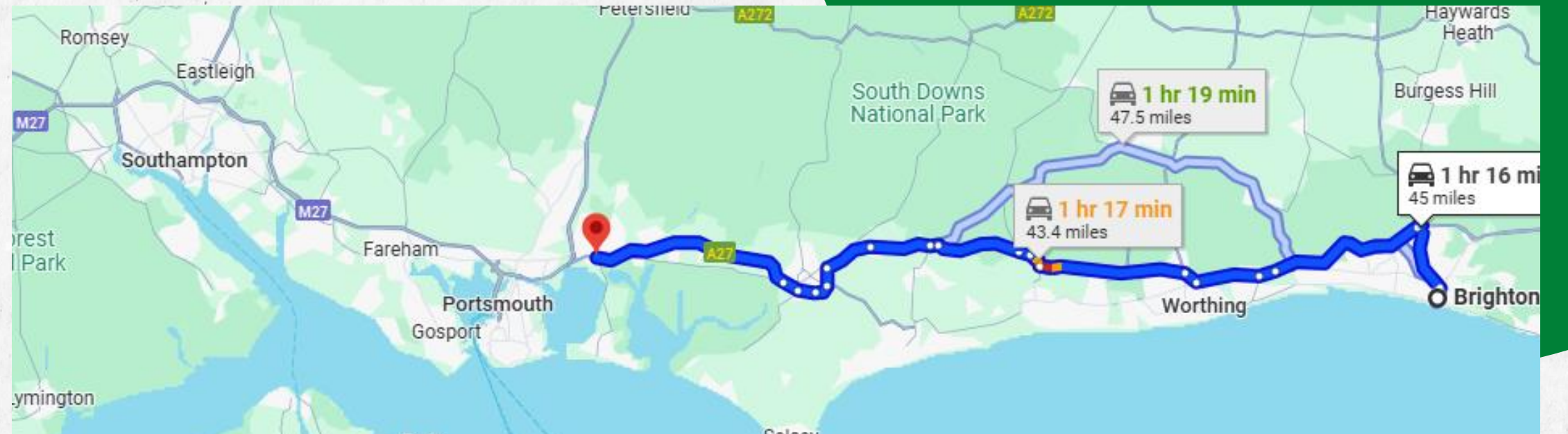


# Road trip

P1 - No FreeSurfer  
3.9 kg = 22 miles  
Littlehampton



P0 - Baseline  
7.5 kg = 43 miles  
Portsmouth

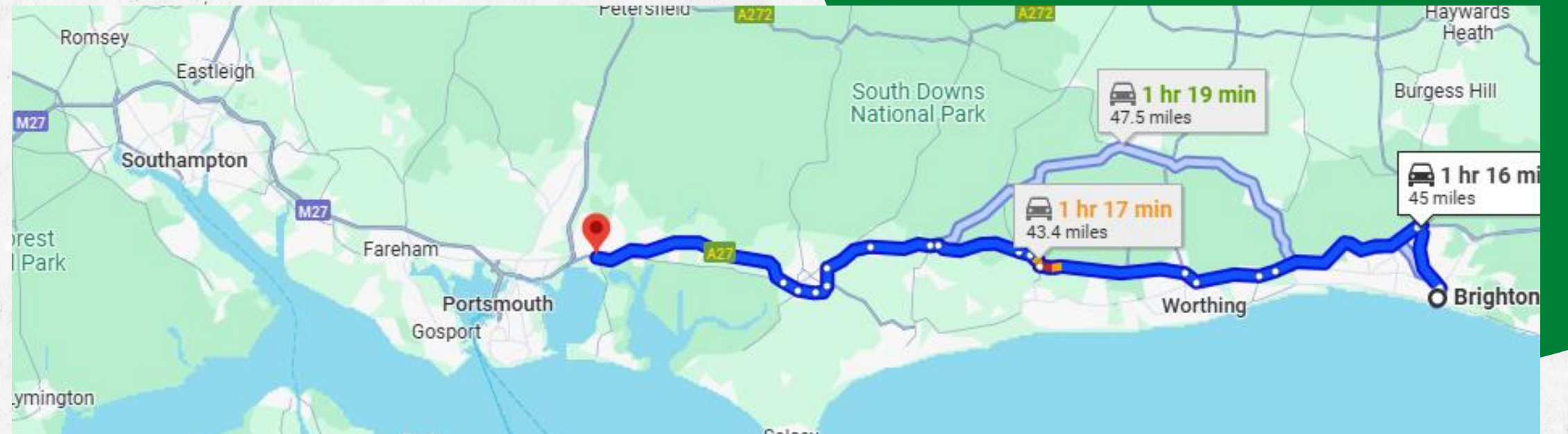


# Road trip

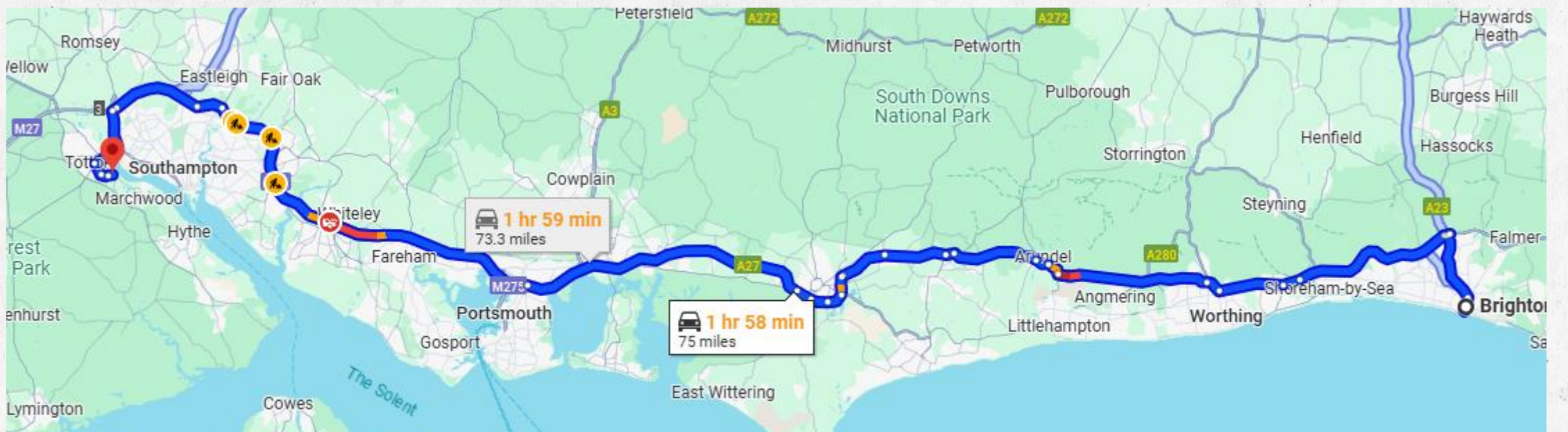
**P1 - No FreeSurfer**  
3.9 kg = 22 miles  
Littlehampton



**P0 - Baseline**  
7.5 kg = 43 miles  
Portsmouth



**P7 - High Resolution**  
12.7 kg = 73 miles  
Southampton



# Recommendations for fMRIPrep

**1** Disable FreeSurfer surface reconstruction (`--fs-no-reconall`) if reconstruction files are not required.

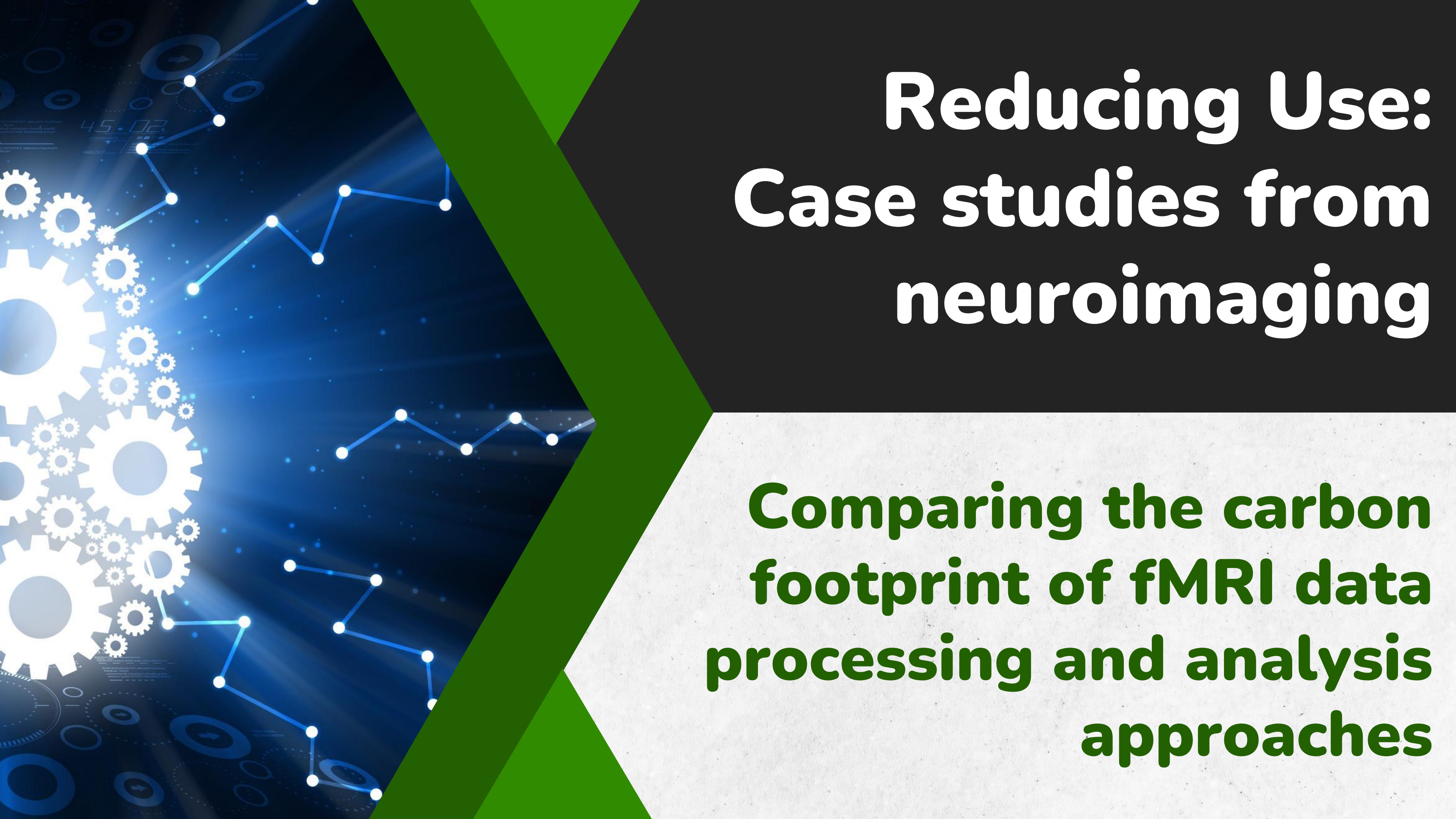
**2** Only when testing the feasibility of a pipeline, use 'sloppy' registration (`--sloppy`).

**3** Implement low memory mode (`--low-mem`).

**4** Implement ICA-AROMA (`--use-aroma`) if needed.

**5** Be aware that fieldmap-free distortion correction technique (`--use-syn-sdc`) can both increase emissions and degrade data quality.

**6** Refrain from using high-resolution volumetric output space templates (`--output-spaces MNI152NLin6Asym:res-1`) unless necessary.

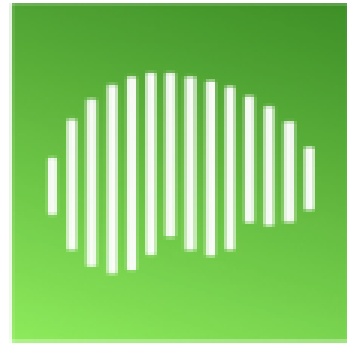


# **Reducing Use: Case studies from neuroimaging**

**Comparing the carbon  
footprint of fMRI data  
processing and analysis  
approaches**

Volume 3

2025



Imaging  
Neuroscience

June 16 2025

## Comparing the carbon footprint of fMRI data processing and analysis approaches



Nicholas E. Souter , Chris Racey , Nikhil Bhagwat , Reese Wilkinson , Niall W. Duncan , Gabrielle Samuel ,  
Loïc Lannelongue , Raghavendra Selvan , Charlotte L. Rae

Check for updates

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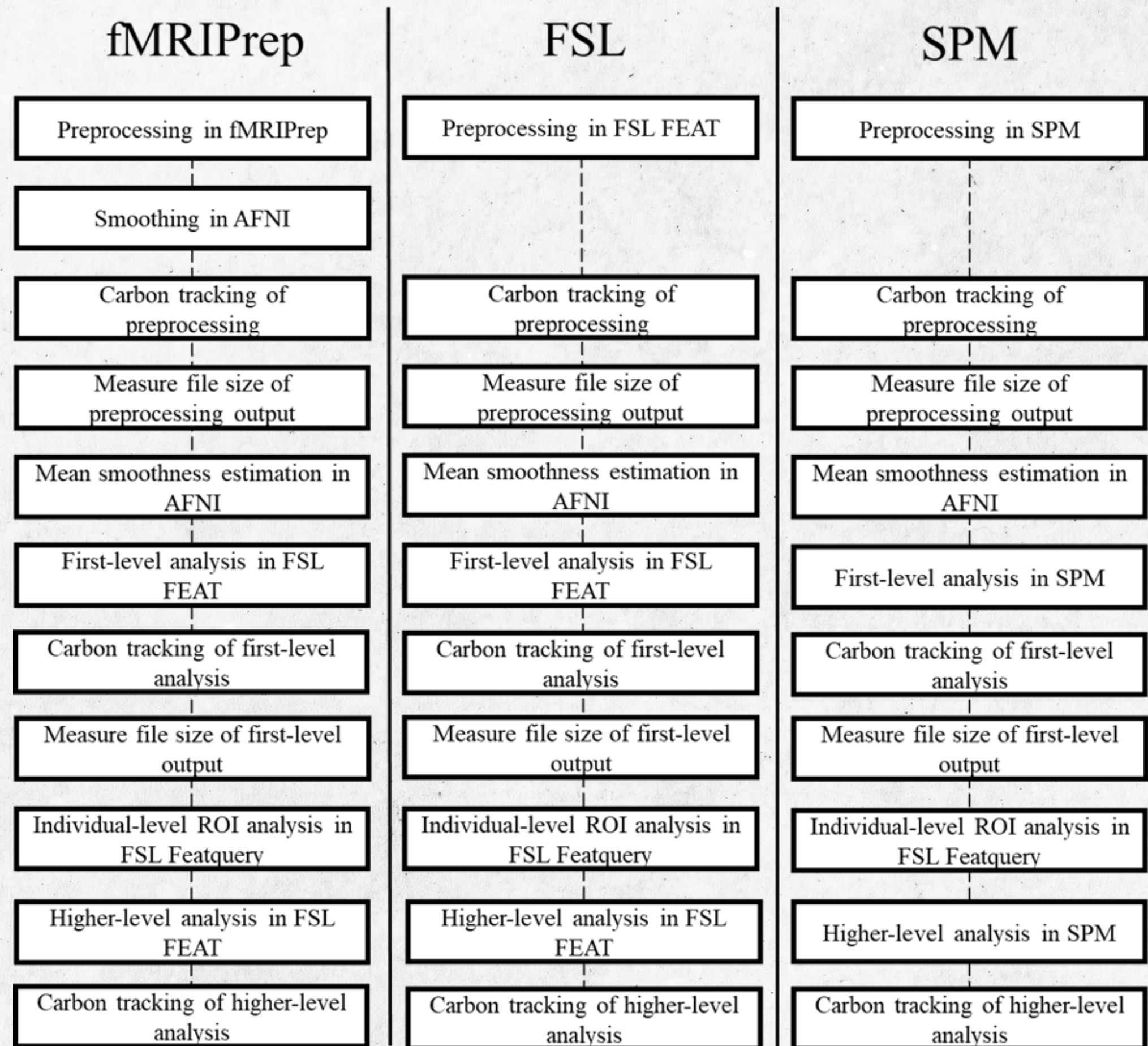
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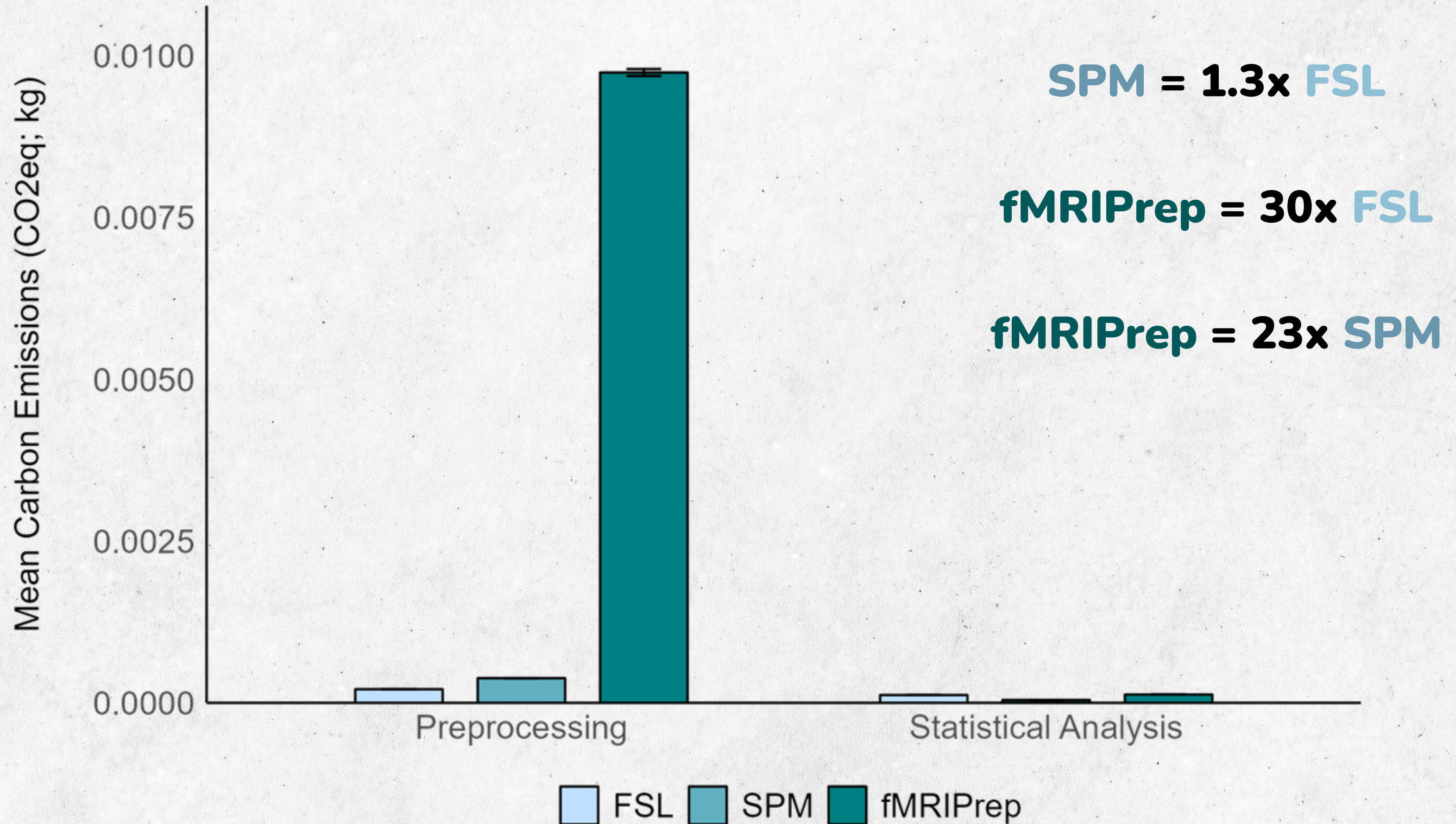
# Comparing Packages

How does the footprint of computing vary across **FSL**, **SPM**, and **fMRIPrep**?

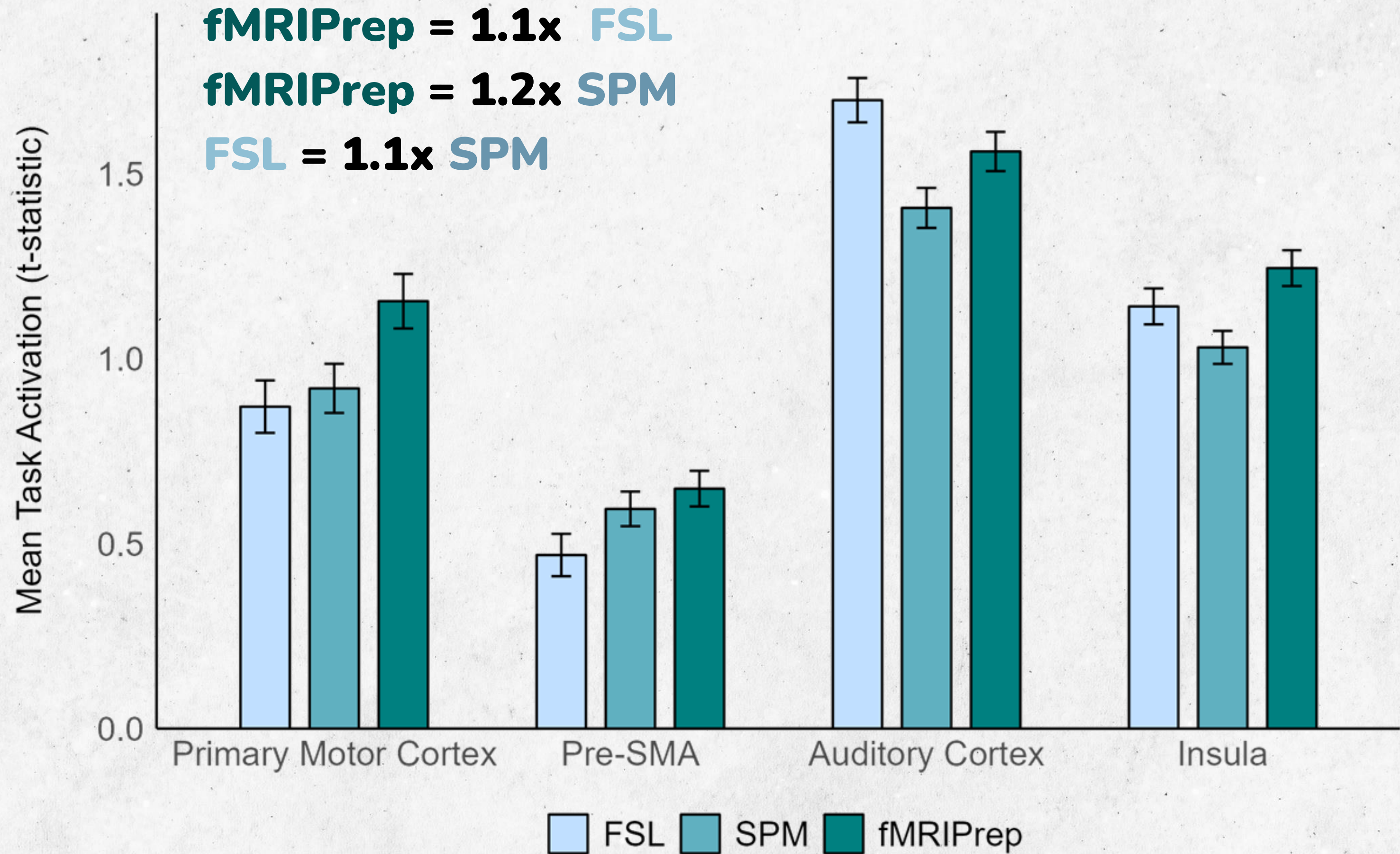
Do higher emissions correspond with higher quality output?



# Carbon Emissions by Package



# Statistical Sensitivity by Package



# Recommendations

- Use of **high-compute tools** (like fMRIPrep) should not be demonised if they provide scientific gains

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- When looking for robust effects, **low-compute tools** (FSL, SPM) may be sufficient

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- Use of **high-compute tools** (like fMRIPrep) should not be demonised if they provide scientific gains
- When looking for robust effects, **low-compute tools** (FSL, SPM) may be sufficient
- **Tool developers** should work to reduce energy usage of preprocessing, providing 'carbon-minimal' flags. We need a balance between sustainability, performance, and usability

# Neuroimaging Green Computing Roving Workshops



Context on the scale of impact

Evidence-based recommendations

Green computing resources

The future of computing

Interactive tool demonstrations

■ Done ■ Upcoming



# Carbon Tracking

# Green Algorithms

**Green Algorithms**  
*How green are your computations?*

Check out the new **Green Algorithms website**: [www.green-algorithms.org](http://www.green-algorithms.org)

**Details about your algorithm**  
*To understand how each parameter impacts your carbon footprint, check out the formula below and the [methods article](#)*

Runtime (HH:MM)


Type of cores


CPUS


Number of cores


Model


CPUS

 ... g CO2e  
Carbon footprint

 Energy needed

 Carbon sequestration

 0.00 km  
in a passenger car

 0  
flights None

<https://calculator.green-algorithms.org/>

# Climate Aware Task Scheduler (CATS)

## CATS: Climate-Aware Task Scheduler

CATS is a Climate-Aware Task Scheduler. It schedules cluster jobs to minimize predicted carbon intensity of running the process. It was created as part of the [2023 Collaborations Workshop](#).



<https://github.com/GreenScheduler/cats>

# *Carbon Tracking*

# **Calc Carbon**

[https://github.com/NickESouter/fMRIPrep-Carbon-Footprint/blob/main/Carbon%20Tracking/Calc\\_carbon.py](https://github.com/NickESouter/fMRIPrep-Carbon-Footprint/blob/main/Carbon%20Tracking/Calc_carbon.py)

# THANK YOU!

FOR YOUR ATTENTION



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