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Representation learning for more reproducible fMRI data analyses

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UNDERSTANDING VARIABILITY

How does analytical variability vary with sample size ?

(Germani et al, 2022)

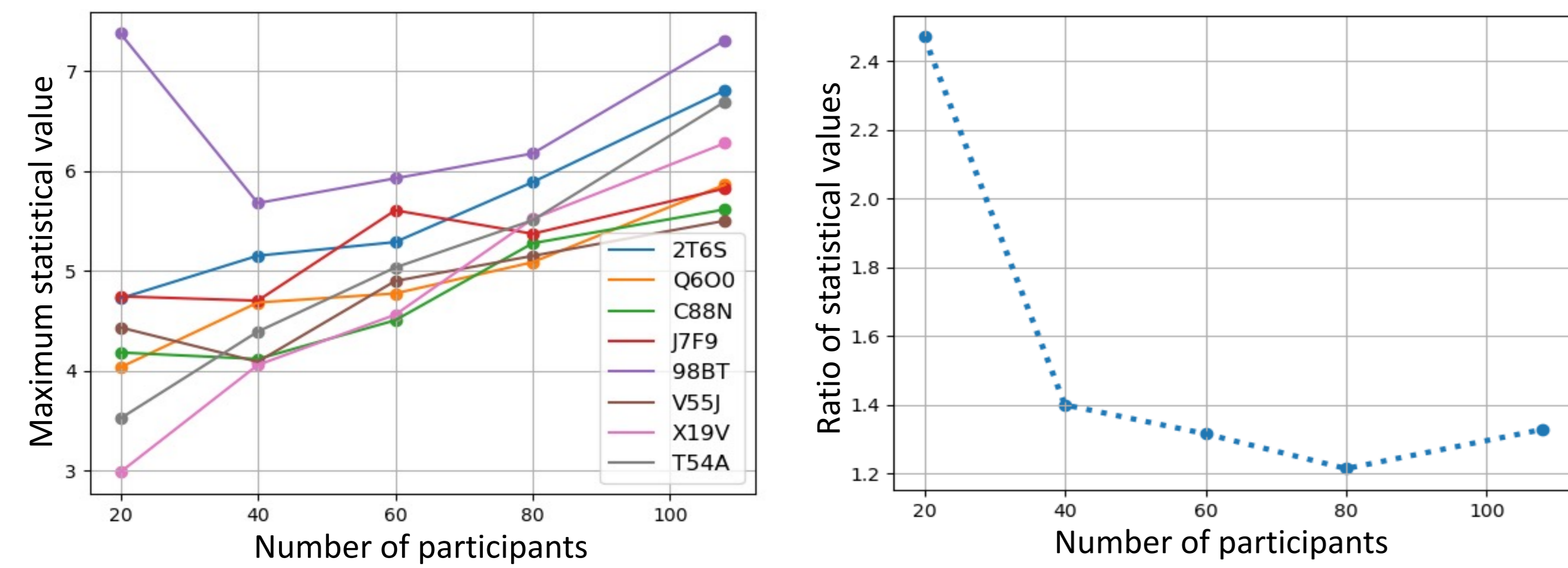


Fig. 1 - Maximum statistical value inside ROI depending on sample size (right) and ratio of largest/smallest maximum statistical value depending on sample sizes (left)

In psychology, (Klau et al., 2020) showed that the vibration of effects decreases and stabilizes as sample size increases.

- ✓ Reproduction of 8 pipelines used in a many-analyst study
→ NARPS Open Pipelines: github.com/Inria-Empenn/narps_open_pipelines
- ✓ Selection of subsets with different numbers of participants;
- ✓ Replication of the results with the subsets.

→ With growing sample sizes, maximum statistical values seemed to converge
→ Confirmed by the stabilization and convergence to 1.3 of the ratio between the largest and the smallest maximum statistical values among teams with sample size.
→ But even for large sample sizes, analytical variability remains non neglectable.

Code available at gitlab.inria.fr/egermani/analytic_variability_fmri/

Exploring variability patterns in the analytical space

(Germani et al, 2023b)

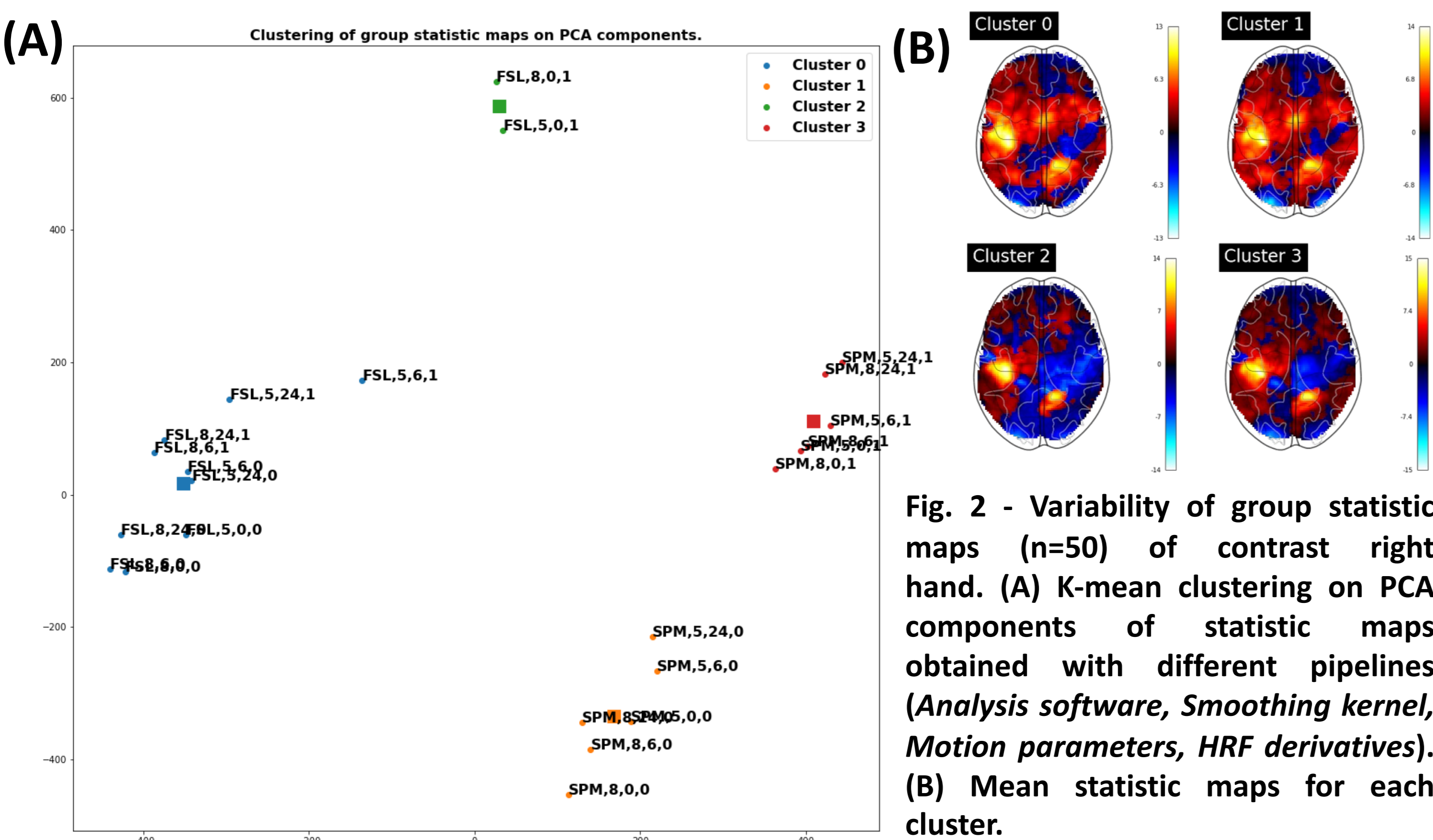


Fig. 2 - Variability of group statistic maps (n=50) of contrast right hand. (A) K-mean clustering on PCA components of statistic maps obtained with different pipelines (Analysis software, Smoothing kernel, Motion parameters, HRF derivatives). (B) Mean statistic maps for each cluster.

The fMRI pipeline-space is especially large and challenging to investigate due the pipeline's sensitivity to particular properties of the data under study.

- ✓ Use of 24 different fMRI pipelines with varying parameters (software, smoothing kernel, etc.) on data from the Human Connectome Project (n=1080 participants)
- ✓ Dimension reduction using PCA or AutoEncoders and clustering methods

→ Pipelines have different behaviors depending on contrasts
→ Some pipelines give closer results than others, especially those sharing specific parameters.

Code available at gitlab.inria.fr/egermani/hcp_pipelines/

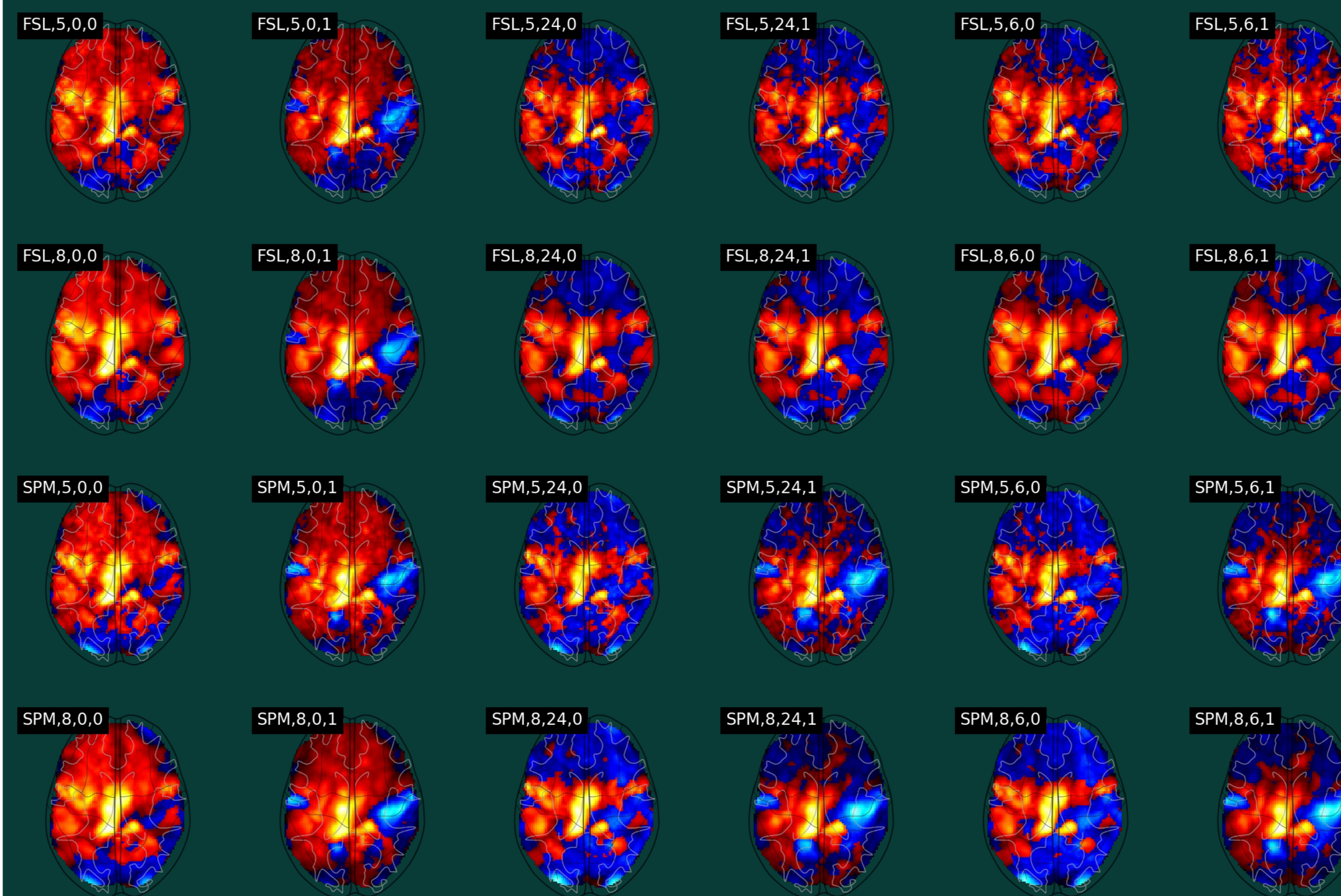
Representation learning for more reproducible fMRI data analyses

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SAME RAW DATA, DIFFERENT ANALYTIC PIPELINES

- Neuroimaging workflows are highly flexible with many possible choices at each step of an analysis (Carp 2012).
- However, different analytical choices can cause variation in the results (Botvinik-Nezer et al., 2020).
- This puts into question the validity of published results and calls for dedicated methodologies to handle this new level of variability (Dafflon et al. 2020)

→ A better understanding of the relationships between results coming from different pipelines is essential in order to develop new methods to tackle this variability.

METHODS TO TACKLE THIS VARIABILITY

Benefitting from data variability to build more generalizable brain decoding models (Germani et al, 2023a)

Training effective Deep Learning models on fMRI data comes with challenges, e.g. lack of training data and large number of sources of variability in the data.

- ✓ Use of the NeuroVault (Gorgolewski et al., 2015) database: N=28,532 maps with unconstrained annotations.
- ✓ Pre-training of an unsupervised model (AutoEncoder) using NeuroVault and fine-tuning for classification tasks on smaller datasets.

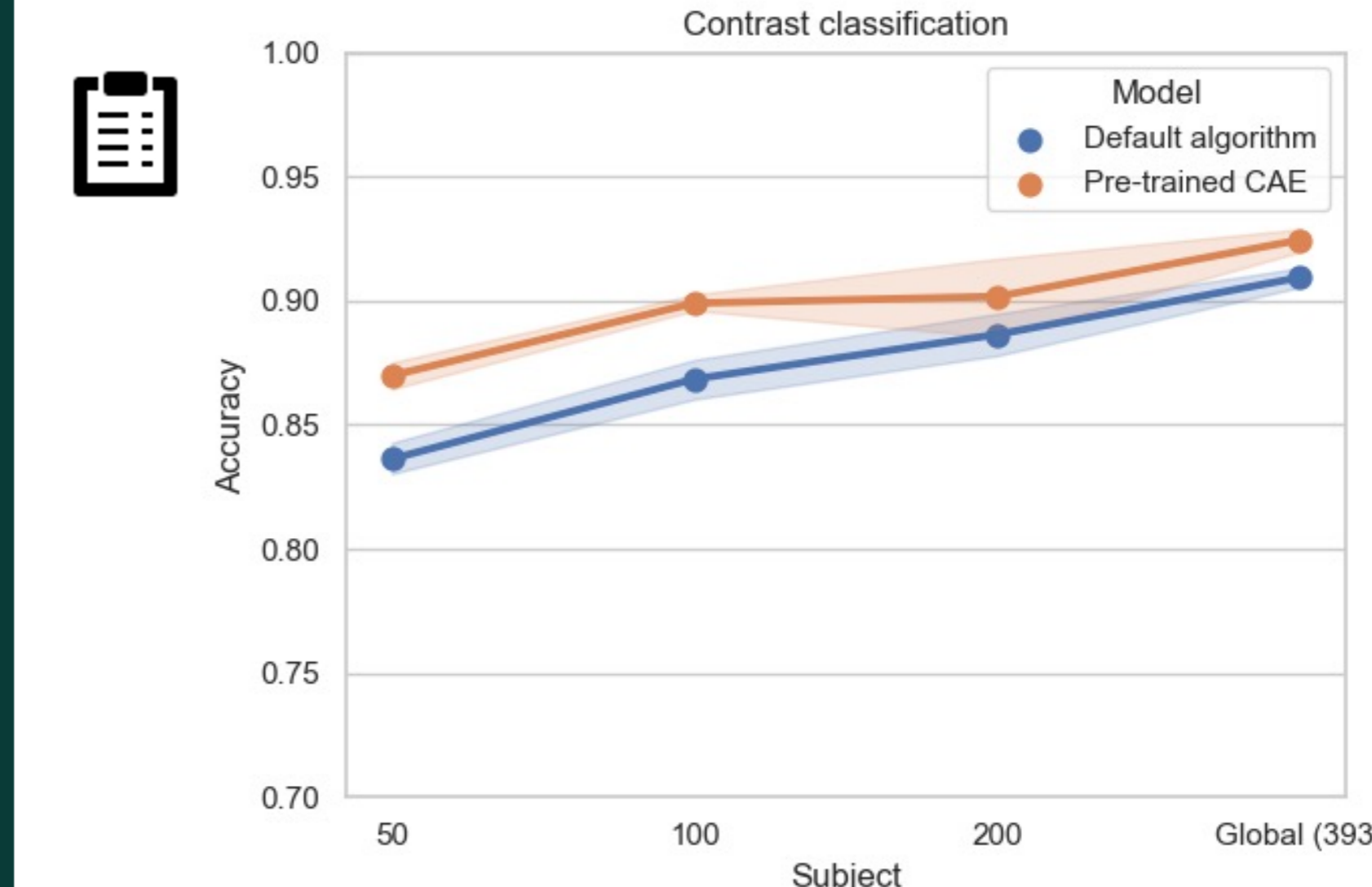


Fig. 3 – Mean accuracies for models initialized with default algorithm (blue) and pre-trained CAE (orange)

→ Better performance on small datasets and difficult classification tasks

→ Improved generalizability due to the ability of the pre-trained to focus on more general features and not on individual patterns of variability.

Code available at gitlab.inria.fr/egermani/self_taught_decoding/

Transferring pipelines patterns between contrast maps

Re-using fMRI maps processed with different pipelines can be difficult and augment the risk of having false positive findings (Rolland et al., 2022)

- ✓ We hypothesize that different pipelines can be seen as different styles applied to an fMRI map.
- ✓ Use of style transfer methods (Isola et al, 2018) to convert contrast maps between pipelines.

→ Some patterns of a pipeline can easily be transferred between contrast maps (e.g. smoothing)

→ Other parameters may display different patterns in contrast maps depending on specific properties of the data, making style transfer difficult to learn

Code available at gitlab.inria.fr/egermani/pipeline_transition/

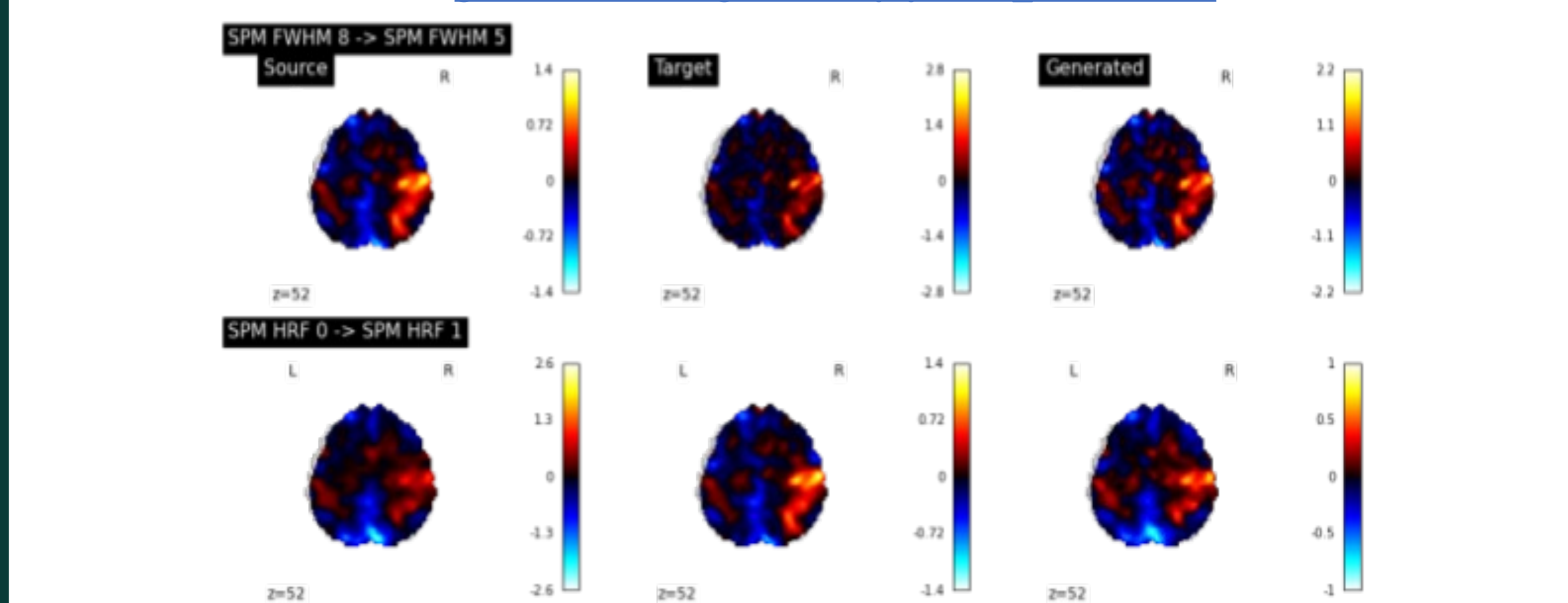


Fig. 4 – Comparison of contrast maps obtained with a source pipeline, a target pipeline and the map generated using style transfer algorithm.

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