

Statistical inference for Same Data Meta-Analysis (SDMA) for neuroimaging multiverse analyzes



OHBM 2024
JUNE 23~27, SEOUL, KOREA



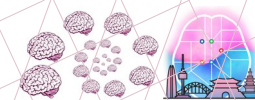
Jeremy
Lefort-Besnard



Thomas
Nichols

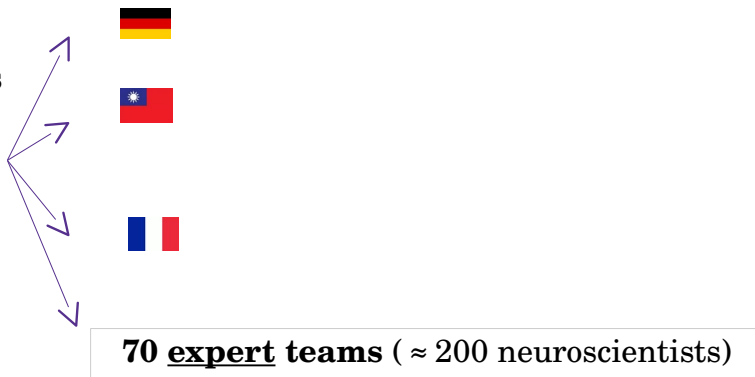


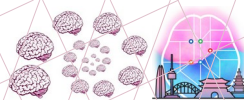
Camille
Maumet



NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

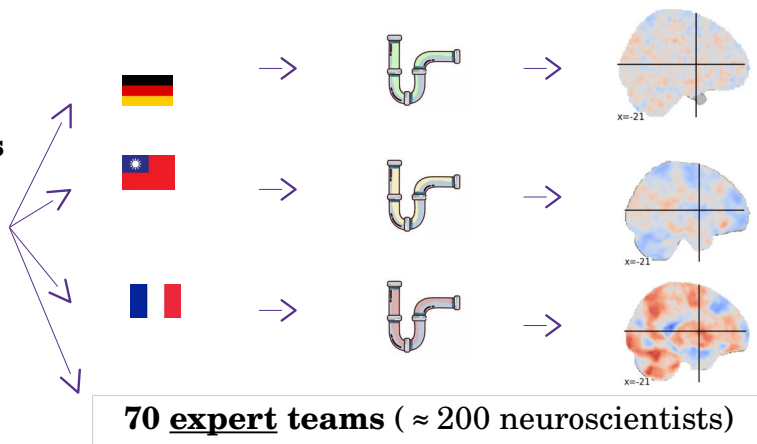
SAME
data & research questions

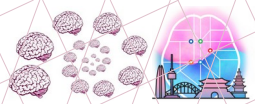




NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

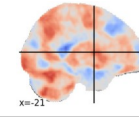
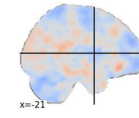
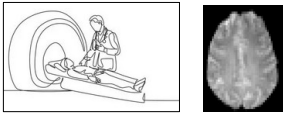
SAME
data & research questions



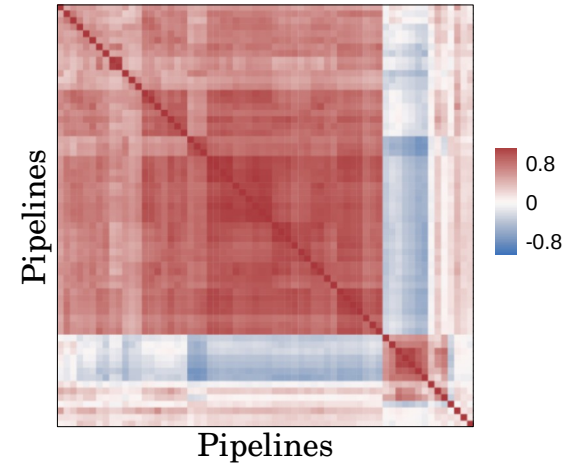


NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

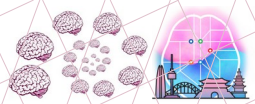
SAME
data & research questions



70 expert teams (≈ 200 neuroscientists)

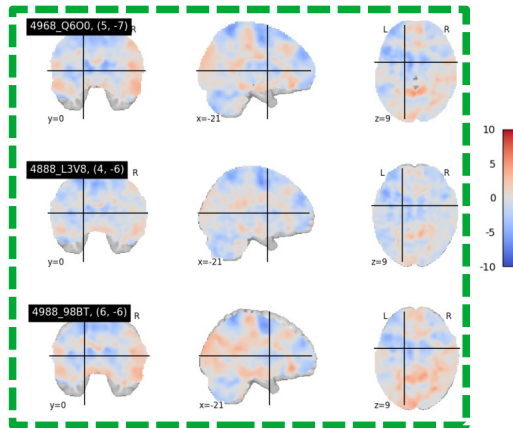
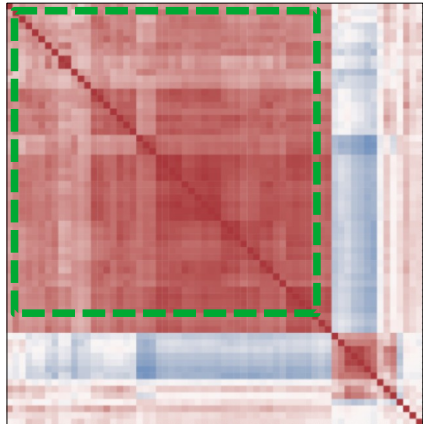
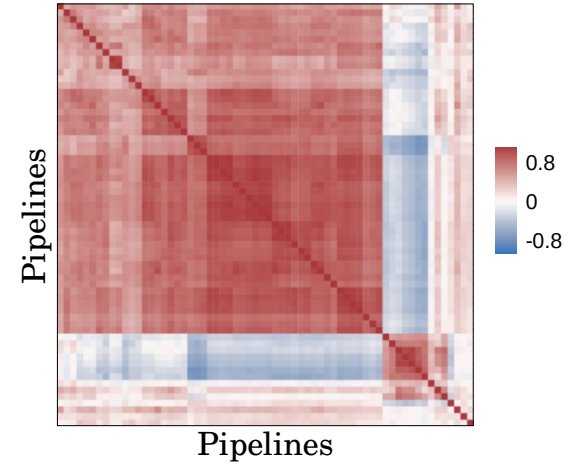
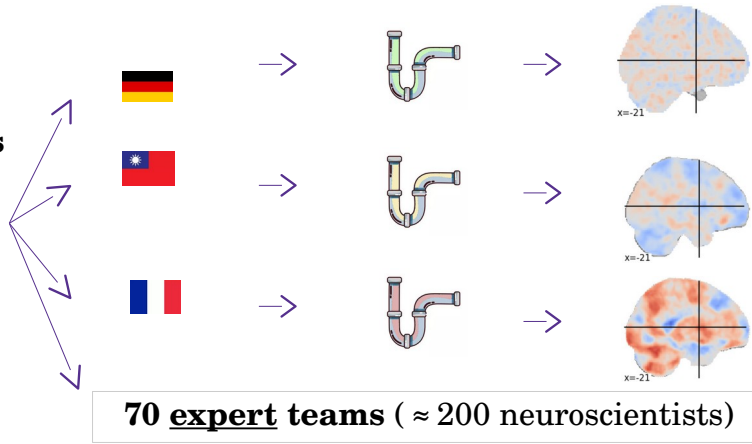
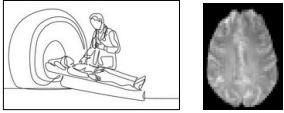


Same Data Meta-Analysis - Introduction

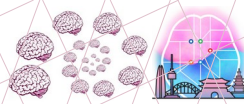


NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

SAME
data & research questions

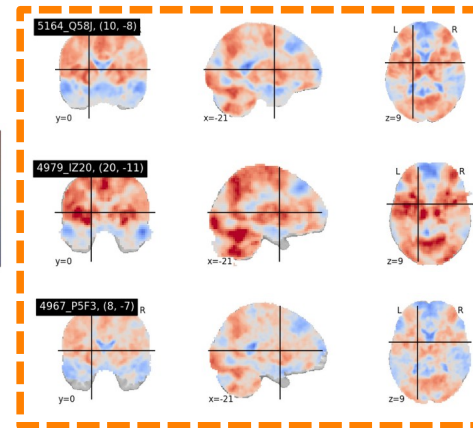
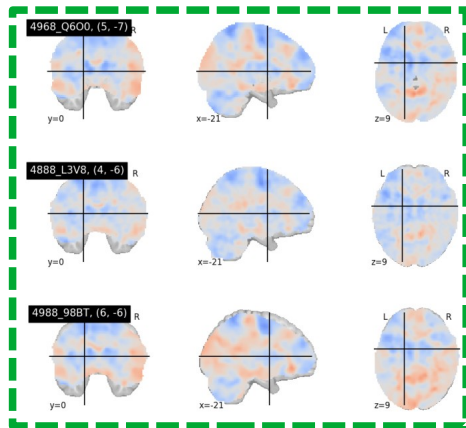
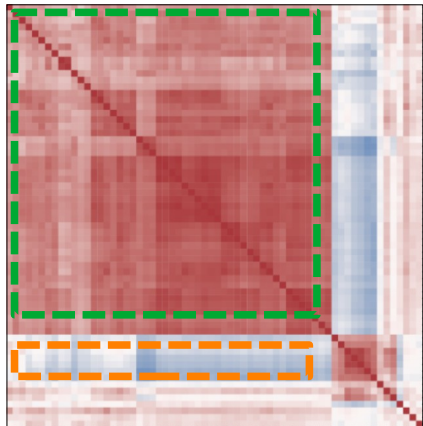
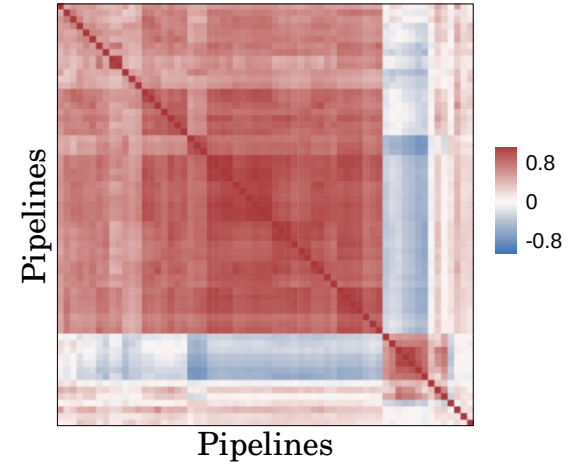
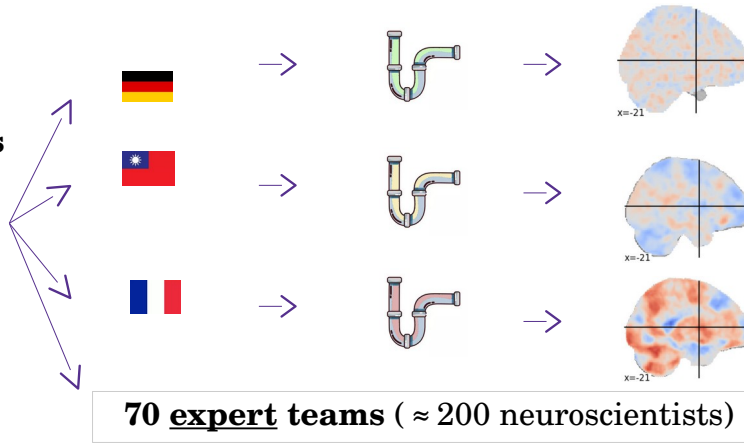
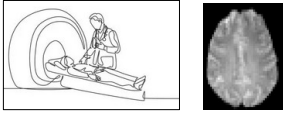


Same Data Meta-Analysis - Introduction

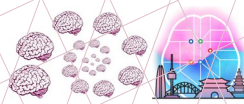


NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

SAME
data & research questions

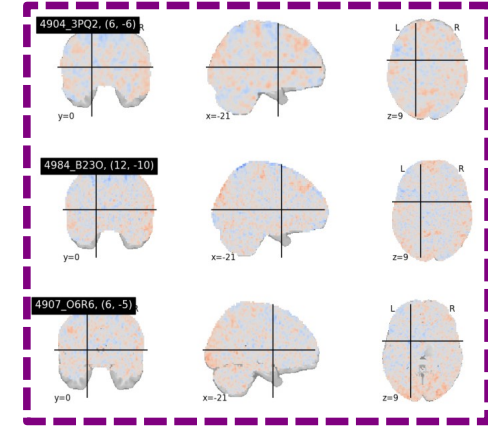
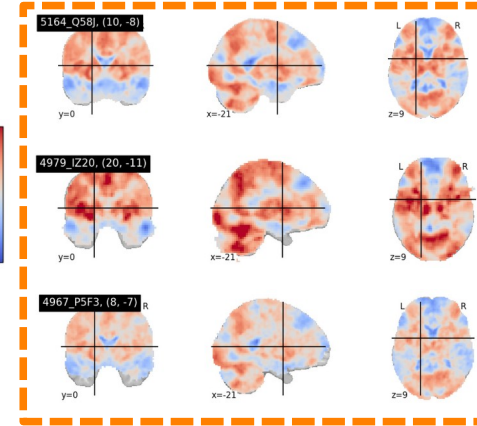
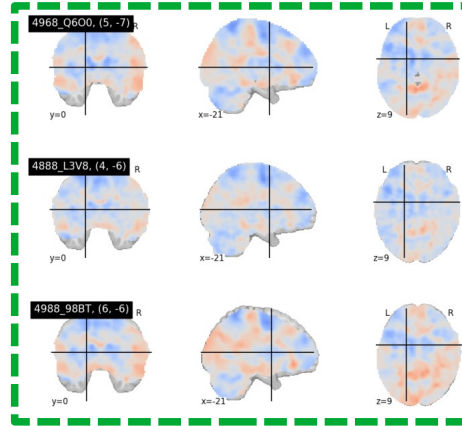
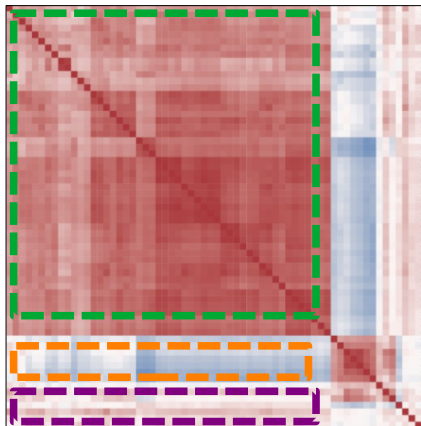
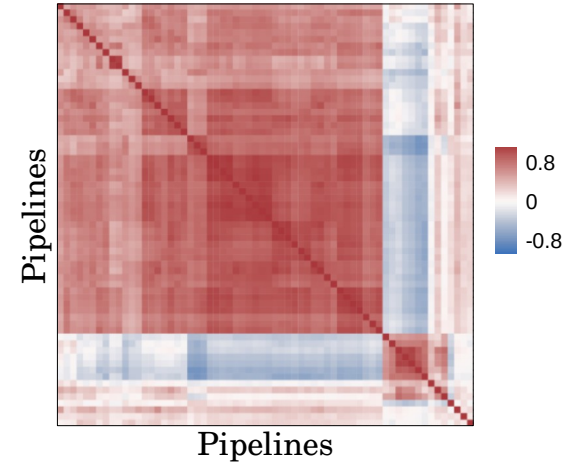
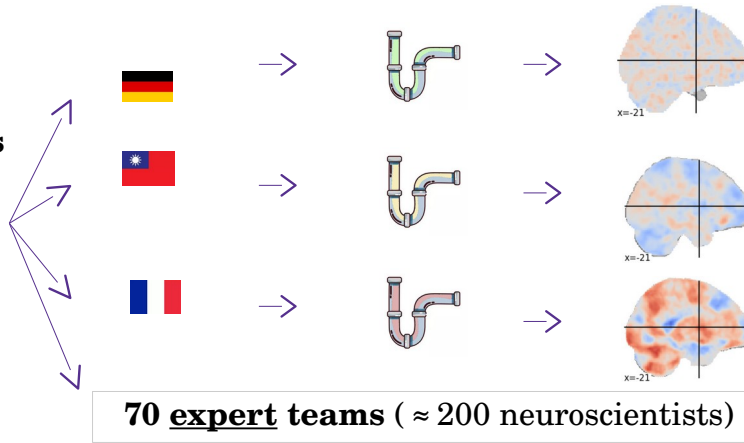
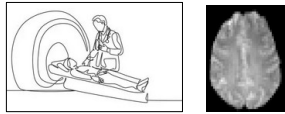


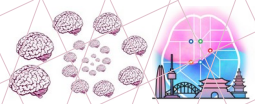
Same Data Meta-Analysis - Introduction



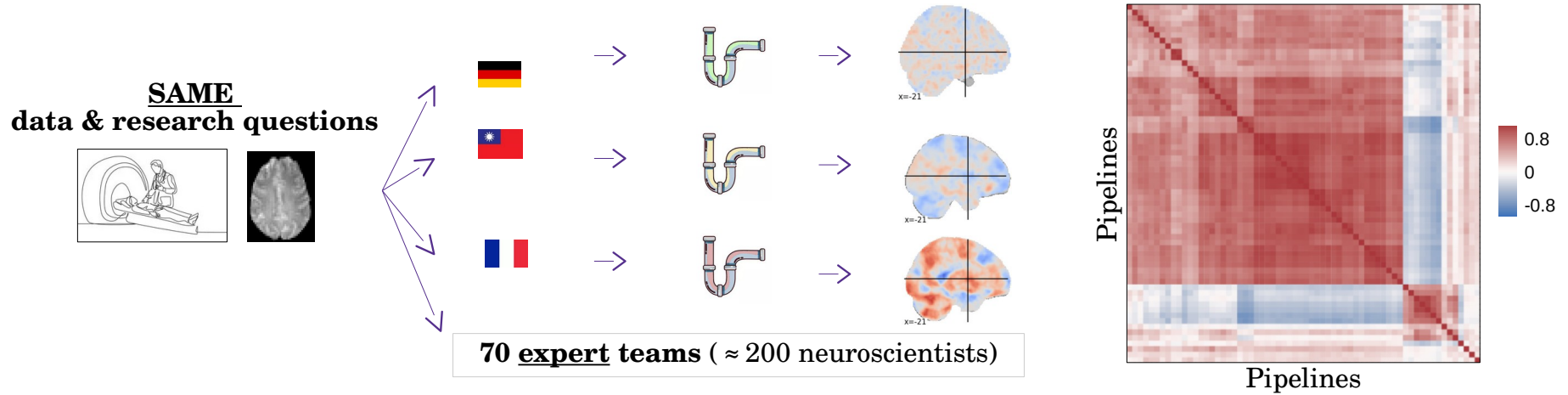
NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

SAME
data & research questions



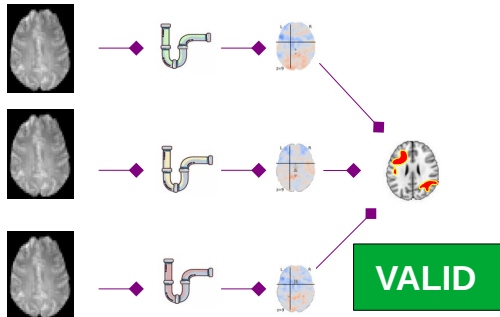


NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

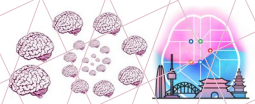


Classical meta-analysis methods in :

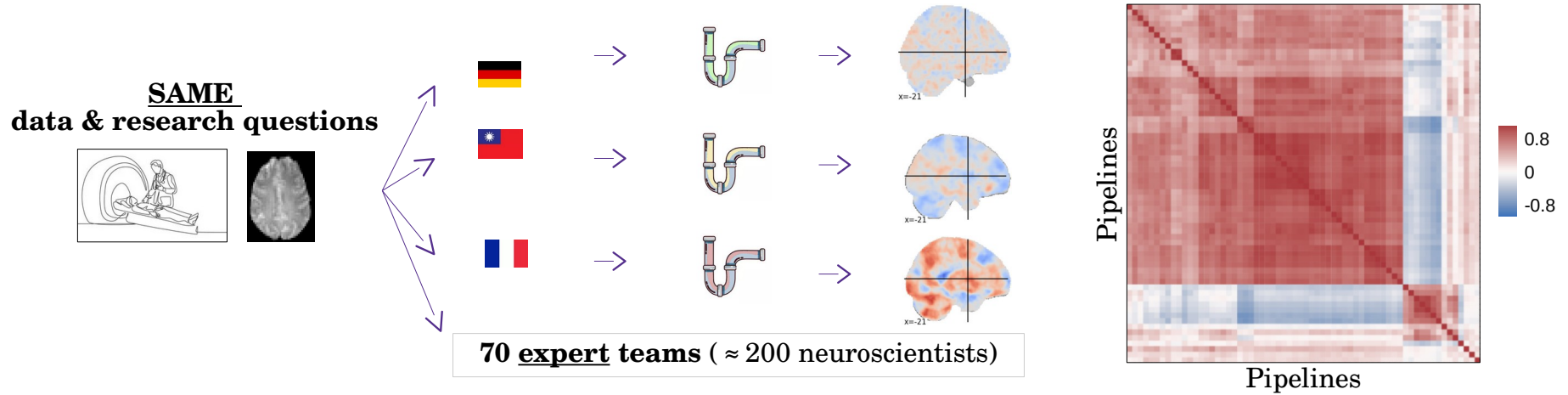
Traditional analysis setting



Same Data Meta-Analysis - Introduction

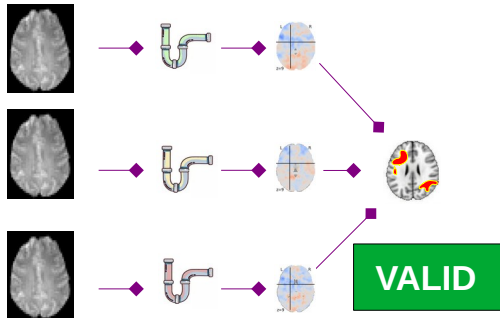


NARPS study (Rotem Botvinik-Nezer et al. Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 2020)

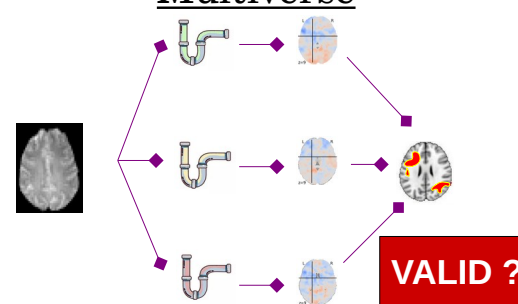


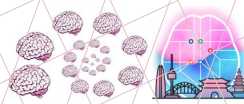
Classical meta-analysis methods in :

Traditional analysis setting



Multiverse





CLASSICAL Meta-Analysis

SAME DATA Meta-Analysis

Stouffer

**SDMA
Stouffer**

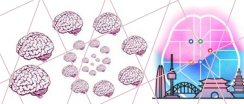
$$Z_j^S = \frac{\bar{Y}_j}{\sqrt{1/K}}$$

$$Z_j^{SS} = \frac{\bar{Y}_j}{\sqrt{\mathbf{1}_k^T \mathbf{Q} \mathbf{1}_k / K^2}}$$

Average standardized

Average standardized
accounting for
dependence

Lefort-Besnard, Nichols* and Maumet*. (2024). Statistical inference for Same Data Meta-Analysis for neuroimaging multiverse analyzes. *In prep.*



CLASSICAL Meta-Analysis

SAME DATA Meta-Analysis

Stouffer

$$Z_j^S = \frac{\bar{Y}_j}{\sqrt{1/K}}$$

Average standardized

**SDMA
Stouffer**

$$Z_j^{SS} = \frac{\bar{Y}_j}{\sqrt{\mathbf{1}_k^T \mathbf{Q} \mathbf{1}_k / K^2}}$$

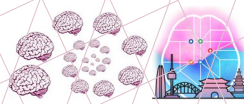
Average standardized
accounting for
dependence

**Consensus
SDMA
Stouffer**

$$Z_j^{CSS} = Z_j^{SS} - \langle Z^{SS} \rangle + \mu_C$$

Average standardized
accounting for
dependence,
and shifted empirically

Lefort-Besnard, Nichols* and Maumet*. (2024). Statistical inference for Same Data Meta-Analysis for neuroimaging multiverse analyzes. *In prep.*



CLASSICAL Meta-Analysis

SAME DATA Meta-Analysis

Stouffer

$$Z_j^S = \frac{\bar{Y}_j}{\sqrt{1/K}}$$

Average standardized

**SDMA
Stouffer**

$$Z_j^{SS} = \frac{\bar{Y}_j}{\sqrt{\mathbf{1}_k^T \mathbf{Q} \mathbf{1}_k / K^2}}$$

Average standardized
accounting for
dependence

**Consensus
SDMA
Stouffer**

$$Z_j^{CSS} = Z_j^{SS} - \langle Z^{SS} \rangle + \mu_C$$

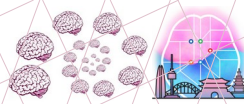
Average standardized
accounting for
dependence,
and shifted empirically

**Consensus
Average**

$$Z_j^{CA} = \frac{\bar{Y}_j - \langle \bar{Y} \rangle}{\sqrt{\langle \bar{Y} \rangle}} \sigma_C + \mu_C$$

Average, scaled
and shifted empirically

Lefort-Besnard, Nichols* and Maumet*. (2024). Statistical inference for Same Data Meta-Analysis for neuroimaging multiverse analyzes. *In prep.*



CLASSICAL Meta-Analysis

SAME DATA Meta-Analysis

Stouffer

$$Z_j^S = \frac{\bar{Y}_j}{\sqrt{1/K}}$$

Average standardized

**SDMA
Stouffer**

$$Z_j^{SS} = \frac{\bar{Y}_j}{\sqrt{\mathbf{1}_k^\top \mathbf{Q} \mathbf{1}_k / K^2}}$$

Average standardized
accounting for
dependence

**Consensus
SDMA
Stouffer**

$$Z_j^{CSS} = Z_j^{SS} - \langle Z^{SS} \rangle + \mu_C$$

Average standardized
accounting for
dependence,
and shifted empirically

**Consensus
Average**

$$Z_j^{CA} = \frac{\bar{Y}_j - \langle \bar{Y} \rangle}{\sqrt{\langle \bar{Y} \rangle}} \sigma_C + \mu_C$$

Average, scaled
and shifted empirically

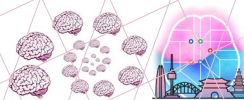
SDMA GLS

$$Z_j^{SG} = \frac{\mathbf{1}^\top \mathbf{Q}^{-1} \mathbf{Y}_j}{\sqrt{\mathbf{1}^\top \mathbf{Q}^{-1} \mathbf{1}}}$$

Optimal average,
standardised

Lefort-Besnard, Nichols* and Maumet*. (2024). Statistical inference for Same Data Meta-Analysis for neuroimaging multiverse analyzes. *In prep.*

Same Data Meta-Analysis - Results in simulations



CLASSICAL Meta-Analysis

Stouffer

SAME DATA Meta-Analysis

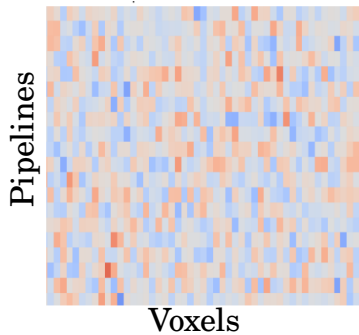
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

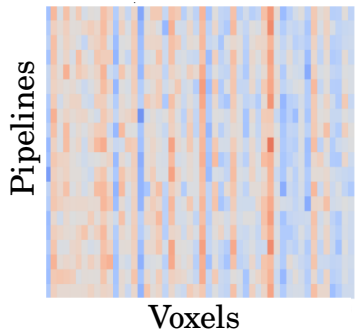
**Consensus
Average**

SDMA GLS

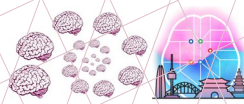
Traditional



Multiverse



Same Data Meta-Analysis - Results in simulations



CLASSICAL Meta-Analysis

Stouffer

SAME DATA Meta-Analysis

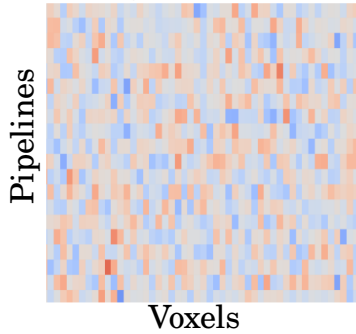
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

**Consensus
Average**

SDMA GLS

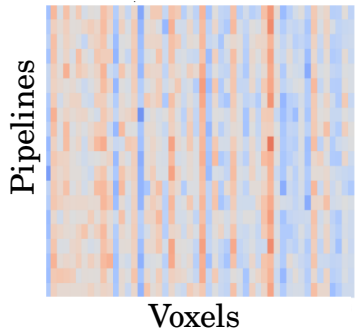
Traditional



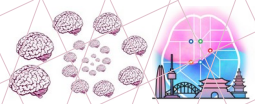
VALID
4.7 %

$\alpha = 5\%$ nominal

Multiverse



Same Data Meta-Analysis - Results in simulations



CLASSICAL Meta-Analysis

Stouffer

SAME DATA Meta-Analysis

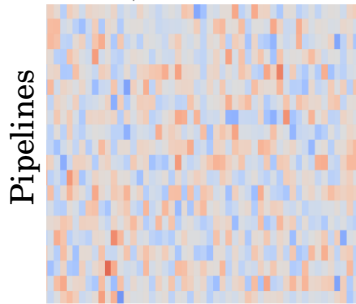
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

**Consensus
Average**

SDMA GLS

Traditional



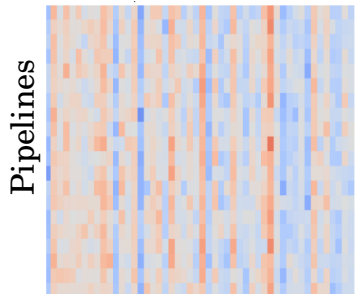
Voxels

VALID

4.7 %

$\alpha = 5\%$ nominal

Multiverse

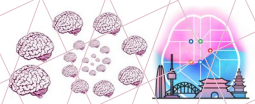


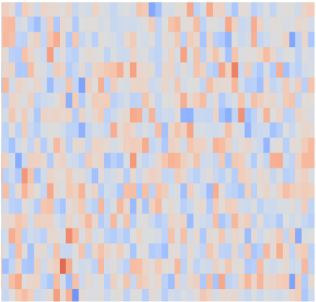
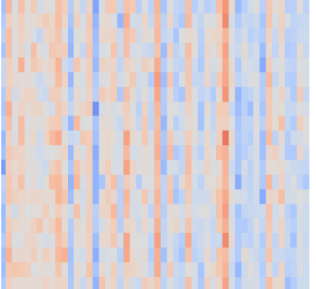
Voxels

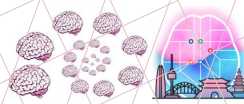
INVALID

30.1 %

Same Data Meta-Analysis - Results in simulations



		CLASSICAL Meta-Analysis	SAME DATA Meta-Analysis			
		Stouffer	SDMA Stouffer	Consensus SDMA Stouffer	Consensus Average	SDMA GLS
Traditional						
Pipelines		VALID 4.7 %	VALID 4.7 %	VALID 4.8 %	VALID 4.8 %	VALID 4.4 %
	Voxels	$\alpha = 5\%$ nominal				
Multiverse						
Pipelines		INVALID 30.1 %	VALID 4.9 %	VALID 5.0 %	VALID 5.0 %	VALID 4.9 %
	Voxels					



SAME DATA Meta-Analysis

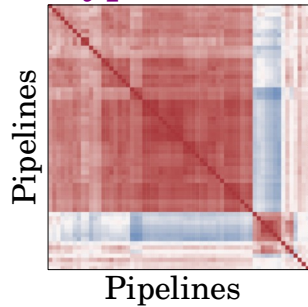
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

**Consensus
Average**

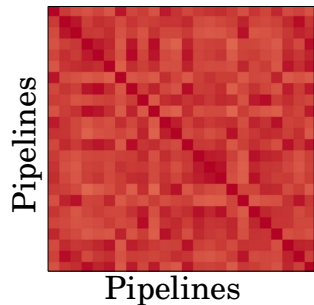
SDMA GLS

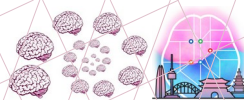
**NARPS
(hypothesis 1)**



0.8
0
-0.8

**HCP Young Adult
(Right hand contrast)**





SAME DATA Meta-Analysis

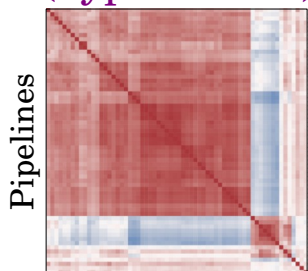
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

**Consensus
Average**

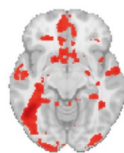
SDMA GLS

**NARPS
(hypothesis 1)**

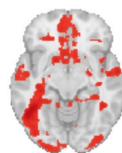


Pipelines

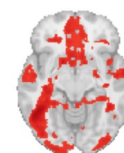
Pipelines



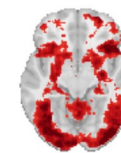
9.1 %



11.0 %

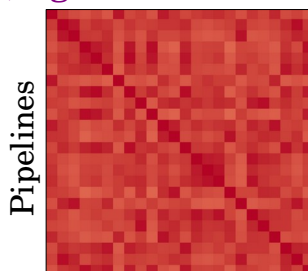


14.1 %



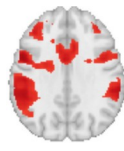
48.3 %

**HCP Young Adult
(Right hand contrast)**

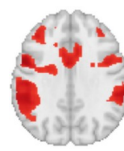


Pipelines

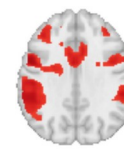
Pipelines



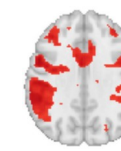
29.1 %



28.2 %

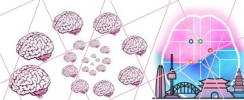


28.3 %



31.3 %

$P \leq 0.05$ (uncorrected)



SAME DATA Meta-Analysis

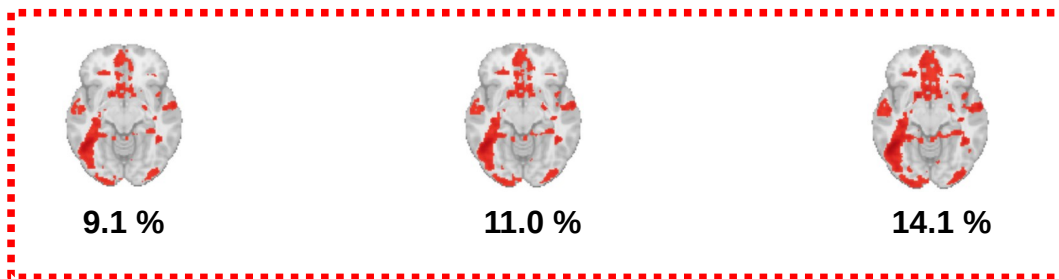
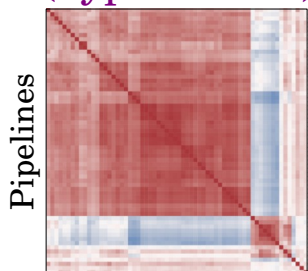
**SDMA
Stouffer**

**Consensus
SDMA
Stouffer**

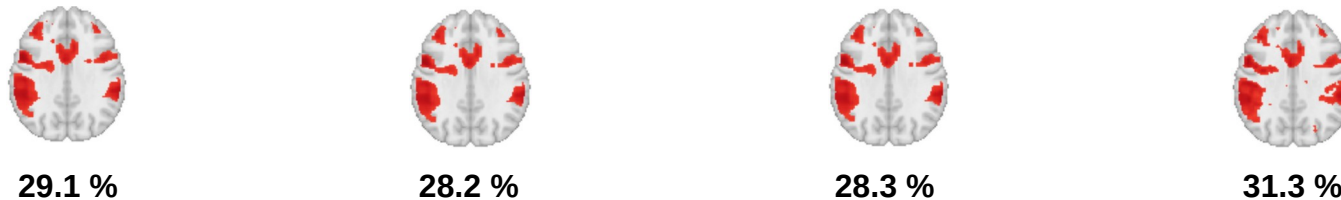
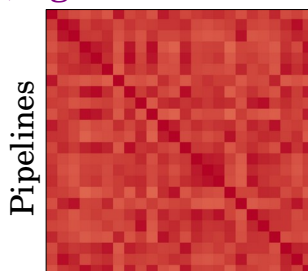
**Consensus
Average**

SDMA GLS

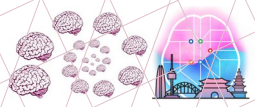
**NARPS
(hypothesis 1)**



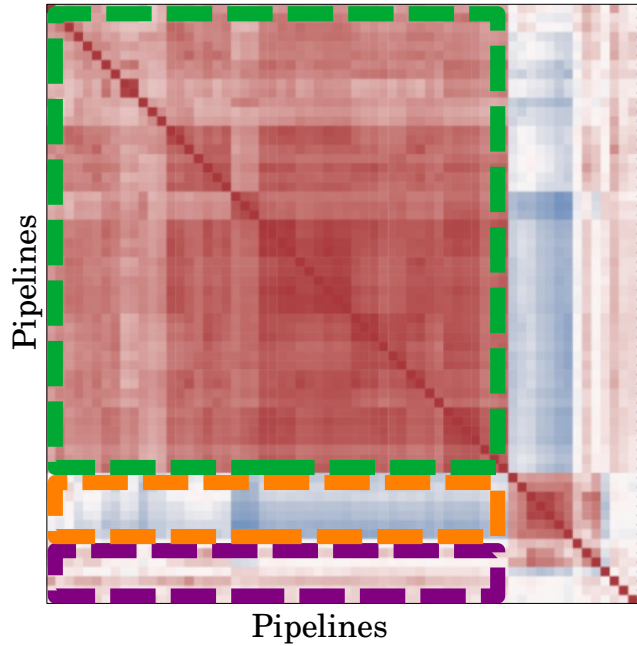
**HCP Young Adult
(Right hand contrast)**



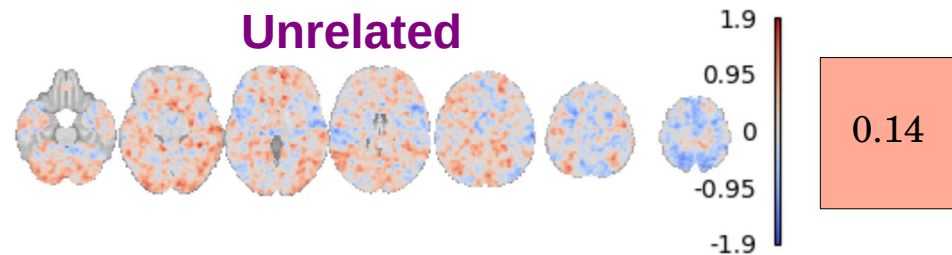
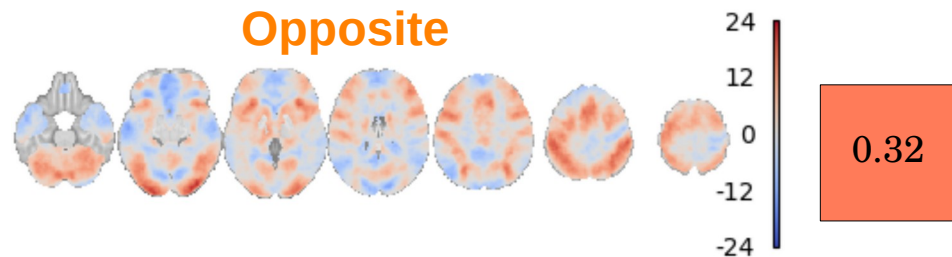
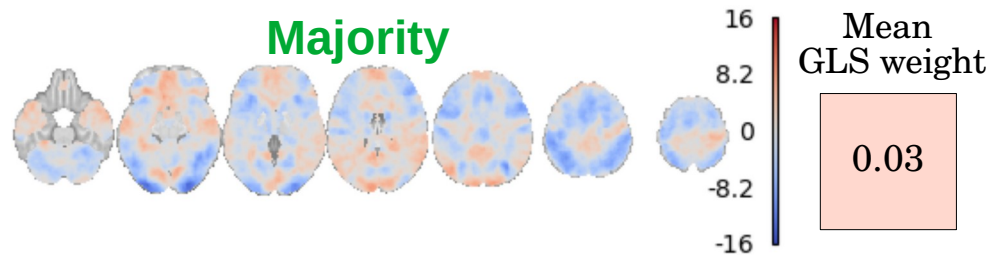
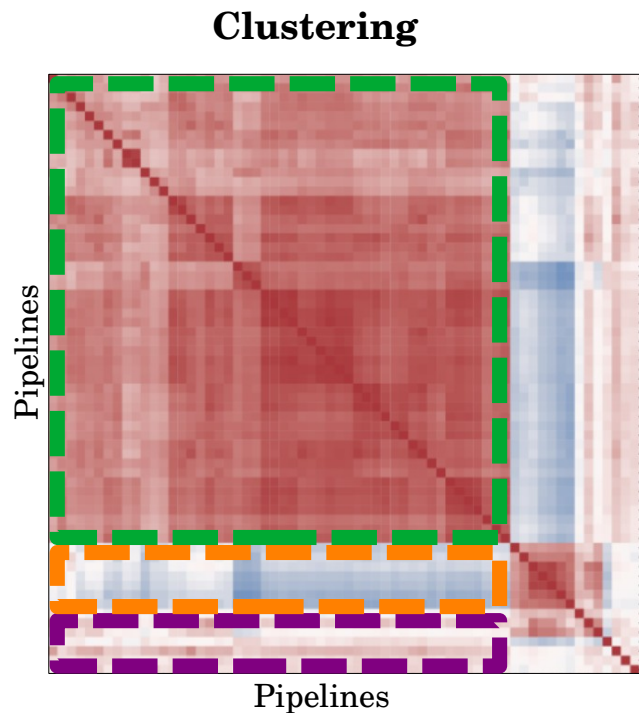
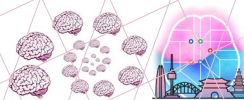
$P \leq 0.05$ (uncorrected)

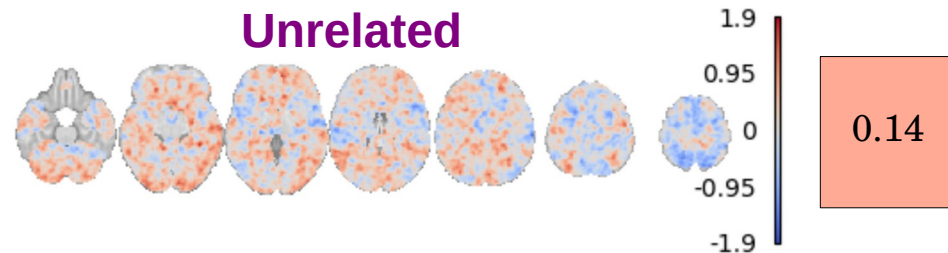
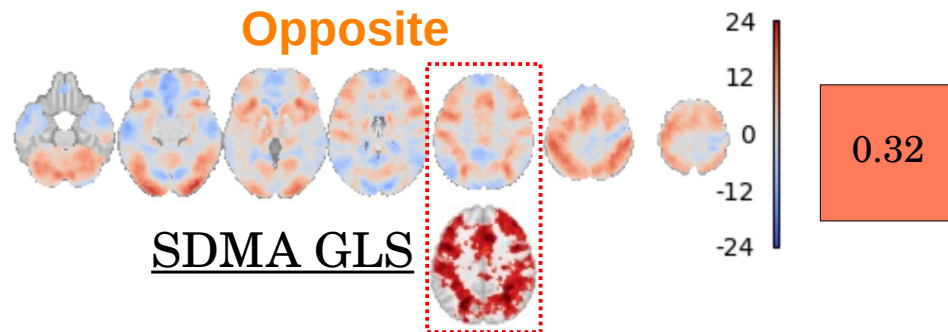
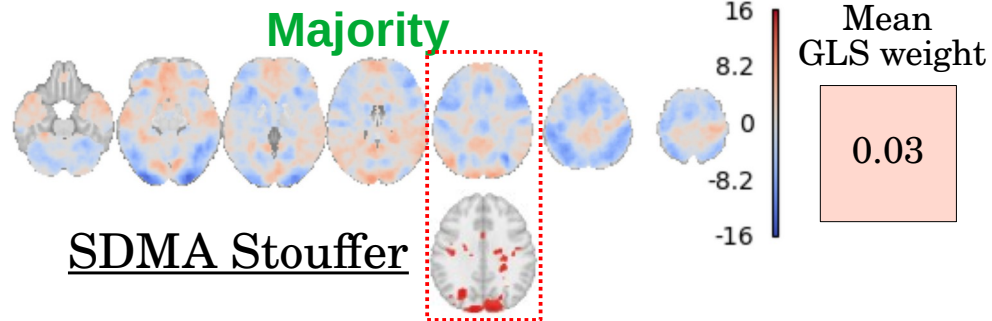
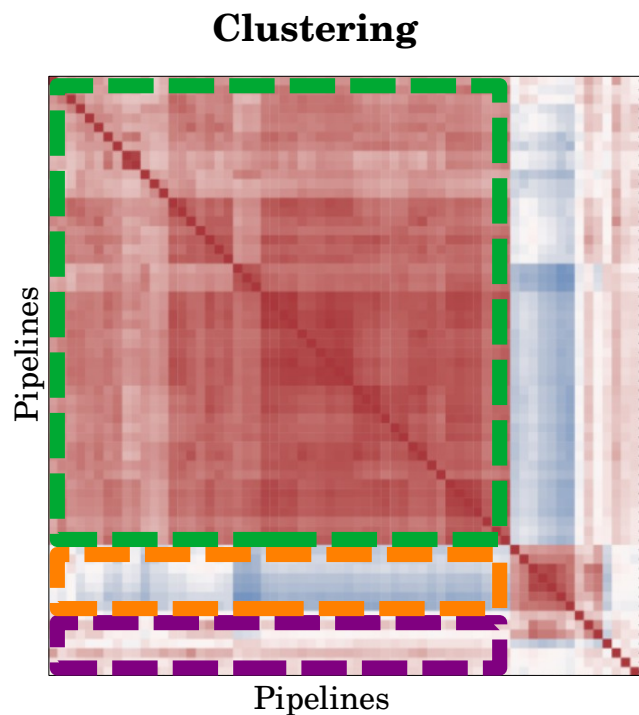
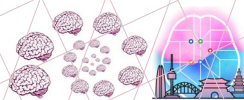


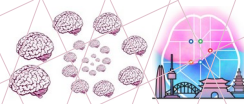
Clustering



Same Data Meta-Analysis - Interpretability of SDMA GLS







Take-home message:

SDMA Stouffer

$$Z_j^{SS} = \frac{\bar{Y}_j}{\sqrt{\mathbf{1}_k^T \mathbf{Q} \mathbf{1}_k / K^2}}$$

Average standardized
accounting for
dependence

Consensus SDMA Stouffer

$$Z_j^{CSS} = Z_j^{SS} - \langle Z^{SS} \rangle + \mu_C$$

Average standardized
accounting for
dependence,
and shifted empirically

Stable

Consensus Average

$$Z_j^{CA} = \frac{\bar{Y}_j - \langle \bar{Y} \rangle}{\sqrt{\langle \langle \bar{Y} \rangle \rangle}} \sigma_C + \mu_C$$

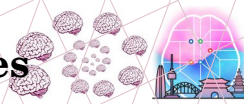
Average, scaled
and shifted empirically

SDMA GLS

$$Z_j^{SG} = \frac{\mathbf{1}^T \mathbf{Q}^{-1} \mathbf{Y}_j}{\sqrt{\mathbf{1}^T \mathbf{Q}^{-1} \mathbf{1}}}$$

Optimal average,
standardised

**Though theoretically
optimal, unstable in
heterogenous sample**



Thank you !



OHBM 2024
JUNE 23~27, SEOUL, KOREA



Jeremy
Lefort-Besnard



Thomas
Nichols



Camille
Maumet